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Radiographic assessment of third molar development and its relation to dental and chronological age in the Saudi Arabian population

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Abstract

Background Radiology plays a vital role in determining human age. Age estimation based on radiographic evaluation of human third molars can prove useful and accurate. The present study aimed to evaluate the reliability of age estimation of the third molar and to study the effects of gender, arch, and side of third molars using the modified Demirjian and Moorrees classifications.

Methods Orthopantomograms (OPG) of 6–24-year-old patients who attended our dental hospital were evaluated, and all eligible OPGs were analyzed for the test reliability based on the third molar modified Demirjian and Moorrees classifications. Statistical tests were performed to investigate the effect of gender, arch, and side.

Results A total of 508 eligible OPGs were included in the study. Female subjects were 54.9%. The mean age was 14.69 ± 4.5 years. Based on each classification, each of the 3rd molars was significantly correlated with age ($p < 0.001$) with positive Pearson correlation values ($r > 0.851$).

Conclusions The third molar modified Demirjian and Moorrees classifications were found to be highly accurate when used with our population. In addition, gender, arch, and side of third molars did not affect the estimated age.

Keywords Demirjian and Moorrees classifications, Third molar, Age of imputability, Forensic dentistry, Forensic radiology

Background

Age estimation and assessment are of critical importance to the forensics, legal, medical, and dental fields. In forensics, autopsy, and criminal law, age estimation can assist in identifying different ages, such as the age of imputability or criminal responsibility, which dictates if a person or a child can be convicted of a crime. Age estimation can also assist in identifying the age of majority (sometimes known as the age of legal capacity), which marks the age at which a person starts to be considered a legal adult, defined as a person who is "granted by law the rights (of having the ability to sue) and responsibilities (of having liability under contract) of an adult." (Schmeling et al. 2016; Doğru et al. 2018; Ritz-Timme et al. 2000).

In Saudi Arabia, the age of imputability or criminal responsibility was 12 years old, which was set in 2006. On the other hand, the age of the majority in Saudi Arabia is determined to be 18 (Time 2021). Both of these ages comply with the Saudi Arabian obligations under

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the Community Rights Counsel Government and Islamic law. Although the age of majority is set to be 18 in many countries, the age of imputability or criminal responsibility is as low as 6 and as high as 18, which makes accurate age estimation a useful method (Time 2021; Muncie 2013).

In medicine and dentistry, age estimation can significantly help identify the different patients' age groups. Age estimation can influence the treatment approach, modality, timing, and other factors. On the other hand, estimated age that does not match the chronological age may alert underlying issues. Of the various methods to assess age, radiology, and specific skeletal and developmental radiographic signs are reliable methods, such as those of the wrists and knees (Verma et al. 2009). However, dentists are not trained in assessing X-ray radiographs of the wrists or knees, and many dental hospitals are not equipped with personnel or hardware to conduct these assessments. Thus, many different classifications were created to incorporate the use of orthopantomograms for growing patients, for tooth calcification and development, and for offering reliable age estimation performed by dentists and dental forensics (Haiter-Neto et al. 2006; Soomer et al. 2003).

Third molars are the last erupting teeth in the human dentition. Like the rest of the human dentition, third molars are considered ectodermal tissue, derived exclusively from the ectomesenchyme of the neural crest (Sharpe 2001). Third molars are considered permanent teeth like the rest of the molars with no predecessors (Hovorakova et al. 2018). The first evidence of calcification for third molars is estimated to be as early as 7 and 8 years of age for the maxillary and mandibular variants. Complete radicular development of the third molars may be at 25 years of age. The estimated age at which third molars erupt is between 17 and 21 years (Nelson et al. 2014).

Multiple classifications are used to estimate age based on the radiographic developmental signs of third molars, with the key differences being in the number of development stages and milestones. Demirjian's and Moorrees' classifications are among the classifications to estimate age (Demirjian et al. 1973; Moorrees et al. 1963). However, multiple modifications were introduced after Demirjian's and Moorrees' classifications were developed, incorporating additional or different teeth in the analysis. Of those modifications are one for Demirjian's and one for Moorrees' classifications that only look at the third molars without involving any other teeth (Dhanjal et al. 2006; Tobel et al. 2017; Rolseth et al. 2019; Liversidge and Marsden 2010).

Several studies investigating the correlation between the radiographic developmental staging of the permanent dentition and the chronological age of the patients were published locally in Saudi Arabia (Ajmal et al. 2012; Alassiry et al. 2019; Al-Dharrab et al. 2017; Al-Emran 2008; Alshihri et al. 2014) studied the southern population using Demirjian's classification and found ages 13–23 to be correlated and statistically significant when paired with the modified classification. However, the authors only included males in their study. Apart from Ajmal et al., no other study used the same classification. Although only one study used the third molars for the age estimation process based on the classification created by Demirjian (Ajmal et al. 2012) and modified by Kasper (Kasper et al. 2009). None have used Moorrees' classification for the third molars (Moorrees et al. 1963).

With all these limitations and orthopantomogram (OPG) related variations, the present retrospective radiographic study aimed at improving the local data for the third molars and at estimating ages. In addition, this study aims to establish a reference for the Demirjian's and Moorrees' modified third molar classifications for the population in the Western region of Saudi Arabia and to investigate the influence of other factors such as the third molar arch, side, and gender.

Methods

Our protocol in this cross-sectional study was approved by the research ethical committee at the Faculty of Dentistry in King Abdulaziz University [128-9-19]. A permit was obtained from the medical director to access the required data in the patients' database.

Study population

The sample was extracted from the patients' database who took an OPG in the last 5 years. The inclusion criteria were the OPGS of healthy patients aged 6–24-years; all four 3rd molars were present on the OPG, and no underlying health condition was identified. Exclusion criteria were any health history that could influence the development or calcification of the 3rd molars (including any orthodontic treatment, bony pathologies, syndromes that either affected the teeth or the bony development and maturation). Additionally, any OPGs that presented acquisition errors such as incorrect exposure, incorrect vertical or horizontal head positioning, or any additional error that could compromise the clarity of developing third molars were excluded from our study. Noteworthy is the fact that all OPGs were acquired by radiology technicians who have extensive training, over 10 years of experience in dental radiology acquisition, and who

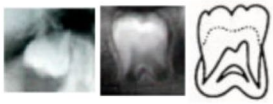
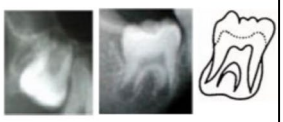
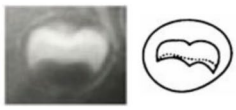
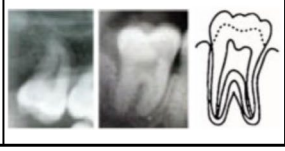
A		Cusp tips are mineralized but have not yet coalesced.	**E**		Formation of the inter-radicular bifurcation has begun. Root length is less than the crown length.
B		Mineralized cusps are united so the mature coronal morphology is well-defined.	**F**		Root length is at least as great as crown length. Roots have funnel-shaped endings.
C		The crown is about ½ formed; the pulp chamber is evident and dentinal deposition is occurring.	**G**		Root walls are parallel, but apices remain open.
D		Crown formation is complete to the dentinoenamel junction. The pulp chamber has trapezoidal form.	**H**		Apical ends of the roots are completely closed, and the periodontal membrane has a uniform width around the root.

Fig. 1 Demirjian classification for age assessment based on third molars as modified by (Kasper et al. 2009)

were classified and licensed by the regional classification authorities. An online randomization website was used to select the sample using the randomly generated numbers within a set range that used the total population count without repetition.

Data collection

We did sample size calculation using 80% power to reach our collected sample size. Orthopantomograms were recorded by certified and licensed oral and maxillofacial radiology technicians between January 2014

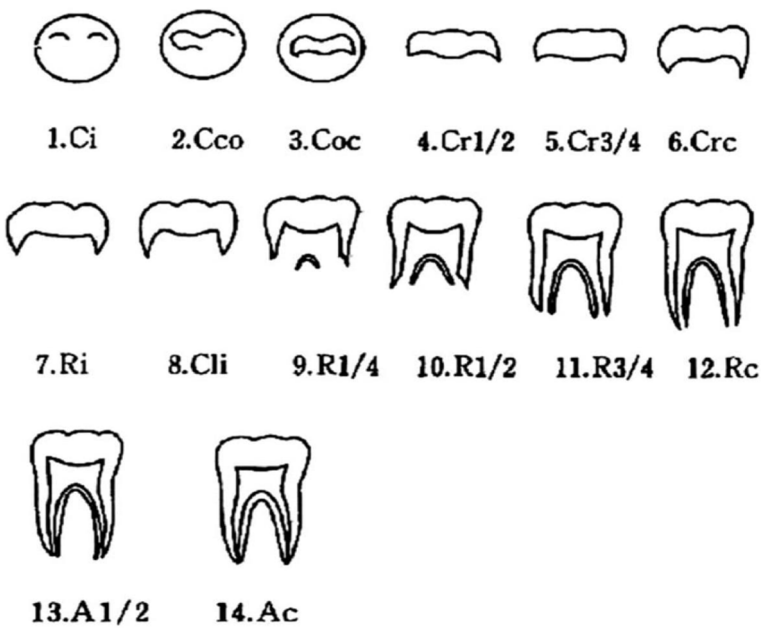


Fig. 2 Moorrees classification for age assessment based on third molars as modified by (Moorrees et al. 1963)

and December 2019 at King Abdulaziz University Dental Hospital in Jeddah, Saudi Arabia. Two classification methods were used: Demirjian's classification for third molars was modified by Kasper (Kasper et al. 2009) (Fig. 1) and Moorrees' modified classification for third molars (Moorrees et al. 1963) (Fig. 2). Demirjian's classification method followed the eight stages (A–H) in alphabetical order, where classes A–D were concerned with the crown development until its completion, and classes E–H were concerned with the root development, starting from the calcification of the inter-radicular bifurcation to a complete closure of the apices. Moorrees' classification was based on numerical order (1–14), which were six stages for crown formation (1–6), six stages for root formation (7–12), and two stages for apex closure (13–14).

Data analysis

All the information was recorded and analyzed by a single investigator. For the purpose of calibration, the investigator first studied and trained on more than a 100 OPGs using both classifications. Then, the investigator analyzed 40 OPGs and reanalyzed them randomly after 2 weeks, and no statistically significant differences were found between both resulting datasets.

We tabulated and processed the data of this study using Microsoft Excel (Microsoft Excel, Microsoft Corporation, Washington DC). We collected the following data from each OPG: gender, the chronological age of the patient when taking the OPG, the classification stage of each of the four 3rd molars for both Demirjian's and Moorrees' classifications, presence of any crowding or mal-eruption, and the presence of any bony pathologies or dental abnormalities. When the examiner classified the third molars, he was blinded to the chronological age of the patient and any other information that could interfere in the classification process.

We coded and analyzed the data using the SPSS v. 25 (IBM Corp., Armonk, NY, USA). Simple descriptive statistics were conducted for the patients' demographic data using means and frequencies where appropriate. Intraclass reliability test was used with a result of > 95% for all the variables. *T*-test was used to test the statistical differences between variables, and ANOVA was used to determine the statistical difference between the means of the groups. A t-test used variables such as gender, arch, and side of the mouth to measure the differences between Demirjian and Moorrees.

Results

The data of 508 patients who had taken OPG radiographs and had fulfilled the inclusion criteria were collected and analyzed. The sample consisted of 279 (54.9%) females and 229 (45.1%) males. Nearly half of the sample (49.8%) were 14 years old or younger. The mean age for the patients was 14.69 ± 4.5 years (Table 1).

Using a *t*-test analysis, no statistically significant association was observed between gender, arch, and side for each of the third molars in both classification methods at ($p > 0.05$). On the other hand, a statistically significant

Table 1 Simple descriptive statistics

Variable	Level	Frequency	Percent
Gender	Male	229.00	45.10
	Female	279.00	54.90
Variable	**Level**	**Mean**	**Std. Deviation**
Age (years)		14.69	4.49

Table 2 Pearson correlation between age, gender, and age estimation classifications for each third molar

Var	Sex	Age (years)	D #18	D #28	D #38	D #48	M #18	M #28	M #38	M #48
Sex	1.00	0.03	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.00
Age	0.03	1.00	.855*	.854*	.859*	.859*	.859*	.864*	.851*	.855*
D #18	0.01	.855*	1.00	.989*	.964*	.966*	.984*	.975*	.946*	.953*
D #28	0.01	.854*	.989*	1.00	.965*	.967*	.972*	.982*	.948*	.953*
D #38	0.01	.859*	.964*	.965*	1.00	.984*	.955*	.959*	.979*	.969*
D #48	0.00	.859*	.966*	.967*	.984*	1.00	.958*	.961*	.967*	.982*
M #18	0.02	.859*	.984*	.972*	.955*	.958*	1.00	.989*	.959*	.964*
M #28	0.01	.864*	.975*	.982*	.959*	.961*	.989*	1.00	.963*	.967*
M #38	0.00	.851*	.946*	.948*	.979*	.967*	.959*	.963*	1.00	.985*
M #48	0.00	.855*	.953*	.953*	.969*	.982*	.964*	.967*	.985*	1.00

D Demirjian, *M* Moorrees

* Significant at 0.01

Table 3 Descriptive table for age estimation classifications

Classification	Stage	Average demographic age (years)	SD	Age range
Demirjian	A	9.34	1.50	6–14
	B	9.91	1.66	6–15
	C	12.09	2.34	6–17
	D	13.99	2.89	9–19
	E	15.80	2.62	10–20
	F	16.58	2.63	12–23
	G	17.89	2.73	14–24
	H	20.21	2.04	16–24
Moorrees	1	9.08	1.44	6–12
	2	9.67	1.95	6–14
	3	9.93	1.72	6–15
	4	11.24	1.98	6–16
	5	12.50	1.24	10–14
	6	13.20	3.06	9–19
	7	13.70	3.16	9–19
	8	14.32	3.01	10–21
	9	15.57	2.63	10–20
	10	17.06	2.45	12–23
	11	17.06	2.81	13–22
	12	18.27	2.84	12–24
	13	19.43	1.62	16–21
	14	20.42	1.82	17–24

association was found between age and each of the four 3rd molars using both classifications ($p < 0.001$). A statistically significant correlation was found between Demirjian's stages and Moorrees' stages for the third molars #18, #28, #38, and #48, with correlation coefficient values of 0.984, 0.982, 0.979, and 0.982, respectively ($p < 0.01$) (Table 2).

An unequal variance independent *t*-test was performed, and no statistically significant difference was observed between gender, arch, and side of the mouth, in both radiographic classifications at $p < 0.05$.

A table was developed to serve as a reference for age estimation based on the radiographic developmental stage using the modified 3rd molar versions for Demirjian's and Moorrees' classifications (Table 3).

Discussion

In this cross-sectional study, age estimation was performed using the radiographic developmental stages of the third molars. The modified versions of Moorrees' and Demirjian's classifications were used, which exclusively used all four 3rd molars. The original versions of the classifications were designed and first published by Dr. Alicia Demirjian in 1973 and Dr. Coenraad Moorrees in the year 1963 (Demirjian et al. 1973; Moorrees et al. 1963). Demirjian's classification is the most used age estimation system based on human dentition, and it comprises eight stages from A to H. A specific developmental radiographic milestone dictates each stage (Fig. 1). However, Moorrees' classification includes 14 stages, from 1 to 14. Moorrees' radiographic developmental milestones are much closer to each other but provide more details for the examiner (Fig. 2). For example, Demirjian's classification classifies the entire apex closure process in a single stage, whereas Moorrees' classification splits it into two stages.

Although these classifications were meant to be used differently, the exclusion of the third molars in Demirjian's original classification limits the age that can be included in the study up to the age at which the 2nd molars complete their development. In our study, a patient with third molars can complete development and calcifications between the ages of 16 and 24 years and between 17 and 24 years for Demirjian's and Moorrees' classifications, respectively. Thus, using the third molars to estimate ages provides a wider range of age groups. According to our analysis, the 2nd modified classifications are highly reliable because they allow forensic scientists and criminal law reinforcements in identifying criminals and victims or in assessing the age of imputability since the ages of the majority of people are unknown.

We tested differences in gender, arch, and side of the mouth; we found no statistically significant difference between the right and left third molars, between the maxillary and mandibular third molars, and between the males and females in both classification methods. The findings are consistent with the findings of many previous studies. Additionally, we found that age estimation is more accurate in the younger age group seeing as how the age range increases as we get to more advanced age (Gunst et al. 2003; Karadayi et al. 2012; Orhan et al. 2007; Bolanos et al. 2003; Olze et al. 2004).

In our study, all patients who had a history of orthodontic treatment, oral or dental pathologies or abnormalities, and missing third molar were excluded. These patients were excluded to avoid any potential effect on growth and development and to establish a standard reference table for our population. Multiple local studies used Demirjian's classification to estimate the ages of the Saudi population. Ajmal et al. used the third molar modification, which was mandibular third molars without the maxillary (Ajmal et al. 2012). Our Table 3 shows a 2-year difference in some stages from those reported by Ajmal et al. The difference could be attributed to the

different backgrounds and ethnic origins of Saudis who populate the southern regions compared to those who populate the western region. This proves that further studies controlling ethnic origins can offer better insight on the topic of age estimation using third molars. Nevertheless, our results are closer to those reported by Jung (2014) for the Korean population (Jung and Cho 2014). Understanding any potential variance or similarities in age estimation between the different regions and ethnicities in the Arabian Peninsula can provide very valuable information, but this is not possible amid the lack of locoregional publications using reliable methods. We believe that this is a gap that needs to be highlighted in future scientific research.

Relationships between ethnicities for age estimation have been previously discussed. Multiple authors have pinpointed the importance of personalizing estimation for each ethnic group (Jayaraman and Roberts 2018; Olze et al. 2004). Since the ethnicities of the Saudi population are mixed or similar, no clear ethnicity can be used as a sample, which has been a limitation of our study.

Conclusions

This study used two different age estimation methods based on the radiographic developmental stages of third molars of patients. Gender, side of the mouth, and arch were not significant factors in estimating the patient age for both classification methods. We found that the third molar Demirjian modified classification by Kasper and the third molar modified Moorrees classification by Moorrees are reliable tools for age estimation. Data regarding age estimation using third methods in Saudi Arabia is very limited; on top of that, our data was not similar to the only other local study that was done using one of the methods we used. Future studies should use larger samples from the ethnic groups and provide references if differences are identified.

Abbreviation

OPG Orthopantomogram

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None

Authors' contributions

MA and MS put together the idea, MA designed the study, MS collected and analyzed the data, MB cleaned and analyzed the data, MS wrote the manuscript, and MA and MB revised the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Research Ethical Committee at the Faculty of Dentistry at King Abdulaziz University (REC-FD KAU) [128-9-19]. A digitally signed consent of participation was obtained from each eligible candidate prior to the data collection process.

Consent for publication

Not applicable.

Competing interests

The authors of this manuscript have no financial or competing interests to declare.

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