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RESEARCH ARTICLE

RADIOGRAPHIC EVALUATION OF THIRD MOLAR DEVELOPMENT AS AN INDICATOR OF CHRONOLOGICAL AGE BY DEMIRJIAN AND KOHLERS METHODS

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ABSTRACT

Aim: To determine the developmental stages of third molars on digital orthopantomogram in relation to the chronological age of an individual in Indian population and to compare the accuracy of two different methods [Demirjian and Gleiser and Hunt modified by Kohler].
Materials and Methods: The study consist of 100 subjects (50 males, 50 females) attending Vydehi Institute of Dental sciences and research center. The panaromic radiograph of each subject was taken. The image of panaromic radiograph taken was imported into Adobe Photoshop CS2 (Adobe Systems Incorporated, San Jose CA) to enhance the view. Development of third molar was evaluated according to the scoring method of Demirijian *et al*. & Gleiser and Hunt modified by Köhler *et al* by two observers. Repeated scoring was done by both the observers with time interval of 2 months.
Results: It was found that intra and inter observer agreement was better for the method given by Demirjian et al than Kohler's method though both the method showed moderate agreement.
Conclusion: Mean mineralisation age of third molar was earlier in males than females according to staging criteria given by both the methods. It was also found that coefficient of determination (R2) in males was relatively high for Demirjian's method than that of the Kohler's method where as it was same for females according to both the methods.

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INTRODUCTION

Age is an important part of the human society reflecting the changes in biological system and cultural & social conventions. Age estimation is useful in differentiating the juvenile from the adult status in cases of criminal law. (Mesotten *et al*., 2002) Dental development correlates with different morphological stages of mineralization that can be observed in X-rays which comprise a more uniform and gradual set of changes than eruption & are less influenced by external factors (such as malnutrition, disease, and mental stress).Teeth represent useful material for age estimation. In childhood, the observation of the dentition status results in highly accurate age assessment but tend to decrease simultaneously with the completion of a person's dental development which gets affected by genetic, hormonal, nutritional, climate and environmental factors. (Rai *et al*., 2010) When most of the teeth are in the process of completing apical formation, dental age estimation becomes more difficult. The only teeth still growing after that age are the third molars, which are highly variable in their pattern of formation: agenesis is frequent, and the age of complete mineralization varies widely. (Rai *et al*., 2010) Hence, the radiographic assessment of third molar mineralisation serves as a particularly important method for forensic age estimation. It also possesses a unique advantage over other teeth because its development tends to continue over a longer period. (Karatas *et al*., 2013) Different age estimation methods have evolved from various studies. Demirjian *et al* presented a classification method which differentiate among eight stages of crown and root development (stages A-H) which is simple and objective, having clearly defined stages and fewer intermediate stages that allowed better reproducibility. 10 stage classification designed by Gleiser and Hunt and modified by Kohler *et al*. was also adhered to in scoring radiological development of third molar as it carries greater ability to discriminate between stages of tooth development.With this background, the present study is being undertaken to study the developmental stages in third molars on digital orthopantomogram in relation to the chronological age and to compare the accuracy of two different methods [Demirjian and Gleiser and Hunt modified by Kohler] that determines the dental age of the individual by the radiological assessment of third molars.

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MATERIALS AND METHODS

The present radiographic study was conducted in department of oral medicine and radiology, Vydehi Institute of Dental Sciences. The study group was comprised of 100 healthy subjects; 50 males and 50 females, in the age group of 10-25 years needing orthopantomogram for any reason.

Inclusion criteria: 1. Healthy dentate patients in the age group of 10-25 year (Needing Orthopantomogram for any reason)

Exclusion criteria: 1. Image deformity affecting the third molars, hypodontia or gross pathology involving third molar 2. Orthopantomogram showing obvious dental pathology, such as a dentigerous cyst associated with a third molar. At the time of radiographic examination, the chronological age of each subject will be calculated on the basis of the reported date of birth. Dental development will be evaluated according to the scoring method of Demirijian *et al*. (Karatas *et al*., 2013) and by Gleiser and Hunt modified by Köhler *et al*. (Bagherpour *et al*., 2012) Orthopantomogram imported into Adobe Photoshop CS2 (Adobe Systems Incorporated, San JoseCA) to enhance the view. On multirooted wisdom teeth the least developed root will be examined. All the samples will be scored by two oral radiologists and rescoring will be done within an interval of two months. The intra and inter observer agreements were evaluated.

Radiographic evaluation of third molars was done by using following scoring criteria

Scoring system given by Demirjian *et al.* (Karatas *et al*., 2013)

Stage A: Calcification of single occlusal points without fusion of different calcifications.

Stage B: Fusion of mineralisation points; the contour of the occlusal surface recognisable.

Stage C: Enamel formation has been completed at the occlusal surface, and dentin 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 amelocemental 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.

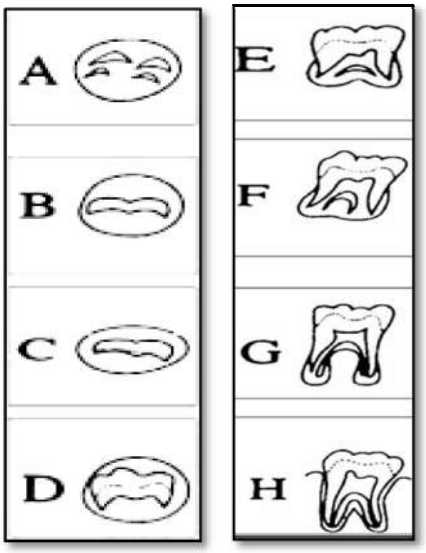

Figure 1. Scoring system given by Demirjian *et al*. Scoring system designed by Gleiser and Huntand modified by Köhler *et al*. (Bagherpour *et al*., 2012)

Crown formation

1. Crown calcification: 1/2
2. Crown calcification: 3/4
3. Complete crown calcification

Root formation

4. Initiation of root formation
5. Root calcification: 1/4
6. Root calcification: 1/2
7. Root calcification: 3/4
8. Mostly complete root length, root canals terminally spreading away from each other
9. Full root length, root canals terminally parallel
10. Finished root formation, root canals terminally coming together.

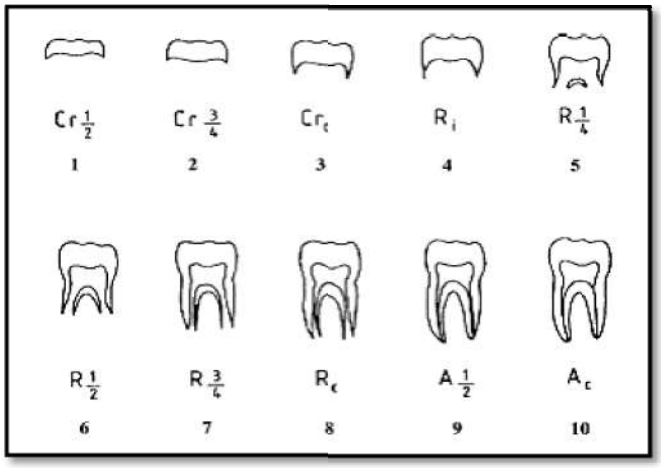

Figure 2. Scoring system designed by Gleiser and Huntand modified by Köhler *et al*

RESULTS

The number of individuals included in sample studied was 100 (50 males and 50 females), with age ranging from 10 to 25

years. For Scoring system given by Demirjian *et al* Inter observer consistency was 60%, 61%, 69%, 64% for 18, 28, 38,48 respectively. Intra observer consistency was rated at 63%, 61%, 76%, 72% for 18, 28, 38, 48 respectively. For scoring system given by Gleiser and Huntand modified by Kohler *et al* Inter observer consistency was 60%, 58%, 64%, 54% for 18, 28, 38, 48 respectively. Intra observer consistency was rated at 53%, 60%, 66%, 69% for 18, 28, 38, 48 respectively. There was moderate agreement between intra observer and inter observer scores and it was found to be statistically significant. Difference in the age at which molar mineralization occurred at different developmental stage (A, B, C, D, E, F, G, H) given byDemirjian *et al* between males and females were evaluated using unpaired student t test. It is found that difference in age between male and female is statistically significant for 18, 28, 38 at developmental stage C, D, C respectively as compared to the other developmental stages. Corresponding to 18 developmental stage C appeared at the mean age of 11.6 (± 0.5) years in males and 12.5 (± 0.6) years in females, where mineralization was 0.9 years earlier in males than female with p value 0.02 (Table 1). In relation to 28 stage D appeared at the mean age of 12.3 (± 1.2) years in males and 15.4 (± 4.0) years in females, where mineralization was 3.1 years earlier in males than female with p value 0.02 (Table 2). In relation to 38 stage C appeared at the mean age of 11.7 (± 0.6) years in males and 13.4 (± 1.9) years in females, where mineralization was 1.8 years earlier in males than female with p value 0.01 (Table 3). Taking significant values into consideration we arrived at the conclusion that mineralization of 18, 28, 38, 48 occurred earlier in males than females. Difference in the age at which molar mineralization occurred at different developmental stage (1, 2, 3, 4, 5, 6, 7, 8, 9, 10) given by Gleiser and Huntand modified by Kohler *et al* between males and females were evaluated using unpaired student t test. It is found that difference in age between male and female is statistically significant for 18, 38, 48 at stage 7, 6, 7 respectively as compared to the other developmental stages. Corresponding to 18 developmental stage 7 appeared at the mean age of 14.3 (± 1.2) years in males and 18.8 (± 1.3) years in females, where mineralization was 4.5 years earlier in males than female with p value 0.005 (Table 7). In relation to 38 developmental stage 6 appeared at the mean age of 14.8 (± 1.3) years in males and 17.5 (± 0.7) years in females, where mineralization was 2.7 years earlier in males than female with p value 0.02 (Table no.9). In relation to 48 developmental stage 7 appeared at the mean age of 15.7 (± 2.0) years in males and 20 (± 1.4) years in females , where mineralization was 4.3 years earlier in males than female with p value 0.03 (Table 10). Taking significant values into consideration we arrived at the conclusion that mineralzation of 18, 28, 38, 48 occurred earlier in males than females.

Table 1. Chronological mineralisation age of 18 by Demirjian Method

Statistic data of chronological mineralisation age of 18 by Demirjian Method											
Stage	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
A	--	--	--	--	--	2	10	0	10	10	--
B	--	--	--	--	--	3	11.3	1.5	10	13	--
C	8	11.6	0.5	11	12	4	12.5	0.6	12	13	0.02*
D	9	12.6	1.3	11	14	7	13.3	1.7	11	16	0.35
E	5	16.4	3.3	12	20	3	13.7	2.5	11	16	0.27
F	2	15.0	0.0	15	15	2	19.0	2.8	17	21	0.18
G	6	15.8	1.9	13	18	8	18.1	2.9	12	22	0.12
H	20	19.6	1.8	16	23	21	19.6	1.3	18	22	0.97

* - Statistically Significant

Table 2. Chronological mineralisation age of 28 by Demirjian Method

Statistic data of chronological mineralisation age of 28 by Demirjian Method											
Stage	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
A	--	--	--	--	--	2	10.5	0.707	10	11	--
B	--	--	--	--	--	3	11.0	1.7	10	13	--
C	5	11.6	0.5	11	12	4	12.5	0.6	12	13	0.05
D	12	12.3	1.2	11	14	5	15.4	4.0	11	21	0.02*
E	4	14.3	1.0	13	15	7	13.6	1.6	11	16	0.46
F	9	16.8	2.2	13	20	--	--	--	--	--	--
G	20	19.6	1.8	16	23	6	18.0	3.4	12	22	0.41
H	20	19.6	1.8	16	23	23	19.5	1.3	18	22	0.87

* - Statistically Significant

Table 3. Chronological mineralisation age of 38 by Demirjian Method

Statistic data of chronological mineralisation age of 38 by Demirjian Method											
Stage	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
A	--	--	--	--	--	1	10	--	10	10	--
B	1	11	--	11	11	4	10.8	1.0	10	12	0.83
C	11	11.7	0.6	11	13	7	13.4	1.9	11	16	0.01*
D	7	13.4	1.4	11	15	5	12.6	1.3	11	14	0.32
E	1	13	--	13	13	2	13.0	1.4	12	14	1.00
F	5	14.8	1.1	13	16	5	17.8	2.4	14	20	0.03*
G	9	18.6	1.2	17	21	6	18.5	1.4	17	21	0.93
H	16	19.8	1.8	16	23	20	19.8	1.4	18	22	0.92

* - Statistically Significant

Table 4. Chronological mineralisation age of 48 by Demirjian Method

Statistic data of chronological mineralisation age of 48 by Demirjian Method											
Stage	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
A	--	--	--	--	--	1	10	--	10	10	--
B	--	--	--	--	--	1	10	--	10	10	--
C	12	11.8	0.9	11	14	7	12.6	1.7	11	16	0.23
D	6	12.8	1.3	11	14	8	12.8	1.9	10	16	0.92
E	1	13	--	13	13	2	15.5	2.1	14	17	0.51
F	5	16.2	2.2	15	20	3	15	3.6	12	19	0.57
G	9	17.3	2.2	13	21	9	19.0	1.4	17	21	0.07
H	17	19.7	1.8	16	23	19	19.7	1.4	18	22	0.95

Table 5. Regression Equation by Demirjian Method

Whole Sample:	Adjusted R^2	P-Value
Age = 1.5 * DS38 +7.5	0.82	<0.001*

* - Statistically Significant
Regression equation - Y = ax + b

Table 6. Regression Equation by Demirjian Method

Gender	Regression Equation	Adjusted R^2	P-Value
Males	Age = 1.6 * DS38 + 6.8	0.82	<0.001*
Females	Age = 1.5 * DS38 + 8.1	0.81	<0.001*

* - Statistically Significant

Table 7. Chronological mineralisation age of 18 by Kohler's Method

Statistic data of chronological mineralisation age of 18 by Kohler's Method											
Scores	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
1	--	--	--	--	--	6	11	1.3	10	13	--
2	8	11.6	0.5	11	12	1	12	--	12	12	0.51
3	5	11.8	1.3	11	14	3	12.3	1.2	11	13	0.58
4	6	13.3	0.8	12	14	8	13.6	1.8	11	16	0.72
5	4	17.8	2.1	15	20	3	17.3	3.5	14	21	0.85
6	1	15.0	--	15	15	1	12	--	12	12	--
7	3	14.3	1.2	13	15	4	18.8	1.3	17	20	0.005*
8	2	17.0	1.4	16	18	1	18	--	18	18	0.67
9	2	18.5	0.7	18	19	3	19.3	2.3	18	22	0.67
10	19	19.6	1.8	16	23	20	19.7	1.3	18	22	0.89

* - Statistically Significant

Table 8. Chronological mineralisation age of 28 by Kohler's Method

Statistic data of chronological mineralisation age of 28 by Kohler's Method											
Scores	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
1	--	--	--	--	--	5	10.8	1.3	10	13	--
2	5	11.6	0.5	11	12	2	12	0.0	12	12	0.37
3	8	11.8	1.0	11	14	3	12.3	1.2	11	13	0.44
4	6	13.3	0.8	12	14	7	15.4	3.2	12	21	0.14
5	2	15.0	0.0	15	15	4	13.3	1.5	11	14	0.19
6	1	20.0	--	20	20	--	--	--	--	--	--
7	6	16.0	2.2	13	19	2	15.5	5.0	12	19	0.83
8	1	18.0	--	18	18	3	19.7	2.5	17	22	0.91
9	4	18.5	1.7	17	21	3	18.3	0.6	18	19	0.88
10	17	19.7	1.8	16	23	21	19.6	1.3	18	22	0.87

Table 9. Chronological mineralisation age of 38 by Kohler's Method

Statistic data of chronological mineralisation age of 38 by Kohler's Method											
Scores	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
1	5	11.4	0.5	11	12	5	11.2	1.3	10	13	0.76
2	5	11.4	0.5	11	12	3	12.0	1.0	11	13	0.30
3	7	13.1	1.2	12	15	4	14.8	1.5	13	16	0.08
4	2	14.0	0	14	14	5	11.8	1.5	10	14	0.10
5	1	13.0	--	13	13	5	15.4	3.1	12	20	0.52
6	4	14.8	1.3	13	16	2	18.5	0.7	18	19	0.02*
7	4	17.3	1.5	15	18	3	19.0	2.0	17	21	0.24
8	4	18.8	1.7	17	21	3	18.3	0.6	18	19	0.70
9	3	18.7	2.3	16	20	5	19.4	1.1	18	21	0.56
10	15	19.9	1.6	18	23	15	19.9	1.5	18	22	0.91

* - Statistically Significant

Table 10. Chronological mineralisation age of 48 by Kohler's Method

Statistic data of chronological mineralisation age of 48 by Kohler's Method											
Scores	Males					Females					P-Value
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
1	3	11.3	0.6	11	12	3	11.0	1.7	10	13	0.77
2	7	11.9	1.1	11	14	4	11.5	0.6	11	12	0.56
3	7	12.6	1.1	11	14	3	14.0	1.7	13	16	0.15
4	1	14.0	--	14	14	6	13.2	1.8	11	16	--
5	1	13.0	--	13	13	4	14.3	2.1	12	17	--
6	2	18.0	2.8	16	20	2	14.5	6.4	10	19	0.55
7	6	15.7	2.0	13	18	2	20.0	1.4	19	21	0.03*
8	3	17.7	0.6	17	18	6	18.8	1.5	17	21	0.23
9	5	18.4	2.2	15	21	2	18.0	0.0	18	18	0.82
10	15	19.8	1.9	16	23	18	19.8	1.4	18	22	0.95

* - Statistically Significant

Table 11. Regression equation by Kohler's Method

Whole Sample:	Adjusted R^2	P-Value
Age = 0.6 * GH38 + 0.4* GH18 + 9.7	0.82	<0.001*

* - Statistically Significant
Regression equation : Y = ax + b

Table 12. Regression Equation by Kohler's Method

Gender	Regression Equation	Adjusted R^2	P-Value
Males	Age = 1.0 * GH38 + 9.9	0.85	<0.001*
Females	Age = 0.5 * DS38 + 0.6 * DS18 + 9.8	0.81	<0.001*

Pearsons correlation coefficient (r) between chronological age and developmental stages given by Demirjian *et al*. for 18, 28, 38, 48 was 0.86, 0.85, 0.91, 0.89 suggesting a powerful positive correlation. Pearsons correlation coefficient (r) between chronological age and developmental stages given by Kohler for 18, 28, 38, 48 was 0.88, 0.87, 0.90, 0.88 suggesting a powerful positive correlation. Linear multiple regression analysis with backward elimination were used to produce formulae, the dependent variable being a chronological age and the independent variables being the third molar developmental stage. The statistical analysis revealed a powerful correlation between age and third-molar developmental stages given by Demirjian *et al* for males (R^2 = 0.84) and for females (R^2 = 0.81) and a powerful correlation between age and third-molar developmental stages given by Kohler for males (R^2 = 0.85) and for females (R^2 = 0.81). This coefficient is the statistical measure of how well the regression line estimates real data points.

DISCUSSION

Dental development correlates with different morphological stages of mineralization that can be observed on X ray films which comprise a more uniform and gradual set of changes than eruption & are less influenced by external factors (such as malnutrition, disease, and mental stress). Various classifications for evaluating tooth mineralization are available in the literature, such as Gleiser and Hunt, (1955) Moorrees *et al*. (1963) and Kohler *et al*. (1994) Dental age can be assessed among young children with greater accuracy because many teeth are undergoing development and mineralization simultaneously where as in adolescence the wisdom teeth represent the only teeth still in development and thereby playing important role in dental age calculation. (Solari and Abramovitch, 2002; Demirjian *et al*., 1973) The present study is a comparative study that radiographically evaluates the third molar development as an indicator of chronological age by two different age estimation methods and also its accuracy (Demirjian and Kohlers methods) in Indian population. It was found that the scoring given in Demirjian's method andKohler's method was statistically significant and there was moderate agreement between intra observer and inter observer scores.This is in agreement to the study done by Dhanjal, in which Demirjian's method of stage assessment of third molars showed very good intra- and inter-examiner agreement (Dhanjal *et al*., 2006), whereas in another study done by Kullman (1995) and Mesotten (2002) significant inter and intra observer variability were found. Also theStudies conducted by Gunst (2003) and Ali Baghepour (2012) using Kohler's method were in agreement to our study. In our study, the highest Kappa value was seen for the mandibular third molar using both the methods, Reproducibility was higher for mandibular third molars than maxillary third molars as superimposition of anatomic structures over the roots are less which is in agreement with the study done by Dhanjal (2006). However our results disagree with the study done by Baghepour *et al*. (2012) When the mean mineralization ages and standard deviations for Demirjian stages of third molar were considered, we arrived at the conclusion that mineralization of third molars occur earlier in males than females. The results of our study were similar to the study done by Karatas, indicating that third-molar genesis was attained 8.16 months earlier in males than in females. (Karatas *et al*., 2013) However, study conducted by Olze *et al*. (2004) on comparison of the two genders did not yield a significant difference. A study done by Pandey on Rajasthan population showed insignificant positive correlation between male and femalesamples, when chronological and dental age by Demirjian's was used. (Pandey *et al*., 2012)

In this study, chronological age and developmental stages given by Gleiser and Hunt modified by Kohler *et al*, showed a powerful positive correlation coefficient between male and female samples similar to study done by Rai (2010) & Gunst *et al*. (2003) The regression formula for the whole sample as well

as for males and females separately based on the mineralization of the third molars were estimated. This method is considered to be an efficient research tool in forensic age estimation purposes. Linear multiple regression analysis with backward elimination were used to produce formulae, the dependent variable being a chronological age and the independent variables being the third molar developmental stage. The statistical analysis revealed a powerful correlation between age and third-molar development for males and for females using both the methods.The mean absolute difference between the dental age and the chronological age showed the highest precision. Our results are in agreement with the studies of other ethnic groups. (Rai *et al*., 2010; Karatas *et al*., 2013; Bagherpour *et al*., 2012; Pandey *et al*., 2012) After obtaining the results of Demirjian's and Kohler methods individually, comparison between two methods was carried out. It was found that intra and inter observer agreement was better for the method given by Demirjian *et al* than Kohler's method though both the methods showed moderate agreement. Having clearly defined stages and fewer intermediate stages allowed better reproducibility for Demirjian's method. Mean mineralization age of third molar was earlier in males than females according to staging criteria given by both the methods. The influence of gender on root formation expressed a trend for earlier development in males than females and did not differ from results of previous studies. (Dhanjal *et al*., 2006; Mincer *et al*., 1993; Willershausen *et al*., 2001) This is a unique finding for third molars, since for the other permanent teeth the root development rate is faster in females. (Tanner *et al*., 1962)

Though various studies in the past have proven the reliability of radiographic evaluation of third molar development in the assessment of dental age of an individual as an indicator of chronological age, no studies were done to compare the accuracy of Demirjian's and Kohler's method on Indian population. We inferred from our study, that Kohler's method gave more accurate prediction of age in males as compared to Demirjian's method, whereas accuracy for age prediction in females was same according to both the methods. Further studies are required with large sample size and with wider range of age to reduce the standard deviation of the findings and optimize the coefficient of determination (R^2) of the multiple regression formulas which will ensure accurate age estimation in indianpopulation.

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