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Comparative evaluation of cervical vertebral maturation assessment with hand and wrist analysis in skeletal maturity

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Abstract

Introduction: Assessment of skeletal maturity is paramount for orthodontists since optimal use and effectiveness of orthodontic and orthopedic appliances depends on it. Hence the objective of this study was to evaluate and correlate hand and wrist analysis (H & W) with cervical vertebral maturation indicator (CVMI) method for the assessment of skeletal maturation.

Material and Methods: The study was carried out on seventy one preadolescent Kuwaiti and Emirati patients from both genders between 10-14 years of age. Hand and wrist evaluation was done by Fishman method on the basis of skeletal maturity indicators (SMI's). Cervical skeletal maturation was analyzed by the method of Hassel and Farman based on the concavity of the lower border, height and shape of vertebral body. Cervical vertebral maturation stages were ascertained.

Results: The study showed significant correlation between both the methods. It was also ascertained that the most frequent stage reporting in this sample according to hand and wrist analysis was stage VII whereas that according to the cervical vertebral maturation indicator method was the stage of deceleration reported at 13 years of age.

Conclusions: The study showed a significant correlation between hand and wrist and cervical vertebral maturation indicator methods for the assessment of skeletal growth status.

Keywords: Skeletal growth, chronological age, cervical assessment

Introduction

Optimal effectiveness of orthodontic and orthopedic appliances has been associated with skeletal maturation status. Physical growth status varies from chronologic age in many children but does correlate well with skeletal age, which is determined by the relative level of maturation of the skeletal system.[1] In planning of orthodontic treatment it is important to know how much skeletal growth remains. Hence an evaluation of the skeletal age is frequently needed.

After Roentgen demonstrated his new radiographic discovery in 1895, Roland in 1986 introduced the idea of using the comparative size and shape of the radiographic shadows of growing bones as indicators of rate of growth and maturity.[2]

In the early 1900's Pryor,[3] Rotch[4] and Crampton[5] began tabulating indicators of maturity on sequential radiographs of the growing hand and wrist. Hellman published his observation on the ossification of epiphysial cartilages of the hand in 1928.[6]

Todd[7] compiled hand and wrist data which was later elaborated in an atlas form. Flory indicated that the beginning of calcification of the carpal sesamoid (adductor sesamoid) was a good guide to determine the period immediately before puberty.[8] The appearance of the adductor sesamoid has highly correlated to peak height velocity and the start of the adolescent growth spurt. Most authors agree that peak height velocity follows adductor sesamoid appearance by approximately 1 year.[9-12]

Fishman developed a system of hand and wrist skeletal maturity indicators using four

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stages of bone maturation at six anatomic sites on the hand and the wrist.[13-15]

Skeletal maturity indicators have been identified for both the childhood and adolescent periods of development. The skeletal maturity indicators were selected on the basis of sequential stability of occurrence, relatively even chronologic distribution and ease of identification on radiographs.

A system of hand and wrist skeletal maturation indicators (SMIs) using eleven stages of bone maturation has been studied and six intermediate SMIs that are easily identifiable have been established.[16]

Various methods using the hand and wrist radiograph to correlate certain maturity indicators with the pubertal growth spurt were created.[17-21]

Many studies were conducted on the cervical vertebrae with emphasis on their morphological changes and its correlation to maturational stage.[22-28]

A lot of studies were carried out to compare hand-wrist to cervical vertebrae development.[29-38] An assessment of skeletal age must be based on maturational status of markers within the skeletal system. Although a number of indicators could theoretically be used, the ossification and changes of the bones of the hand and wrist and cervical vertebrae are normally the standard of assessment for skeletal development.

It is interesting that the developmental age correlates better among them than that of developmental ages correlating with chronologic age. There is a great likely hood that a child who is advanced in one characteristic, skeletal age for example would be advanced in another as well. The mature looking and behaving 8 year old is likely to have precocious development of the dentition. What will actually occur in any one individual is subject to almost infinite variety of human variation and the magnitude of the correlation coefficients must be kept in mind.

Hence the aim of this study was to determine the correlation of skeletal maturation by cervical vertebrae and hand and wrist evaluation and to correlate this with chronological age of the patients.

Material and Methods

Hand & wrist and cephalometric radiographs were collected from the Ministry of Health, Department of Dentistry, Kuwait and from dental clinics in Ajman University. Seventy one samples were collected from both genders with ages between 10 - 14 years. The distribution and mean chronological age evaluation of hand and wrist radiograph according to cervical stages were ascertained (Table I).

Inclusion criteria included patients seeking orthodontic treatment, without; hormonal disorders, trauma or injuries to the face, hand, wrist region and no congenital or acquired malformations of the cervical vertebrae or hand and wrist. Radiographs were taken the same day with standardization (cephalometric radiograph: 10 MA – 69 KV - S 1.0, hand-wrist radiograph: 7MA - 70 KV - S 0.06).

Hand & wrist analysis was based on Fishman method of skeletal maturity indicators (SMI) while cephalometric analysis of cervical vertebrae was staged from I-V using Hassel and Farman method of cervical vertebral maturation indicator method (CVMI). Correlation of the two analyses was done. Descriptive statistics were obtained by calculating the means of chronological ages for the six stages of cervical vertebrae and the eleven stages of hand & wrist skeletal maturity indicators. The spearman rank order correlation coefficient was used to assess the relationship between chronological age and cervical vertebral maturational stages, chronological age and hand & wrist vertebral maturational stages, cervical vertebral maturational stages and hand and wrist vertebral maturational stages.

The postero-anterior view was obtained for hand and wrist. If the patient was unable to

Table I. Distribution and mean chronological age evaluation of hand and wrist radiograph according to the cervical stages

Cervical vertebrae stage	N	Hand wrist stage	N	Chronological Age
Initiation	2	Stage II Stage VII	1 1	11 yrs
Acceleration	17	Stage I Stage II Stage III Stage VII	5 4 3 2	12 yrs
Transition	14	Stage I Stage II Stage IV Stage VII Stage VIII Stage IX Stage X Stage XI	1 1 2 5 2 1 1 1	11 yrs and 7 month
Deceleration	20	Stage II Stage III Stage VII Stage VIII Stage IX Stage X Stage XI	1 3 4 6 1 4 1	11 yrs and 2 month
Maturation	17	Stage III Stage V Stage VII Stage VIII Stage IX Stage X Stage XI	1 1 4 1 1 6 3	13 years and 2 month
Completion	1	Stage X	1	13 years

place the hand flat on the cassette, an antero-posterior (AP) view of the same region was obtained. The skeletal maturity indicators were selected on the basis of sequential stability of occurrence and ease of identification on radiographs. The objective was to identify the most advanced maturational stage that existed on any individual hand and wrist radiograph.

The adolescent skeletal maturity indicators (SMI 1 to 11) involved stages of development of specific phalanges, the adductor sesamoid of the thumb and the radius bone.[13-15] The following SMI's were focused;

SMI 1: Third finger, proximal phalanx with width of epiphysis as wide as diaphysis.

SMI 2: Third finger, middle phalanx with width of epiphysis as wide as or wider than diaphysis.

SMI 3: Fifth (little) finger with width of epiphysis as wide as or wider than diaphysis.

SMI 4: Ossification of adductor sesamoid of thumb.

SMI 5: Third finger, distal phalanx with capping of both sides of epiphysis.

SMI 6: Third finger, middle phalanx with capping of both sides of epiphysis.

SMI 7: Fifth finger, middle phalanx with capping of both sides of epiphysis.

SMI 8: Third finger, distal phalanx with complete fusion.

SMI 9: Third finger, proximal phalanx with complete fusion.

SMI 10: Third finger, middle phalanx with complete fusion.

SMI 11: Radius with complete fusion (skeletal growth completed).[16]

Cervical vertebral maturation was evaluated with lateral cephalometric radiograph using the stages described by Hassel and Farman,[27] which is based on changes occurring in the concavity of the lower border, height and shape of the vertebral body related to the cervical vertebral maturity indicator stages (CVMIs).

To standardize the spinal position, all lateral cephalograms were exposed in natural head position. The odontiod process and the body of the cervical vertebrae were traced on acetate paper. The stages of vertebral maturation were evaluated according to the anatomical changes of the cervical bone (concavity of the lower border, height, and shape) as describe by Hassel and Farman (Figure 1).[35]

1. Concavity of the lower border was considered to be present when there was a distance of more than 1 mm between the middle of the lower border of the vertebral body and a line traced from the posterior-inferior angle to the anterior-inferior angle of the vertebral body. According to the concavity six stages were defined:

Stage 1: All vertebrae have a flat lower border.
Stage 2: A concavity is present on the lower border of C_2.
Stage 3: A concavity is present on the lower border of C_3.
Stage 4: C_2 and C_3 concavity increases and concavities are present in C_4, C_5 and C_6.
Stage 5: Concavity increases in all vertebrae.
Stage 6: A deep concavity is present in all vertebrae and the inferior angles are rounded.

2. Vertebral body height and width were calculated in C_3 and C_4 at the middle of the vertebral body. The lower border was considered to be the line traced from the posterior-inferior angle to the anterior-inferior angle of the vertebral body. Four stages were defined (Figure 2):

Stage 1: Height is less than 80% of width.
Stage 2: Height is between 80 and 99% of width.
Stage 3: Height is greater than width.
Stage 4: Height is greater than width.

3. The shape of the vertebral body was calculated at C_3 and C_4 and the following stages were defined (Figure 3):

Stage 1: Upper border tapered from the posterior to the anterior and being wedge-shaped.
Stage 2: Wedge shaped C_3 and nearly rectangular shaped C_4 with the absence of the superior-anterior angles.
Stage 3: Rectangular shaped bodies.
Stage 4: Nearly squared bodies.
Stage 5: Squared bodies.
Stage 6: Rectangular bodies with height greater than width.

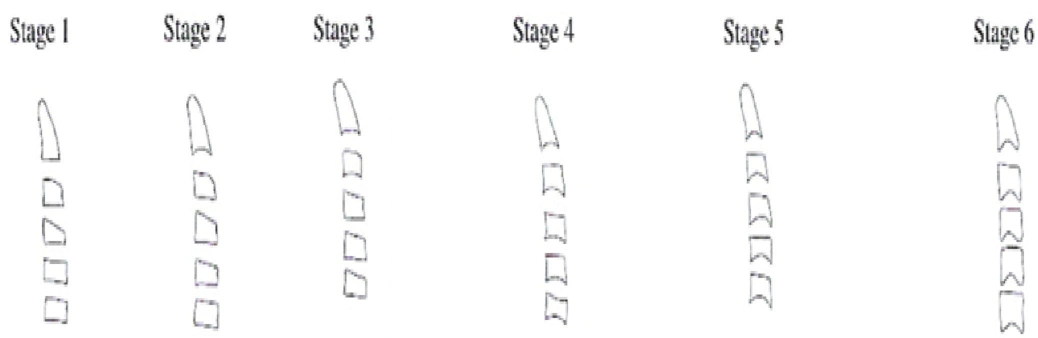

Figure 1. The stages of cervical maturity

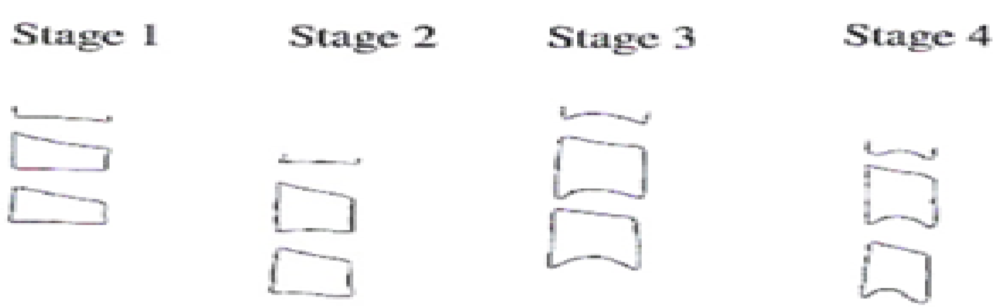

Figure 2. Stages according to height & width calculation at C_3-C_4

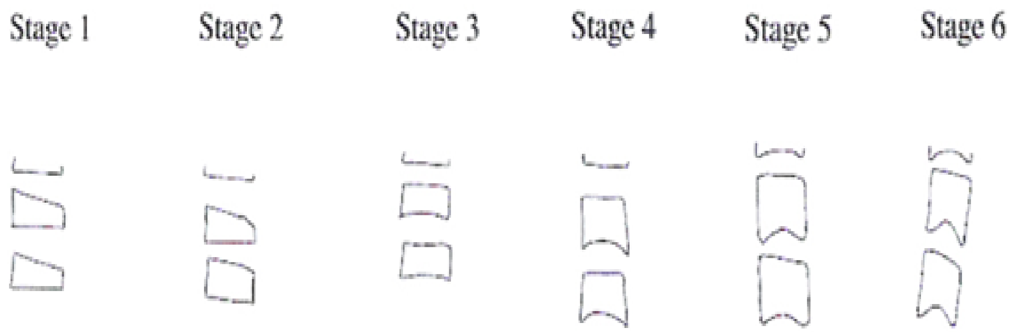

Figure 3. Stages calculated according to shape of the body at C_3-C_4

Interpretations of the morphological changes in the cervical vertebrae were as follows:

1. Initiation: Inferior borders of the second, third and fourth vertebrae are flat at this stage. The third and fourth vertebrae are wedge-shaped and the superior vertebral borders are tapered from posterior to anterior. 100% of pubertal growth remains.
2. Acceleration*:* Concavities on the inferior borders of second and third vertebrae begin to develop. Inferior border of fourth vertebrae remains flat. Vertebral bodies of third and fourth vertebrae are nearly rectangular in shape. 65 to 85% of pubertal growth remains.
3. Transition: Distinct concavities are shown on the inferior borders of second and third vertebrae. A concavity begins to develop on the inferior border of fourth. Vertebral bodies of third and fourth are rectangular in shape. 25 to 65% of pubertal growth remains.
4. Deceleration: Distinct concavities can be observed on the inferior border of second, third and fourth cervical vertebrae. Vertebral bodies of third and fourth begin to be squarer in shape. 10-25% of pubertal growth remains.
5. Maturation: Marked concavities are observed on the inferior borders of second, third and fourth cervical vertebrae. Vertebral bodies of third and fourth are almost square in shape. 5 to 10% of pubertal growth remains.
6. Completion: Deep concavities are observed on the second, third and fourth cervical vertebrae. Vertebral bodies are greater vertically than horizontally. Pubertal growth has been completed.

Results

Spearman correlation index showed a significant correlation between chronological age and hand and wrist assessment method (0.474), chronological age and cervical vertebrae (0.535) and between hand and wrist and cervical vertebrae (0.431). The most frequent stage observed in hand and wrist analysis of the sample was stage VII (26.76%), followed by stage X (16.9%, Table II).

Regarding the cervical stages, the stage of deceleration stage showed most frequently, followed by maturation stage which showed 28.16%-22.53% (Table III). The correlation of hand and wrist to cervical vertebrae were also evaluated (Table IV).

Table II. Correlation between chronological age and hand and wrist stages

Hand-Wrist			**Chronological Age**				
	N	**%**	***10***	***11***	***12***	***13***	***14***
I	6	8.45	4			1	1
II	7	9.85	1	2		4	
III	7	9.85	1	1		5	
IV	2	2.81			2		
V	1	1.40			1		
VI	0	0					
VII	19	26.76		4	1	8	6
VIII	9	12.67		1		7	1
IX	3	4.22			1	1	1
X	12	16.90		1	1	10	
XI	5	7.04				4	1
Correlation between chronological age and hand wrist = 0.474							

Table III. Correlation between chronological age and cervical vertebrae stage.

Cervical vertebrae			**Chronological Age**				
	N	**%**	***10***	***11***	***12***	***13***	***14***
Initiation	2	2.81		2			
Acceleration	17	23.94	4	4		8	1
Transition	14	19.71	1	1	4	6	2
Deceleration	20	28.16	1	2	1	14	2
Maturation	16	22.53			1	11	5
Completion	1	1.40				1	

***Correlation between chronological age and hand wrist* =0.535**

Table IV. Correlation between cervical vertebrae stage and hand and wrist stage

Hand-Wrist	**Cervical vertebrae**					
	I	**A**	***T***	***D***	***M***	***C.***
I		5	1			
II	1	4	1	1		
III		3	3	1		
IV			2			
V					2	
VI						
VII	1	7	5	4	4	
VIII			2	6	1	
IX			1	1	1	
X			1	4	6	1
XI			1	1	3	

**(I=Initiation, A=Acceleration, T= Transition, D= Deceleration, M= Maturation, C= Completion).*

Discussion

Fishman stated that identifiable maturational indicators provide more reliable means of evaluating individualized maturational level in the wide chronologic age ranges of normally growing children.[13-15] Thus the use of skeletal age would be more accurate and more clinically beneficial than chronological age. The hand and wrist radiograph has been used classically to determine the level of child's maturation. To avoid taking additional x-rays, the cervical vertebrae investigation method has become more popular in recent years. Almost all authors found statistically significant correlation between hand & wrist and cervical vertebrae maturation assessment methods.[29,31]

It is important to assess the maturational stage of any young patient who visits the orthodontic office but may be considered too young to initiate active orthodontic treatment. The decision of starting treatment is often exclusively focused on the stage of dental development particularly if many primary teeth are present. A misdiagnosis and a faulty treatment plan can result as no correlation exists between dental eruption time and skeletal development. Many children initiate their period of adolescent development at very young ages. One cannot reliably evaluate a child's maturational development by a physical characteristic and pubertal development.

Identification of a chronologically young patient who demonstrates more advanced skeletal age could certainly influence the clinician to initiate therapy involving orthopedic appliances. If such a therapy is indicated and the skeletal discrepancy is not severe, it may be more appropriate to time its initiation at a later maturational age. It has been clearly demonstrated that successful orthopedics treatment is dependent on proper timing of growth. The rate of maxillary growth and the amount of the favorable maxillary change that occurs are directly dependent on each other. Regardless of the patient's chronologic age, the decision of orthopedic therapy should depend almost exclusively on the maturational profile of the patient.

Completing the cephalometric analysis during this early developmental period is also of significant value. Facial growth pattern of any young patient will reveal itself during childhood. It is true that many patients demonstrate malocclusions that are associated with inter-arched space problems, whether it be an inadequacy or excessive amount of arch length to accommodate the dentition, but a definitive number of patients demonstrate significant skeletal growth problems and these are the ones that need identification and evaluation. The cephalometric analysis provides for initial and subsequent follow-up analyses to confirm the diagnosis and to monitor treatment progress.

Surgical cases certainly benefit from both cephalometric and maturational evaluations. Although the surgeon usually wants to wait for all jaw growth to have terminated, the maturational analysis can determine how much skeletal growth will be forthcoming. Advanced maturers can be seriously considered for surgery even at relatively young chronologic ages. Results of this study correlate and agree with that of Garcia,[38] Tancan,[37] Farmen[28] and Bjork.[11,19]

Conclusions

There is a significant correlation between hand wrist and cervical vertebrae assessment methods. Furthermore these analyses correlate well with the chronological age. Use of skeletal age is considered to be more accurate and clinically beneficial.

The ability to accurately appraise skeletal maturity from the cervical vertebrae, without the need for additional radiographs, has the potential to improve orthodontic diagnostic and therapeutic decisions. The technique's simplicity and ease of use should encourage more orthodontist to use this method to assess skeletal maturation.

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