Original Article

Variability of Subjective v/s Objective Method of determination of skeletal age

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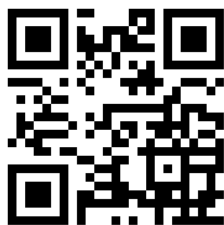
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ABSTRACT

Introduction. The aim of this study was to examine the variability between the subjective and objective methods of assessing skeletal age using cervical vertebral maturation stages and to find out which objective method gives a better estimate of skeletal age.

Materials and Methods. Standardised lateral cephalograms of thirty subjects (female-12, male-18) in their circum-pubertal growth period were taken. For the subjective assessment of skeletal age using cervical vertebral maturation stages, Hassel and Farman (HF) and Franchi, Baccetti and McNamara(FBM) methods were used. For the objective method, T.Mito et al (TM) and P.Beit et al (PB) methods were used. Two observers assessed, the skeletal maturation for each subject to find out the inter-examiner error for both subjective and objective methods, also the co-relation of skeletal age obtained by the two objective methods with the bone age determined by hand wrist radiograph was done.

Results. The results showed that there was a poor agreement present between two observers in both the subjective methods and the objective method given by P.Beit. There was significant inter-examiner agreement while calculating age through T.Mito et al objective method. However, the result showed that P.Beit method showed higher co-relation with the skeletal age when the same was assessed by hand wrist.

Conclusion. There is less inter-examiner error present between observers in objective methods when compared to subjective methods of skeletal age assessment and P.Beit method of objective assessment of skeletal age better co-relates with the Tanner Whitehouse method of skeletal age assessment.

Introduction

Skeletal maturation refers to the degree of development of ossification in bone.[1]During the growth, every bone goes through a series of changes and the sequence of changes is relatively consistent for a given bone in every person. The timing of skeletal maturation varies because each person has his or her own biological clock.

One of the important diagnostic tools currently used is the cervical vertebral maturation in determining the onset, peak and completion of pubertal growth. The changes in the shape of the cervical vertebrae that is, the concavity of the inferior edge and the vertical height can help in determining skeletal maturity and residual growth potential which is very essential in deciding the treatment plan.[2] However, till recently these methods were subjective, which was based on observation of the

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size and shape of cervical vertebrae and hence were more prone to inter and intra-examiner error. To overcome this variability newer objective methods based on measurement of various parameters on the cervical vertebrae have been introduced for estimating the skeletal age of the patient. However there has been no literature regarding the reliability of assessing the skeletal age using these objective methods. This paper aims at focussing on the variations in different subjective and objective methods of assessing the skeletal maturity of the patient, in order to find out which method gives the most reliable estimate of skeletal age. It also aims to assess the inter-examiner variability in the skeletal age using two subjective methods of cervical maturation indices and two objective methods of cervical maturation indices to find out which method causes less inter-examiner variation and to find which objective method correlates better with hand wrist bone age.

Materials and Methods

Source of data

The study sample consisted of hand wrist radiographs and lateral cephalograms of 30 subjects aged between 8 and 16 years (male-18 and female-12) from the patients visiting Department of Orthodontics and Dentofacial Orthopedics, Dayananda Sagar College of Dental Sciences.

Inclusion criteria

The subjects taken were within circum-pubertal growth period with no previous trauma or injury to the face and hand wrist region.

Methodology

Standardized Lateral cephalograms and hand wrist radiographs of each patient were taken. The skeletal maturation was assessed for each patient by two observers subjectively by methods given by Hassel and Farman(HF)[4] and Franchi, Baccetti and McNamara(FBM)[5]. The morphology of three cervical vertebrae (C2, C3, C4) was evaluated by visual inspection to give the staging. The skeletal age for each patient was calculated using objective method by Philip Beit et al and Philip Beit et al Toshinori Mito et al as follows:

A. Objective assessment of cervical vertebrae maturation using Philip Beit et al method.

On the lateral cephalograms, the following lines and points to define the morphologic features of the cervical vertebrae were traced and measured with the use of a micrometer calipers for the Philip Beit et al method. (Fig 1A)

1. C2p, C2m, C2a: The most posterior, the deepest and the most anterior points on the lower border of the body of C2.

2. C3up, C3ua: The most superior points of the posterior and anterior borders of the body of C3.

3. C3lp, C3m, C3la: The most posterior, the deepest and the most anterior points on the lower border of the body of C3.

4. C4up, C4ua: The most superior points of the posterior and anterior borders of the body of C4.

5. C4lp, C4m, C4la: The most posterior, the deepest and the most anterior points on the lower border of the body of C4.

B. The following lines and points were traced on the third and fourth cervical vertebrae and measured with the use of a micrometercalipers for the T.mito et al method. (Fig 1B)

1. Anterior vertebral body height (AH),

2. Vertebral body height(H),

3. Posterior vertebral body height (PH), and

4. Anteroposterior vertebral body length (AP).The ratios of these parameters were calculated (AH/AP, H/AP, PH/AP, AH/H, H/PH, and AH/PH)

The skeletal age was calculated by taking these measurement using formula for skeletal age calculation.[1,2]

The cervical vertebrae skeletal maturation was evaluated using the formula as follows:

A. Formula by T.Beit et al–

Cervical Skeletal Age Boys = 4.559 + 9.897 X Concavity C2 + 6.866 X Concavity C3 + 10.066 X Concavity C4 +6.193 X anterior height C3 + 2.844 X anterior height C4.

Cervical Skeletal Age Girls = 5.242 + 5.758 X Concavity C2 + 6.629 X Concavity C3 + 9.176 X Concavity
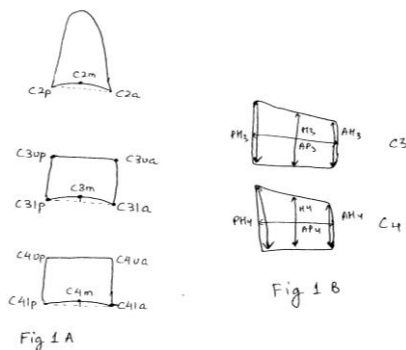

Figure 1: A. Philip Beit method B. T.Mito method

C4 + 2.953 X anterior height C3 + 4.306 X anterior height C4.

B. Formula by T.mito et al

Cervical vertebral bone age = -0.20 + 6.20 X AH_3/AP_3 + 5.90 X AH_4/AP_4 + 4.74 X AH_4/PH_4

The inter-examiner error was calculated between the two subjective methods (HF and FBM)and the two objective methods(TM and PB) to find out which methods give less error.

In addition the skeletal age was also determined from the Hand wrist radiograph using Tanner and Whitehouse method[6] with the help of Bone Age Calculator.[7] The two objective methods of calculating skeletal age(TM and PB) by cervical vertebral staging were correlated, with the bone age obtained by the Tanner and Whitehouse hand and wrist method.

Statistical analysis

For the statistical analysis Cohen's Kappa statistics was done to find the inter-examiner error between subjective methods of assessing skeletal maturation. A paired *t* test was used to determine if there was a significant inter-examiner difference in the objective method of skeletal age estimation. Correlation coefficients was used to determine the co-relation between cervical vertebral bone age and bone age determine by hand wrist radiograph. All analyses were performed using SPSS software.

Results

The table I and table II compares the inter observer subjective assessment of the skeletal maturity by Hassel & Farman (CVMI) staging method and Franchi Baccetti and Mcnamara (CS) staging using Cohen's Kappa statistics, which shows poor agreement between two observers having kappa value of 0.16 and 0.06 respectively.

Table -III, IV shows the inter-examiner variability for the skeletal age calculated by P.Beit and T.Mito method using student paired t test. This shows that there is better agreement between the observers when objective method is used to calculate the skeletal age.

Table V and Fig 2 shows correlation between the Hand wrist bone age and skeletal age by T.Mito and P.Beit.

Correlation coefficient between bone age and skeletal age by P.Beit method(r-value- 0.96) was higher as compared to bone age and skeletal age by T.Mito method(r value-0.69).

Table -I: Comparison of the inter observer subjective assessment of the skeletal maturity by Hassel & Farman (CVMI) staging method using Cohen's Kappa statistics								
CVMI-Obs-1	CS-Obs-2					Total	Kappa Value	P-Value
	SMI-1	SMI-2	SMI-3	SMI-4	SMI-5			
SMI-2	4	7	0	0	0	11	0.16	0.09
	100.00%	43.80%	0.00%	0.00%	0.00%	36.70%		
SMI-3	0	6	3	0	1	10		
	0.00%	37.50%	50.00%	0.00%	50.00%	33.30%		
SMI-4	0	2	0	1	0	3		
	0.00%	12.50%	0.00%	50.00%	0.00%	10.00%		
SMI-5	0	1	3	1	1	6		
	0.00%	6.30%	50.00%	50.00%	50.00%	20.00%		
Total	4	16	6	2	2	30		
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%		

Table II :Comparison of the inter observer subjective assessment of the skeletal maturity by FranchiBaccittiMcnamara (CS) staging method using Cohen's Kappa statistics								
CS-Obs-1	CVMI-Obs-2					Total	Kappa Value	P-Value
	SMI-1	SMI-2	SMI-3	SMI-4	SMI-5			
SMI-2	3	0	0	0	0	3	0.06	0.47
	50.00%	0.00%	0.00%	0.00%	0.00%	10.00%		
SMI-3	3	6	2	0	1	12		
	50.00%	75.00%	28.60%	0.00%	33.30%	40.00%		
SMI-4	0	2	1	4	0	7		
	0.00%	25.00%	14.30%	66.70%	0.00%	23.30%		
SMI-5	0	0	3	2	1	6		
	0.00%	0.00%	42.90%	33.30%	33.30%	20.00%		
SMI-6	0	0	1	0	1	2		
	0.00%	0.00%	14.30%	0.00%	33.30%	6.70%		
Total	6	8	7	6	3	30		
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%		

Table- III Comparison of mean skeletal age (in yrs) of both the observers by P.Beit method using student paired t test										
						95% CI of the Differ				
Observers	N	Mean	SD	S.E.M	Mean Diff	Lower	Upper	t	df	P-Value
Observer-1	30	12.04	1.28	0.23	-0.20	-0.33	-0.07	-3.111	29	0.004*
Observer-2	30	12.24	1.18	0.22						

Table-IV Comparison of mean skeletal age (in yrs) of both the observers by T. Mito method using student paired t test										
						95% CI of the Differ				
Observers	N	Mean	SD	S.E.M	Mean Diff	Lower	Upper	t	df	P-Value
Observer-1	30	11.75	1.37	0.25	0.01	-0.13	0.14	0.087	29	0.93
Observer-2	30	11.74	1.39	0.25						

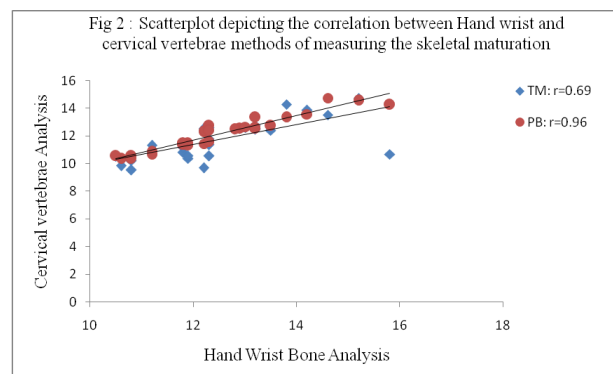| Table-V Correlation between Hand wrist and cervical vertebrae methods of measuring the skeletal maturation					
Observers	Method	Values	T & W	T. Mito	P.Beit
Observer-1	T & W	r-value	1	0.71	0.94
		P-value		<0.01*	<0.01*
		N	30	30	30
Observer-2	T & W	r-value	1	0.67	0.95
		P-value		<0.01*	<0.01*
		N	30	30	30
Obs 1 & 2 Avg	T & W	r-value	1	0.69	0.96
		P-value		<0.01*	<0.01*
		N	30	30	30

Discussion

Growth modulation procedures are carried out on patients based on the growth potential of the patient during the skeletal maturation period. Skeletal age is very important tool to determine skeletal maturity and residual growth potential for deciding the proper treatment plan in young patients.[3]Cervical vertebrae maturation have been widely used to assess the skeletal maturity by visualizing the concavity on the inferior borders and the size and shape of the

vertebrae. [4,5]However these methods are subjective based on visual assessment and give erroneous results when done by different examiners due to the differences in assessment between observers. To overcome these variations objective method[1,2]can be used based on various measurements on the cervical vertebrae to give the estimated skeletal age.

This study compared two different subjective methods for inter-examiner variations. The results showed that there was poor agreement present between the observers in both subjective methods, with a kappa value - 0.16 for Hassel and Farman and kappa value- 0.04 for Franchi, Baccetti, McNamara method. Comparison was also done for inter-examiner variations for the two objective methods by T.Mito and P.Beit by paired Student t test. The objective method by T.Mito showed insignificant inter-observer variation with a p-value of 0.93 while P.Beit method showed statistically significant variation between observers with a p-value of 0.04. This statistically significant difference in the P.Beit method can be attributed to the difference in parameters which are measured on the cervical vertebrae. While the T.Mito method measures the borders of the vertebrae which are more discernible on the cephalogram, P.Beit

method also measures the height of the concavity which can be a source of variation in measurement between observers.

The co-relation was determined between the bone age by Tanner and Whitehouse Hand Wrist method and the objective method by T.Mito and P.Beit, using the co-relation coefficient (r-value). The objective method by P.Beit showed co-relation co-efficient (r-value)of 0.96 and T.Mito method showed co-relation coefficient(r-value) of 0.69. Although both the objective methods of skeletal age determination using cervical vertebrae

Fig 2 : Scatterplot depicting the correlation between Hand wrist and cervical vertebrae methods of measuring the skeletal maturation

showed a higher co-relation with the Tanner and White House hand wrist method, the P.Beit method had a significant higher co-relation as compared to the T.Mito method. Thus the P.Beit method of objective assessment will give better skeletal age estimate inspite of having statistical significant difference in inter-examiner variations, which are very small to have any clinical significance.

Conclusion

The results of the study concluded:

1. There is significant inter-examiner variations present when determining skeletal maturation by Subjective methods.

2. There is less inter-examiner variations present in estimating the skeletal age using Objective Methods.

3. Among the objective methods of estimating skeletal age by P.Biet and T.Mito, P.Beit method had a higher co-relation with the bone age determined by Tanner and Whitehouse hand wrist method and can be efficiently used for estimating the skeletal age.

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