ORIGINAL ARTICLE

Digital radiographic evaluation of mandibular third molar for age estimation in young adults and adolescents of South Indian population using modified Demirjian's method

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Abstract

In recent years, it has become increasingly important to determine the age of living people for a variety of reasons, including identifying criminal and legal responsibility and for many other social events such as birth certificate, marriage, beginning a job, joining the army and retirement. **Objectives:** The aim of this study was to assess the developmental stages of mandibular third molar for estimation of dental age (DA) in different age groups and to evaluate the possible correlation between DA and chronological age (CA) in South Indian population. **Materials and Methods:** Digital orthopantomography of 330 subjects (165 males, 165 females) who fit the study and the criteria were obtained. Assessment of mandibular third molar development was performed using Demirjian *et al.*, modified method and DA was assessed using tooth specific stages. **Results and Discussion:** The present study showed a significant correlation between DA and CA in both males and females. Third molar development commenced around 9 years and root completion takes place around 18.9 years in males and in females 9 years and 18.6 years respectively. Demirjian modified method underestimated the mean age of males by 0.8 years and females by 0.5 years and also showed that females mature earlier than males in selected population. **Conclusion:** Digital radiographic assessment of mandibular third molar development can be used to generate mean DA using Demirjian modified method and also the estimated age range for an individual of unknown CA. Since the Demirjian method is based on French-Canadian population, to enhance the accuracy of forensic age estimates based on third molar development, the use of population-specific standards is recommended.

Keywords: Age estimation, chronological age, dental age, forensic odontology, mandibular third molar, south Indian population

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Introduction

The application of forensic odontology is expanding as the science develops. Teeth and bones are most commonly used for identification of an unknown individual and for age determination.[1-3] Dental age (DA) is useful for evaluating a child's growth status and for assessing the ages of subjects

in anthropological, forensic and medico-legal situations. DA is a practical method of gauging a child's degree of maturity. Dental maturation is a complex sequence of events from initial mineralization of a tooth, crown formation, root growth, eruption of tooth in to the mouth and root apex maturation.[4] Among these, developing teeth are generally considered to be the most useful and reliable indicators of maturation and thus the biological and chronological age (CA) because they are less affected than other body tissues by endocrinopathies and environmental insults, exogenic factors such as malnutrition or disease.[5-8] Tooth formation used for assessing dental maturation because it is a continuous and progressive process that can be followed radiographically and most teeth can be evaluated at each examination.[9] Dividing tooth formation in to discrete maturity events such as crown and root stages provides the opportunity to assess maturity from childhood to early adulthood. The most widely used method is the assessment of crown and root formation stage.[10,11]

Radiology plays an indispensable role in human age determination. Radiographic analysis of third molar development expands the years of age estimation to 9-23 years as crown and root development can be studied independent of eruption. The third molar is of particular interest because (a) it is the last and most variable tooth to form and (b) it is the only tooth to complete formation after puberty, which has made it attractive in forensic and legal circles as an estimator of adulthood. The basis for dental identification is the theory that human dentition is never same in any two individuals. The morphology and arrangement of teeth vary from person-to-person.[12] This study aims to assess the developmental stages of mandibular third molar in young adults and adolescents at different ages for the estimation of DA and to evaluate the possible correlation with CA and estimated DA.

Materials and Methods

Study consisted of 330 randomly selected subjects (165 males and 165 females) with age ranging from 9 years to 20 years divided in to 11 groups according to age [Table 1]. Informed consent was taken from all the individuals and the study was approved by the Ethical Committee of Narayana Dental College and Hospital, Nellore Andhra Pradesh. Patients with: (a) serious medical illness. (b) History of extraction of permanent teeth. (c) History of trauma to face. (d) Impacted or ankylosed teeth or transposition of teeth. (e) Congenital absence of third molars was excluded from the study. Clinical examination of all 330 subjects was performed and name, sex, date of birth of each individual and date of X-ray was recorded. 330 digital orthopantomographs (OPG) were taken with a Planmeca digital machine.

DA determination by Demirjian's modified method

CA of an individual was calculated by subtracting the birth date from the date, on which the radiographs were exposed for that particular individual. Decimal age was taken for simplicity of statistical calculation and ages were estimated on a yearly basis, e.g. 9 years 9 months as 9.09 years and it was considered in 9 years age group. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number (1-330) to ensure that the examiner was blind to sex, name and age of subjects. Evaluators were given written instructions for staging, including drawings and written descriptions of the stages of tooth development of Demirjian's modified method that supplements the graphic representations with archetypical radiographs for each stage. The third molar was scored"0"to"H,"depending on the stage of calcification [Table 2].[13-15] In this study,"48"tooth was assessed for staging of molar with no history of extraction of tooth on that side. DA of each subject was assessed by comparing developmental stages of mandibular third molar with the rating system [Table 3].[1,13,16] For statistical computations, stages were assigned a numeric value where stage 0 = 1, stage A = 2, stage B = 3, stage C = 4, stage D = 5, stage E = 6, stage F = 7, stage G = 8 and stage H = 9. To test intra-examiner reliability, each examiner unknowingly re-evaluated 20 of their images after 1 month.

Table 1: Distribution of sample according to age and sex

Age	Males	Females	Total
9 years to 9 years 11 months	15	15	30
10 years to 10 years 11 months	15	15	30
11 years to 11 years 11 months	15	15	30
12 years to 12 years 11 months	15	15	30
13 years to 13 years 11 months	15	15	30
14 years to 14 years 11 months	15	15	30
15 years to 15 years 11 months	15	15	30
16 years to 16 years 11 months	15	15	30
17 years to 17 years 11 months	15	15	30
18 years to 18 years 11 months	15	15	30
19 years to 20 years	15	15	30
Total	165	165	330

Results

The significance of the difference between the means of different ages was determined using a paired sample *t*-test. Pearson's correlation between means of different ages was also calculated. To test the reliability of the DA assessment, the examiner re-evaluated 20 randomly selected radiographs of the same subjects. The correlation between first and second assessments was determined using Kappa statistics. The differences were considered significant when the *P* value is less than 0.05.

In males, mandibular third molar development commenced around 9.4 years and root completion took place around

Table 2: Schematic drawings and brief description of stages of crown and root formation used to score third molar development (modified Demirjian *et. al.* method)

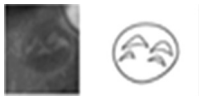
Stage	Radiographic appearance	Description of stage
Stage 0		Crypt outline visible. No calcification
Stage A		Calcification of single occlusal points without fusion of different calcifications
Stage B		Fusion of mineralization points; the contour of the occlusal surface is recognizable
Stage C		Enamel formation has been completed at the occlusal surface and dentine formation has commenced. The pulp chamber is curved and no pulp horns are visible
Stage D		Crown formation has been completed to the level of the Enamelocemental junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved
Stage E		The root length remains shorter than the crown height. The walls of the pulp chamber are straight and the pulp horns have become more differentiated than in the previous stage. In molars, the radicular bifurcation has commenced to calcify
Stage F		The walls of the pulp chamber now form an isosceles triangle and the root length is equal to or greater than the crown height. In molars the bifurcation has developed sufficiently to give the roots a distinct form
Stage G		The walls of the root canal are now parallel, but the apical end is partially open. In molars only the distal root is rated
Stage H		The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout

Table 3: Assessment of DA from third molar developmental stage

Developmental stages	Males	Females
Stage 0	9.2	9.1
Stage A	9.7	9.8
Stage B	10.8	10.9
Stage C	12.1	11.8
Stage D	13.4	13.0
Stage E	14.5	14.5
Stage F	16.3	16.3
Stage G	17.6	18.3
Stage H	19.2	20.7

DA: Dental age

18.9 years [Table 4] and in females third molar development commenced around 9 years and root completion took place around 18.6 years [Table 5], which shows that there is no significant sex difference in third molar development. Standard deviation between estimated DA and CA in males is increased in groups 7, 10 and in females 4, 5, 6 groups. Demirjian's modified method was found to underestimate age with mean accuracy of 0.8 years for males and 0.5 years for females. Reliability of the Demirjian *et al*., method was verified by testing intra-and inter-observer agreement. The Felli's Kappa value for intra-observer agreement was 92.9% and confidential limit was 0.914-0.941 [Table 6]. Inter-observer agreement was 92.4% [Table 7]. Pearson correlation test showed a significant correlation between CA and DA [Table 8].

Discussion

Age estimation has become increasingly important to determine the age of living individuals. Identification of age is very important for a variety of reasons, including identifying criminal and legal responsibility, determining the emotional support needed for the victim of a sexual assault and for many other social events such as birth certificate, marriage, beginning a job, joining the army and retirement.[6,12,17,18] Radiographic analysis of third molar development expands the years of age estimation to 9-23 years as crown and root development can be studied independent of eruption. After the early teens, most teeth

Table 4: Comparison between DA using the Demirjian method and CA (in years) in males

Group	Mean CA (±SD)	Mean DA (±SD)	Mean difference (SD)	95% CL	t-statistics (df)	*P* value
1	9.02 (0.015)	9.41 (1.06)	−0.38 (1.06)	−1.0-0.22	−1.35 (13)	0.19
2	10.03 (0.029)	9.67 (1.39)	0.36 (1.38)	−0.37-1.09	1.04 (15)	0.31
3	11.03 (0.027)	10.5 (0.87)	0.51 (0.86)	0.05-0.97	2.38 (15)	0.03
4	12.05 (0.019)	11.2 (1.02)	0.85 (1.02)	0.28-1.4	3.22 (14)	0.00
5	13.04 (0.026)	11.56 (2.04)	1.48 (2.05)	−0.38-2.57	2.87 (15)	0.01
6	14.05 (0.029)	12.84 (2.34)	1.21 (2.33)	−0.08-2.5	2.0 (14)	0.06
7	15.05 (0.022)	13.89 (1.0)	1.15 (0.9)	0.6-1.7	4.49 (14)	0.00
8	16.04 (0.03)	14.53 (1.55)	1.5 (1.55)	0.6-2.4	3.62 (13)	0.00
9	17.04 (0.028)	17.27 (2.24)	−0.234 (2.26)	−1.6-1.13	−0.37 (12)	0.71
10	18.04 (0.024)	18.3 (1.29)	−0.25 (1.29)	−0.97-0.45	−0.77 (14)	0.45
11	19.04 (0.027)	18.9 (1.64)	0.116 (1.64)	−0.76-0.99	0.28 (15)	0.78

DA: Dental age, CA: Chronological age, CL: Confidential Limit SD: Standard deviation; In males, mean values of actual age (CA) did not differ significantly from mean values of age derived from mandibular third molar in all age groups except in group 1 (9.4±1.06), Group 2 (9.6±1.3), Group 9 (17.2±2.2), Group 11 (18.9±1.6)

Table 5: Comparison between DA using the Demirjian method and CA (in years) in females

Group	Mean CA (±SD)	Mean DA (±SD)	Mean difference (SD)	95%CL	t-statistics (df)	*P* value
1	9.04 (0.014)	9.04 (0.026)	0.006 (0.03)	−0.01-0.02	0.78 (14)	0.44
2	10.05 (0.039)	9.5 (0.83)	0.54 (0.84)	0.08-1.01	2.51 (14)	0.02
3	11.05 (0.028)	10.97 (2.32)	0.07 (2.3)	−1.33-1.4	0.11 (12)	0.9
4	12.04 (0.023)	11.37 (1.14)	0.67 (1.15)	0.03-1.31	2.27 (14)	0.04
5	13.03 (0.017)	11.7 (1.08)	1.33 (1.08)	0.72-1.93	4.7 (14)	0.00
6	14.04 (0.024)	12.12 (1.6)	1.92 (1.61)	1.03-2.82	4.6 (14)	0.00
7	15.05 (0.028)	13.5 (1.39)	1.54 (1.4)	0.76-2.32	4.2 (14)	0.00
8	16.05 (0.0028)	14.16 (1.35)	1.88 (1.38)	1.15-2.61	5.5 (15)	0.00
9	17.04 (0.029)	16.16 (2.37)	0.87 (2.38)	−0.44-0.19	1.4 (14)	0.17
10	18.05 (0.016)	17.7 (1.23)	0.33 (1.23)	−0.32-0.9	1.08 (15)	0.29
11	19.03 (0.03)	18.62 (0.81)	0.4 (0.81)	−0.04-0.85	1.94 (14)	0.07

DA: Dental age, CA: Chronological age, CL: Confidential Limit, SD: Standard deviation. In females, mean values of actual age did not differ significantly from mean values of age derived from mandibular third molar in all age groups except in 3,9,10,11 groups

Table 6: Intra-observer correlation coefficient

Two examiners	Intra-class correlation	95% confidence interval		*F* test with true value 0			
		Lower bound	Upper bound	Value	df1	df2	Significant
Single measures	0.929	0.914	0.941	41.305	329	658	0.000
Average measures	0.975	0.97	0.98	41.305	329	658	0.000

Intra-observer correlation coefficient is92.9% and is statistically significant

Table 7: Inter-observer correlation (Cohen Kappa)

Two examiners	Observer 1	Observer 2
Observer 1	1	0.924
Observer 2	0.924	1

Table 8: Pearson correlation for females and males

Correlation between DA and CA	CA	DA (females)	DA (males)
CA age (years)			
Pearson correlation	1	0.889**	0.891**
Significant (2-tailed)		0.000	0.000
N		165	165

**Correlation is significant at the 0.01 level (2-tailed); CA: Chronological age, DA: Dental age, Pearson correlation test showed significant correlation between CA and DA

have calcified and erupted except for the third molars. This makes the third molar development the most important choice for age assessment among young children and adolescents with greater accuracy from the late teens to the early twenties.[12,16,19]

A large number of dental stages make it very difficult to discriminate the tooth development (Moorrees *et al*. 1963). Hence, in this study, Demirjian's modified method is used as it is widely accepted as the maturity scoring system and it is universal in application. Advantage of this method was that the predicted DA was relatively accurate since it was not based on the eruption process of teeth. Digital imaging provided high quality images and greatest flexibility with reduced exposure.

Only a few studies compare dental maturity of individual teeth in populations using average age entering tooth stages and most find similarities between regional and ethnic groups (Liversidge 2008, 2011). Levesque *et al*. (1981) determined the age of alveolar and gingival

Figure 1: Digital OPG showing right Mandibular Third molar in Stage B

Figure 3: Digital OPG showing right Mandibular third molar in Stage E

Figure 2: Digital OPG showing right Mandibular third molar in stage D

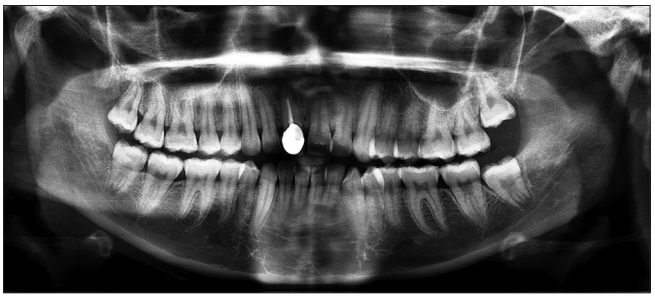


Figure 4: Digital OPG showing right mandibular third molar in stage G

eruption and mineralization state of the third molars based on the evidence from 4640 OPG from 2278 male to 2362 female Franco-Canadians of ages ranging from 7 years to 25 years.[16] In this study, developmental stages of mandibular third molar in different age groups were assessed. In males, third molar development commenced around 9 years and root completion took place around 18.9 years and in females 9 years and 18.6 years respectively, which showed females mature slightly earlier than males, in accordance with Hassen *et al*. (2007). The mean ages for the lower third molar developmental stages in this study seem to be within the age ranges reported by previous authors (Moorrees *et al.* 1963, Koski 1963).

In the present study, we found a significant correlation between DA and CA in both males and females i. e., $r = 0.89$ for males and $r = 0.88$ for females [Table 8] similar to Tritiana (1989), Orhan (2007), Engstrom *et al.*(1983), Lamons Gray (1958), Green (1961), Krogman (1967), Cheraskin (1972), Malagola (1989), Jaeger (1990), Carvaho *et al.*(1990), Zaborra and Terranova (1989).[20] In this study, we found that Demirjian's modified method showed the highest Kappa value (very good agreement) for intra-observer readings for the mandibular third molar. Intra-observer correlation coefficient is 92.9% and was statistically significant.

The inclination of developing third molar relative to X-ray film may result in the crown appearing tilted on the radiograph making crown stage difficult to assess. Roots of third molar are less divergent than other molars and are often found making root stage assessment more difficult especially if stages include an estimation of root length. Greatest limit of the method seems to be the operator experience in determining the dental stages of development.

In previous studies, Demirjian's method has been tested in different populations. In all populations, the authors have obtained an overestimation of DA ranging from 0.02 to 3 years. Koshy and Tandon recorded an overestimation of 2.82 years for females and 3.04 years for males in Indian population.[21] Liversidge *et al.* explained that overestimation in DA using Demirjian's method in different populations may be due to positive secular trend in growth and development during last 25 years. However, in this present study, there is underestimation of DA similar to Acharya.[22] X-ray standards to individuals of a socio-economic status lower than that of the reference population usually may lead to underestimation of that person's age.

According to International study Group on Forensic Age Diagnostics, a forensic age diagnosis for the purpose of criminal investigations consist of clinical examination, evaluation of signs of sexual maturity, X-ray examination of hand and evaluation of dental status of an individual.[23-27] Most important aspect of DA estimation is to remember that he or she should not be restricted to only one age estimation technique, but to apply different techniques available and perform repetitive measurements and calculations in order to establish more reproducibility. Comprehensive age estimation will utilize all available methods for a particular case and third molar development data compliments the skeletal maturation to give a complete assessment of age of unknown individuals.

Demirjian method is based on standards of French-Canadian population. When this method is applied to South Indian population, mean difference between true age and assessed DA is minimal [0.8 years in males and 0.5 years in females] and also showed significant positive correlation. The present study supports the use of Demirjian modified method for assessment of DA in selected population.

Conclusion

Teeth represent useful material for age estimation. Digital radiographic assessment of development of mandibular third molar can be used a better choice for predicting biological age of an individual because of its simplicity, reliability and reduced radiation exposure to the individual and should be the preferential method in forensic applications. Third molar root development can be reliably used to generate mean age and the estimated age range for an individual of unknown CA. Third molar can be commonly available biologically valid tool for age estimation in late teens to early adult group. Hence, it should be used with caution because of considerable variability among individuals.

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