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Skeletal and Dental Maturity: A Radiographic Co-relation

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ABSTRACT

Introduction: Dental maturity plays an essential role in assessing the chronological age of a person because of its high predictivity. The procedure for assessment of skeletal maturity is composed of visual inspection of the developing bones, their initial formation and consequent changes in shape and size related to ossification. The foot, ankle, hip, elbow, hand-wrist and cervical vertebrae are among the several skeletal portions that have been used to analyze the skeletal maturity.

Materials & Methods: This study comprised of 150 male and 150 female subjects ranging in age from 9 to 25 years. A total of 300 dental panoramic radiographs and lateral cephalograms were obtained and analysed. Calcification stages of the mandibular third molar were rated according to the system of Demirijian. Skeletal age and skeletal maturity stages [cervical vertebrae maturity indicators-(CVMI) and middle phalanx of middle finger] were determined by using the method of Hasal and Farman as well as Hagg and Taranger's method.

Results: Correlation between observed age and age predicted on the basis of study parameters among males and females was found in our study. For males, observed age and predicted ages by different methods positively correlated ($p<0.001$) with each other. The mandibular third molar method was found to have the strongest correlation ($r=0.62$) followed by the cervical vertebrae ($r=0.46$) and predicted age by middle phalanx of third finger ($r=0.38$). In case of females also, observed age and predicted ages by different methods positively correlated ($p<0.001$) with each other. The mandibular third molar method was found to have the strongest correlation ($r=0.50$) by middle phalanx of third finger ($r=0.48$) and predicted age by the cervical vertebrae ($r=0.47$).

Conclusion: The dental and skeletal methods can both be used for age estimation with dental method being more accurate than the skeletal method.

Keywords: Tooth calcification, Panoramic radiograph, Lateral cephalogram, CVMI, Demirijian method, Hassel and Farman method & Hagg and Taranger's method.

INTRODUCTION

The assessment of age is an important aspect in providing information in demographic studies and is of clinical use in diagnosis and treatment planning. The idea of physiological age is based upon the degree of maturation of distinct tissue systems.[1]

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Radiology plays an essential role in human age determination. Radiographs employed in the process of age estimation is one of the crucial tools in recognition in forensic science.[2]Age estimation has a massive amount of utility in person detection as well as to assess the suitable age for beginning of orthodontic treatment in dentistry as well. Dental and skeletal growths are the biological indicators for physiological maturity.[3] Forensic age estimation in human being is a present area of research in the field of forensic science.[4]

Keeping in mind the above, the present study aims to compare the dental maturity by determining tooth calcification in orthopantomogram, skeletal maturity by assessing the cervical maturation in the lateral cephalograms and radiovisiography and correlating both with the chronological age of the patient.

MATERIALS & METHODS

The study was conducted in the Department of Oral Medicine and Radiology, Teerthanker Mahaveer Dental College & Research Centre Moradabad, Uttar Pradesh after obtaining the required approval of the institutional ethical committee. The study compromised of 300 subjects (male 150 & female 150) selected randomly with an age ranging from 9-25 years (with known chronological age) referred to Oral Radiology in whom Orthopantomogram and Lateral cephalogram were advised (mostly by the Department of Orthodontics & Dentofacial Orthopaedics). A standard format was prepared to record the necessary details required for the study.

Healthy individuals with normal occlusion comprised the inclusion criteria. Patients with history of trauma to the neck and hand/finger region, any bone deformities and bone diseases, patients with history of systemic disorders or any congenital or acquired abnormalities of cervical vertebrae and middle phalanx of third finger region were excluded from the study.

Chronologic age of a patient was noted. Patients were questioned to find out any previous history of injury or any underlying systemic disorders. They were clinically screened using mouth mirror and explorer for caries, any clinically missing tooth/teeth or any abnormality. Mandibular left quadrant was screened which was followed by mandibular right quadrant and it was made sure that at least one quadrant was free from any pathology, only then these patients were selected for the study. Skeletal examination mainly dealt with visualizing any pathology in their left hand and cervical vertebrae or any injury. Only those patients who were free of any pathology in there left hand and cervical vertebrae were selected for this study. Those patients who had any pathology which was noticed on the radiograph were also excluded from the study.

A panoramic and lateral cephalogram was obtained for every subject included using Planmeca proline XC 80 kb Digital Panoramic and cephalometric System. Magnifying glass was used where ever necessary for interpreting radiographs. (fig 1and fig .2)

The radiograph of middle phalanx of third finger (MP3) was taken with a standard size (31 × 41 mm Kodak, E- speed) periapical dental X-ray film by placing the hand with the palm downward on a flat table in such a way that the middle phalanx was located in the center of the film. The cone of the standard dental X-ray machine (60 kV and 7mA) was positioned in light contact with the middle phalanx perpendicular to the dental X-ray film, with exposure time of 0.25 seconds. (fig 3)

In orthopantomogram, dental developmental stages of mandibular third molar were separately determined by the Demirjian's method. According to Knell et al[4,1] the development stage and third molars were categorized into one of the following stages

Stage A- top protuberances are mineralized but have not yet fused.
Stage B- mineralized top protuberance are fused; definitive coronal morphology is defined.
Stage C- crown is half formed, the pulp chamber is visible & dentine deposit is in process.
Stage D- coronal formation is complete up to amelodentinal junction pulp has trapezoidal contour.
Stage E- formation of interradicular bifurcation is underway; root length is less than the coronal length.
Stage F- root length is atleast as long as coronal length; roots have funnel shaped ends.

Stage G- roots walls are parallel; root apex is still open.
Stage H- apex of the roots are completely closed.

According to Negi et al[5] Lateral cephalometric radiographs were evaluated by the Hassel and Farman's method that establishes six stages. In this method, C2,C3 and C4 vertebrae are analysed according to their shape and classified into one of these six stages: -

I- Initiation
II- Acceleration
III- Transition
IV- Deceleration
V- Maturation
VI- Completion

Ossification stages of middle phalanx of third finger(MP3) was determined by Hagg and Taranger's method mentioned by Negi et al[5,1] .Middle phalanx also undergoes the four sequential stages- Epiphyseal widening, Ossification, Capping & lastly the fusion. Mean and standard deviation was calculated for different groups. Correlation was made among cervical vertebral maturation, middle phalanx of third finger and third molar calcification stages.

RESULTS

Dental development stage

Dental development stages were calculated for 300 orthopantomogram. The percentage distributions of the stages of calcification for studied third molar teeth are shown in Graph 1 which shows the highest percentage of 42.7% in stage H.

Cervical vertebral maturation stage

300 lateral cephalometric radiographs were observed by the principal investigator (Examiner 1) and then independently by a second investigator (Examiner 2) to calculate the maturation stage. The highest percentage of stage 4 that is 47.7% was noted in 143 subjects as shown in Graph 2.

Skeletal maturity stage of Middle phalanx of middle finger (MP3)

300 IOPAR of middle phalanx of middle finger was taken and the percentage distribution of maturation stages of middle phalanx (MP3) is shown in Graph 3 which shows the highest percentage of stage 6 that is 81.7% in 245 subjects.

Distribution of parameters of different stages according to Gender

Percentage distributions for the relationship between dental development stages of the lower third mandibular molar teeth calcification stage for all subjects are shown in Graph 4. The third molar stage H showed the highest percentage distribution in both males (46%) and females (39.3%) and total percentage was 42.7%.

Percentage distributions for the relationship between Cervical maturation stages for all subjects are shown in graph 5. The stage 4 showed the highest percentage distribution in both males (38%) and females (57.3%) with a total percentage of 47.7%.

Percentage distributions for the relationship between Skeletal maturation stages of the middle phalanx of middle finger (MP3) for all subjects are shown in graph 6. The stage 6 showed the highest percentage distribution in both males (80%) and females (83.3%) with a total percentage of 81.7.

Table 1: Correlation between age and dental and skeletal maturation stages.

Group			AGE	3 M0LAR	CVMS
Male	3 M0LAR	Correlation Coefficient	0.66	1	
		p-value	<0.001*	.	
	CVMS	Correlation Coefficient	0.44	0.62	1
		p-value	<0.001*	<0.001*	.
	MP3	Correlation Coefficient	0.40	0.14	0.28
		p-value	<0.001*	0.10(NS)	0.001*
Female	3 M0LAR	Correlation Coefficient	0.54	1	
		p-value	<0.001*	.	

	CVMS	Correlation Coefficient	0.44	0.49	1
		p-value	<0.001*	<0.001*	.
	MP3	Correlation Coefficient	0.52	0.17	0.16
		p-value	<0.001*	0.03*	0.052(NS)

Spearman's correlation test *p<0.05 statistically significant, p>0.05 non-significant, N

Table 2: Descriptive statistics of age of both sexes of dental calcification stage

Group	3 molar	Paired Differences					t	df	p-value
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Male	1	4.11	4.93	2.01	-1.06	9.28	2.05	5	0.09(NS)
	3	-2.56	1.79	0.80	-4.79	-0.34	-3.21	4	0.03*
	4	-0.47	2.49	0.42	-1.32	0.39	-1.11	34	0.28(NS)
	5	-1.01	2.98	0.94	-3.14	1.12	-1.07	9	0.31(NS)
	6	-0.42	2.48	1.01	-3.02	2.19	-0.41	5	0.69(NS)
	7	-0.43	1.89	0.43	-1.35	0.48	-1.00	18	0.33(NS)
	8	0.37	3.73	0.45	-0.53	1.26	0.82	68	0.42(NS)
Female	1	3.13	4.74	1.43	-0.05	6.31	2.19	10	0.053(NS)
	4	-1.56	2.79	0.44	-2.45	-0.67	-3.54	39	0.001*
	5	0.57	3.72	1.07	-1.79	2.94	0.53	11	0.60(NS)
	6	0.45	3.60	0.90	-1.47	2.36	0.50	15	0.63(NS)
	7	0.34	2.17	0.69	-1.21	1.90	0.50	9	0.63(NS)
	8	0.27	3.47	0.45	-0.63	1.18	0.61	58	0.55(NS)

Paired t test*p<0.05 statistically significant, p>0.05 non significant, NS

Table 3: Descriptive statistics of age of both sexes of Skeletal maturation stage CVM

Group	CVMS	Paired Differences					t	df	p-value
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Male	1	-2.17	3.00	1.00	-4.48	0.14	-2.17	8	0.06(NS)
	2	-1.34	2.36	0.42	-2.20	-0.48	-3.17	30	0.004*
	3	3.12	4.02	0.64	1.81	4.42	4.84	38	<0.001*
	4	-0.71	3.30	0.44	-1.58	0.17	-1.62	56	0.11(NS)
	5	-1.44	2.93	0.78	-3.13	0.25	-1.84	13	0.09(NS)
Female	1	-2.74	0.82	0.41	-4.04	-1.44	-6.71	3	0.007*
	2	0.62	3.96	0.83	-1.09	2.33	0.75	22	0.46(NS)
	3	-0.43	3.42	0.67	-1.81	0.95	-0.64	25	0.53(NS)
	4	0.27	3.38	0.36	-0.45	0.99	0.74	85	0.46(NS)
	5	-1.40	4.95	1.49	-4.72	1.92	-0.94	10	0.37(NS)

Table 4: Descriptive statistics of age of both sexes of Skeletal maturation stage MP3.

Group	MP3	Paired Differences					t	df	p-value
		Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Male	4	2.65	1.91	0.96	-0.40	5.69	2.76	3	0.07(NS)
	5	-0.81	4.26	0.84	-2.54	0.91	-0.97	25	0.34(NS)
	6	0.09	3.84	0.35	-0.61	0.78	0.25	119	0.80(NS)
Female	4	2.21	1.79	0.60	0.83	3.58	3.70	8	0.006*
	5	-2.48	2.52	0.63	-3.83	-1.14	-3.94	15	0.001*
	6	0.16	3.64	0.33	-0.49	0.80	0.49	124	0.62(NS)

Table 5: Correlation between observed age and age predicted on the basis of study parameters.

Group			Observed age	Predicted age - CVMS	Predicted age - MP3
Male	Predicted age - CVMS	R	0.46	1	-
		p-value	<0.001*	-	-
	Predicted age – MP3	R	0.38	0.32	1
		p-value	<0.001*	<0.001*	-
	Predicted age – 3 Molar	R	0.62	0.608**	0.17
		p-value	<0.001*	<0.001*	0.04*
Female	Predicted age - CVMS	R	0.47	1	-
		p-value	<0.001*	-	-
	Predicted age – MP3	R	0.48	0.151	1
		p-value	<0.001*	0.07(NS)	-
	Predicted age – 3 Molar	R	0.50	0.49	0.16
		p-value	<0.001*	<0.001*	0.05(NS)

DISCUSSION

The development status of an individual is usually assessed in relation to physical events that take place during the progress of growth like skeletal ossification stages, the attainment of peak growth velocity, pubescent changes in the body, or dental calcification stages.[6]

It has long been contended that dental eruption, which is the most conspicuous and easily determined indicator of dental maturation, is much more variable in its timing than skeletal maturation. According to Nolla, dental eruption has also been reported to be more variable than the calcification sequence in the dentition. In the present study, calcification stages of teeth instead of eruption were preferred because tooth formation is proposed as a more reliable criterion for determining dental maturation. Therefore, the dental maturity assessment stages of Demirjian et al were used. This Demirjian's method also shows high accuracy when applied to north Indian population.[7]

Panoramic radiograph was selected over intraoral periapical radiographs to study the stages of calcification of third molar due to clear visibility of the image of the area required and less radiation exposure.[8]

In the present study third molar stage H showed the highest percentage distribution in both males (46%) and females (39.3%) with a total percentage of 42.7% & Correlation between the obtained dental age and chronologic age was found to be statistically significant (p<0.001, r=0.62 in males

and r=0.50 in females). Hagg and Matsson[8] found a high correlation level (r=0.7-0.9) between true and estimated ages in children between 3.5 and 6.5 years regardless of the method used. Statistically high correlation has also been reported by Gulati et al[9] (r=0.86).

In present study CVMIs were evaluated using lateral cephalograms, which are routine diagnostic radiographs for orthodontic treatment. When the correlation was observed separately in the two genders in our study, better correlation was observed in females (r= 0.47 P<.001) than males (r=0.46, P<.001) as in table 5. Regarding the sex our findings were supported by Kamal[10] (male r=0.892, female r=0.858). In contrast to the present study females in the study of Roman (male r=0.77, females r=0.84), Caltabino[11] (male r=0.450, females r=0.564), Uysal[12] (males r=0.78, females r=0.88), Grippaudo[13] (male-0.70, females=0.84) and Sun Y et al[14] (male r=0.858, females r=0.882) presented higher correlation values than males. Lamparski suggested that cervical vertebral maturation was more reliable in female than males.

The difference in correlation in the present study and other international studies might be due to difference in racial and ethnic background, sample selection technique and criteria, sample size, gender and the methodology used for skeletal maturation assessment. Gabriel et al[15] showed poor reproducibility of CVM stages. In contrast Chen et al concluded that the quantitative CVM method is an efficient, objective, and relatively simple approach to assess the level of skeletal maturation during adolescence.

The results of the study reveal that the maturation of the middle phalanx of third finger and cervical vertebrae progress with advancing age. It can be seen from Graph 5 and 6 that there are gradually increasing stages of CVMI and MP3 stages with age. It was found that at the same chronological age, there was highly significant difference (p<0.01) (Table 1). In all, the CVMI & MP3 stages were more advanced in females than in males. Similar types of sexual dimorphism regarding the maturational parameters are in agreement with previous observation in growth studies.

Many studies reported that the high correlations between the tooth calcification stages and the skeletal maturity indicators probably allow the clinician to more easily identify the stages of the pubertal growth period from the panoramic radiograph. On the other hand, Lewis and Garn[16], Garn et al[17], and Tanner[18] have reported low or insignificant correlations between the level of skeletal and dental maturation. The lack of concordance among the results of previous studies may be attributed, at least in part, to the different methods used for assessing skeletal and dental maturity. Because the similar methods and same population were used, in the studies of B. Rai et al[19] we compared most of our results with their findings and the results are significantly correlated. We also found similar trends from the studies done in Turkish subjects and Thai individuals.

For males, age and maturation stages are positively correlated (p<0.001) with 3 molar maturation stage having the strongest correlation(r=0.66) followed by CVMS(r=0.44) and MP3(r=0.40). For females also, age and maturation stages are positively correlated (p<0.001) with 3 molar maturation stage having the strongest correlation(r=0.54) followed by MP3(r=0.52) and CVMS(r=0.44). This finding agreed with those of Garn et AL[17.1], who reported a poor relationship between third molar formation and skeletal maturity. Great variation in development of this tooth, as stated by many investigators, may adversely affect the identification of the relationship between dental and skeletal development. However, in contrast to the finding in the present study, Engstrom and coworkers found a strong correlation (*r* =0.72). The strong relationship reported may have resulted from the use of fewer differentiated stages of mandibular molar development in their study. This tooth offers an advantage over other teeth because its development tends to continue over a longer period and until a later age.

In our study the anatomical features of the second (odontoid process), third and fourth cervical vertebrae were evaluated here as visualized on lateral cephalograms in a time interval ranging on average from 9 to 25 years where visible definable changes occur in the shapes of C2, C3 and C4. Dental calcification stages measured using the Demirjian's method (the simplest and most practical method), were used to determine dental maturity, whereas skeletal maturity was assessed by the widely used CVM method. A statistically significant correlation

was found between tooth calcification stage and cervical vertebra maturation stage and third molar is best for males and females in predicting age.

CONCLUSION

The finding of study indicates that there was strong correlation between age assessed by third molar AND is best for males and females in predicting age. There was good correlation between age assessed by MP3 and CVMI. CVMI and third molar could also be used as a skeletal maturity indicator besides MP3 and both the dental and skeletal method can be used for age estimation with dental method being more accurate than the skeletal method

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