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Determination of skeletal maturity- a comparison of three methods

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Abstract

Aim

1. To evaluate the reliability of using middle phalanx for third finger (MP3) & mandibular second molar (37) as indicators of skeletal age by relating their ossification/calcification stages to those of the cervical vertebrae (CV).
2. To determine whether any significant difference exists between the sexes when MP3, 37 & CV are used as maturity indicators.

Materials and Method: 20 children (10 girls and 10 boys) between 8-16 years of age were included and divided into two groups each (8-11 & 12-16 yrs). All the children were subjected to: Lateral cephalogram, IOPA 37, Digital radiograph of the MP3 region. Staging was done according to different methods and assessed by three examiners. The inter- and intra-examiner variability were determined by the Wilcoxon signed rank test and the Kruskal-Wallis test and were found to be non-significant. Examiner A was selected to evaluate all radiographs as she showed the least intraexaminer variability.

Statistical Analysis: Performed using SPSS version 20. The correlation between the percentage distribution of the subjects within the MP3 and 37 stages with CVMI and the peak-wise distribution of the MP3 and 37 stages were statistically analyzed using Pearson's chi-square test; ANOVA was used to determine the correlation between the MP3 & 37 stages with the calendar age.

Results: The correlation between MP3 & CVMI and 37 & CVMI stages were found to be highly significant.

Conclusions: Digital radiography of MP3 and 37 can be used conveniently for skeletal maturity assessment.

Keywords: CVMI, MP3, 37, Digital radiograph, Skeletal and maturity

Introduction

Growth is a critical variable in diagnosis and treatment planning especially in the field of orthodontics, pedodontics and off late- forensics. Change is the only thing constant, variability being a law of nature; because of the infinitely possible permutations and combinations of genetic codons, no two individuals are alike. Human growth is very complex in nature being influenced by a multitude of factors. The developmental status of a child may be assessed on the basis of different events such as skeletal ossification stages, attainment of peak growth velocity or pubescent changes etc., however these events vary considerably in their time of occurrences among different children. Therefore, it may not be wrong to assume that the skeletal age is a better indicator of biological stage of maturity than the chronological age. Solely, chronological age cannot help identify the stages of developmental progression from adolescence through adulthood.[1]

Of all the physical events indicating the changing physiology with chronology, growth is the one factor whose assessment should take precedence over others as we have tools to observe and predict its characteristics.[2] Different orthognathic procedures use the occurrence of growth spurts to maximize their efficacy for modification of growth.

Several methods have been developed for assessment of skeletal maturity. Hellman[3] in 1928, published his observations on the ossification of epiphysial cartilages of the hand. Greulich and Pyle[4] prepared the first standards of maturational development using hand-wrist radiographs. Dental radiographs were first used by Chapman[5] to record the ossification of the adductor sesamoid. Demirjian et al[6] put forth a new method of age assessment wherein the development of teeth was radiographically categorized into different stages for calculation. In 1982, Fishman[7] developed a method he termed as Skeletal Maturation Assessment (SMA) wherein he categorized maturation of bones at six different anatomical sites in the hand and wrist into four stages. Leite et al[8] considered the first three fingers of the hand to provide a reliable marker. It was noticed by Hägg and Taranger[9,10] that the middle phalanx of the third finger of the hand (MP3 stages) goes through various stages of ossification that follow the pubertal growth spurt.

Changes in the size and shape of the vertebral bodies with growth can also be used for determination of maturation from birth up to full maturity.[11-16] Hassel and Farman[17] developed a new technique in order to evaluate the skeletal development from cephalometric roentgenograms.

Our study aimed at assessing the reliability of using MP3 ossification stages and calcification stages

of mandibular left second molar (37) for maturity assessment and comparing with the standard cervical vertebrae maturity assessment (CVMI) and also to correlate these with the chronological age.

Materials and Method

Ethical committee clearance was obtained prior to commencement of the hospital-based study. 20 children (10 girls and 10 boys) between 8-16 years of age were included who were undergoing orthodontic treatment and divided into two groups each (8-11 & 12-16 yrs). Informed written consent of parents/guardians of the subjects was obtained.

All the children were then subjected to:

1. Lateral cephalogram
2. IOPA 37
3. Digital radiograph of the MP3 region

Extraoral radiograph machine (Orthophos, Sirona, Germany) was used to take the Lateral cephalograms using the exposure parameters 78 kVp, 10 mA & 1.2 sec. Source to midsagittal distance was 60 inches.

IOPA 37 was taken using Kodak E-speed intraoral films, size 2 using bisecting angle technique, Snap-A-Ray film holding instrument. Exposure was given using intraoral X-ray unit- ERGON-X HF, MI, Italy using the exposure parameters: 70 kVp, 7 mA, 0.70 sec.

Digital radiograph of MP3 was taken using the CDR Wireless RVG (Schick Technologies, LIC, NY) using size 2 CCD sensor. Exposure was given using intraoral X-ray unit- ERGON-X HF, MI, Italy. Exposure parameters- 70 kVp, 7 mA, 0.05 sec. For this, the subject was made to sit comfortably on a chair with their left hand on a table top with the MP3 region kept on the wireless sensor along its long axis and the fingers wide apart. The central X-ray beam was then passed perpendicular to the area of interest.

All radiographs were processed with standardized processing technique and were numbered for identification. Only good quality radiographs were included for further staging and scoring. The MP3 and CVMI radiographs were assessed by three different examiners (A, B and C) on two different occasions three weeks apart. The lateral cephalograms obtained were traced on matte acetate paper of 0.003-inch thickness with a sharp graphite pencil while placing horizontally on a clean X-ray view box in a darkened room using a magnification lens of 2.5x magnification.

Staging

Developmental stages of cervical vertebrae: The method proposed by Lamparski[15] and modified by Hassel and Farman[17] was used for the assessment of the cervical vertebrae. Stages were categorized and allotted from CVMI 1 through 6.

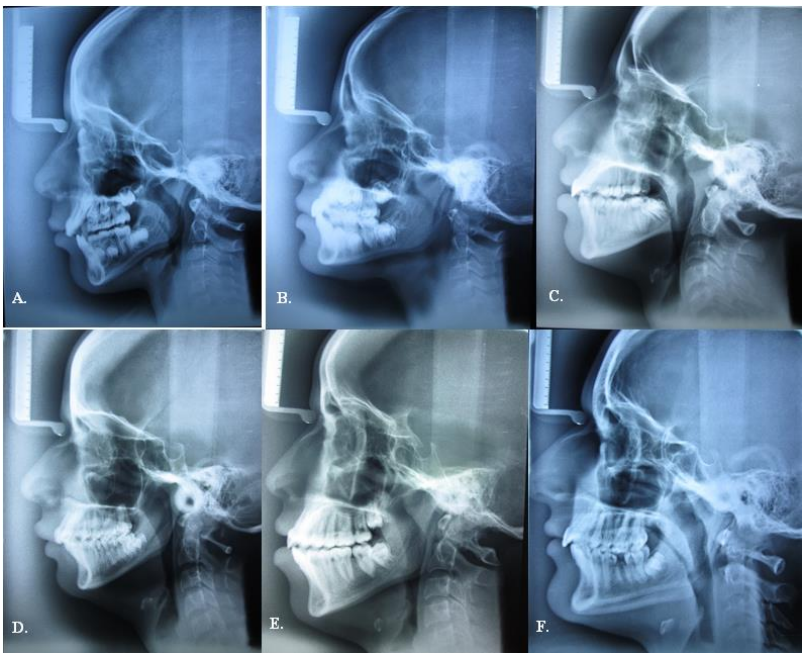

Fig. 1

Fig. 1: Developmental stages of the cervical vertebrae: These were staged according to the Hassel and Farman method.[17] We came across stages CVMI 1 to 6 in our study.

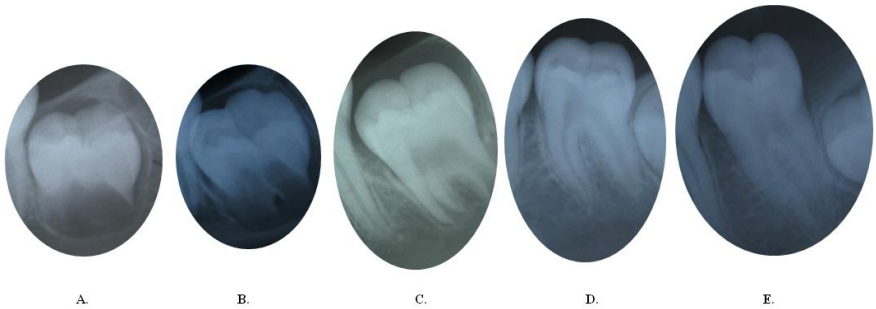

Fig. 2

Fig. 2: Development stages of mandibular left second molar: There were staged according to the calcification stages put forth by Demirjian et al.[16] We came across stages D through H in our study.

Fig. 3

Fig. 3: Developmental stages of middle phalanx of the third finger: For radiographic interpretation of MP3 stages, (E3/4) stage (Leite et al[8]) was added in Hägg and Taranger's[9,10] method of MP3 stages so the stages were allotted as E3/4, F, FG, G, H and I.

Statistical Analysis: All statistical analysis was performed using SPSS® (Statistical Package for Social Sciences) for Windows®, version 20. Statistical significance was set at $P = 0.05$. Wilcoxon signed rank test and Kruskal-Wallis test respectively were used to assess the inter- and intra-examiner variability amongst the three examiners, respectively. The results were found to be insignificant. The least variability was seen for examiner A (VK) and she was selected to evaluate all the radiographs.

The data thus gathered was tabulated and subjected to further statistically evaluation. The correlation between the percentage distribution of the subjects within the MP3 and CVMI and 37 stages and the peak-wise distribution of the MP3 and 37 stages were statistically analyzed using Pearson's chi-square test. The correlation between the MP3 and 37 stages with the calendar age was determined using ANOVA.

Results

The mean age of the subjects was 11.70 + 2.751 for males and 11.90 + 2.601 for females, which was statistically not significant implying that the population studied was homogenous.

The percentage distribution of the subjects within the MP3 and CVMI stages are presented in Figure 4 and Table 1. The percentage distribution of the subjects within the 37 and CVMI stages are presented in Figure 5 and

Table 2. Table 3 shows the peak-wise distribution of the MP3 stages into prepeak, peak and postpeak stages. There was a notable correlation amongst the developmental stages determined using all the three methods. The correlation between the MP3 and CVMI stages especially was highly statistically significant ($p < 0.0001$) (Table 4).
The correlation between MP3 with chronological age and 37 with chronological age was found to be statistically significant. See Table 5, 6.

Table 1: Distribution of the MP3 & the CVMI stages % within CVMI

		CVMI						Total
		CVMI 1	**CVMI 2**	**CVMI 3**	**CVMI 4**	**CVMI 5**	**CVMI 6**	
MP3	E3/4	75.0%						15.0%
	F	25.0%	40.0%					15.0%
	FG		60.0%	50.0%				25.0%
	G			25.0%	50.0%			15.0%
	H				25.0%	50.0%	100.0%	15.0%
	I			25.0%	25.0%	50.0%		15.0%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2: Distribution of the 37 & the CVMI stages % within CVMI

		CVMI						Total
		CVMI1	**CVMI 2**	**CVMI 3**	**CVMI 4**	**CVMI 5**	**CVMI 6**	
37	D	50.0%						10.0%
	E	50.0%	20.0%					15.0%
	F		80.0%	100.0%	25.0%			45.0%
	G				75.0%		100.0%	20.0%
	H					100.0%		10.0%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 3: Peak-wise distribution of the MP3 stages % within CVMI PEAKS

		CVMI Peaks			
		PRE Peak	**Peak**	**Post Peak**	**Total**
MP3	E3/4	33.3%			15.0%
	F	33.3%			15.0%
	FG	33.3%	25.0%		25.0%
	G		37.5%		15.0%
	H		12.5%	66.7%	15.0%
	I		25.0%	33.3%	15.0%
Total		100.0%	100.0%	100.0%	100.0%

Table 4: Correlation between the distribution of the MP3 & CVMI stages

	Value	**d.f.**	**Asymptotic sig (2 sided)**
Pearson's Chi-square test	39.867*	25	0.30

Table 5: One way ANOVA-Boys+Girls for MP3 Descriptive

Calender Age (in yrs)									p-value
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
E3/4	3	8.33	.577	.333	6.90	9.77	8	9	≤0.0001
F	3	9.33	.577	.333	7.90	10.77	9	10	
FG	5	11.60	1.517	.678	9.72	13.48	10	14	
G	3	12.00	1.000	.577	9.52	14.48	11	13	
H	3	14.67	1.528	.882	10.87	18.46	13	16	
I	3	15.00	1.000	.577	12.52	17.48	14	16	
Total	20	11.80	2.608	.583	10.58	13.02	8	16	

Table 6: One way ANOVA-Boys+Girls for 37

Descriptive									
Calendar Age (in yrs)									
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P value
					Lower Bound	Upper Bound			
D	2	8.00	0.000	0.000	8.00	8.00	8	8	
E	3	9.00	0.000	0.000	9.00	9.00	9	9	
F	9	12.00	1.871	.624	10.56	13.44	10	15	
G	4	13.25	1.258	.629	11.25	15.25	12	15	
H	2	16.00	0.000	0.000	16.00	16.00	16	16	
Total	20	11.80	2.608	.583	10.58	13.02	8	16	p=≤0.0001

Discussion

Every bone undergoes a series of change during growth which radiology can help us visualize. The sequential changes that a given bone goes through are relatively consistent but the timing varies for each individual. It is not necessary to know the exact skeletal age of patient, but what is important to know is the leftover growth potential during the period of treatment and the percentage of growth expected at the time of treatment.

It is a known fact that chronological age needn't correlate exactly with maturational age. The biological changes an individual goes through on a temporal scale are a result of multiple factors. Thus, one may be skeletally accelerated or delayed when it comes to maturational development.[8,10,18]

The hand-wrist region has been the most frequently used area of the skeleton for growth assessment. The reason for its use is that many centers are available in this area of the skeleton, with changes occurring at different times and rates. Furthermore, dental radiographs of the lower molar region are routinely taken for patients of this age group. So our study evaluated an additional parameter for skeletal age assessment in comparison with past studies.

Using digital radiography reduced the exposure time considerably (4-5 times) thereby fulfilling the ALARA (as low was reasonably achievable) principle.

The results of this study clearly reveal that the maturation of the cervical vertebrae, middle phalanx of the third finger and ossification stages of mandibular second molar progress with advancing age. In all the subgroups, the CVMI, MP3 and 37 stages were more advanced in females than in males. This is in agreement with previous studies.[1,10]

The results of this study will provide the clinician with an additional tools to help determine the growth potential in the adolescent patient.

This was to be accomplished by using anatomic changes of the middle phalanx of the third finger (MP3) & calcification stages of mandibular second molar (37), which was then compared with the known standard CVMI as observed on the lateral cephalometric radiograph to determine skeletal maturity.

In the digital image of the middle phalanx of the third finger, the clinician will have a reliable diagnostic tool to aid in formulating treatment options.

Conclusion

Digital radiography of the MP3 region is definitely a simple, reliable, cost-effective, and time-saving

technique with relatively very less radiation exposure for the assessment of skeletal maturity. The digital MP3 radiographic method of skeletal age assessment and the evaluation of 37 calcification was found to be highly comparable with the known standard method of cervical vertebrae maturity assessment (CVMA). The MP3 stages could be further categorized peak-wise into pre-peak, (corresponding to MP3 E3/4, MP3F and MP3FG), peak (corresponding to MP3G), and post-peak (corresponding to MP3H and MP3I) stages of pubertal growth spurt. Also, the existence of sexual dimorphism at the same chronological age was demonstrated by our study.

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