COMPARATIVE EVALUATION BETWEEN CERVICAL VERTEBRAE AND HAND-WRIST MATURATION FOR ASSESSMENT OF SKELETAL MATURITY ORTHODONTIC PATIENTS

[1]GHULAM RASOOL, [2]ULFAT BASHIR, [3]IBAD ULLAH KUNDI

ABSTRACT

The aim of the study was to find a correlation between the evaluation of skeletal maturation performed by the study of cervical vertebrae maturation indicators and the evaluation obtained by the hand and wrist maturation indicators. A radiographic hand-wrist bone analysis and cephalometric cervical vertebral analysis of 100 patients (36 males and 64 females) ranging from 9 to15 years were examined. The hand-wrist bone analysis was evaluated by the Bjork index, whereas the cervical vertebral analysis was assessed by the cervical vertebral maturation stages method of Bacetti. To define vertebral stages, morphological evaluation of three cervical vertebrae (2nd to 4th) was done. Bjork's nine stages were reduced to five growth intervals (A-E) to relate to five stages (I-V) of cervical vertebral maturation method. The spearman correlation coefficient was 0.944 (P<.01) between cervical vertebral maturation and hand-wrist maturation for sexes combined and 0.936 (P<.01) for males and 0.912 (P<.01) for females respectively. The result shows that cervical vertebrae can be used with the same confidence as hand-wrist radiographs to evaluate skeletal maturity, thus avoiding the need for an additional radiograph.

Key words: *Hand-wrist radiographs, cervical vertebral maturation, skeletal maturation, growth prediction*

INTRODUCTION

In orthodontics and dentofacial orthopedics it is becoming increasingly evident that the timing of treatment onset may be as crucial as the selection of specific treatment protocol, because in the organization, differentiation, development, and growth of any somatic structure, time plays a viable role in determining the final morphological and dimensional results.[1]

Maturity is a term used to describe the physiological progression; an individual has undergone or conversely, is yet to take place (tanner et al 1975). It is a developmental process that proceed from being completely immature to completely mature. A way of measuring progression towards maturity and thus the patient's growth potential is to use biological markers known as developmental "milestones". These are the events that occur in all normally developing individuals. The more refined the grading system of maturity, the more fully a child2 s progress towards maturity can be described, which is useful to an orthodontist. General rates of skeletal growth have been established for both sexes, which demonstrate accelerations and decelerations in growth velocities at various developing maturational stages of growth.[2] Because of individual variation in timing, duration and velocity of growth, assessment of skeletal age is essential in formulating viable orthodontic treatment plan.[3-5]

The technique for assessing skeletal maturity consists of visual inspection of the developing bones, their initial appearance and their subsequent ossification-related changes in shape and size. Various areas of the skeleton that have been used are the foot, ankle, hip, elbow, hand-wrist and the cervical vertebrae.[6,7] The classical and most widely used method for skeletal age evaluation is the highly reliable hand-wrist bone analy-

[1] Associate Professor & Head Dept of Orthodontics, Khyber College of Dentistry, Peshawar

[2] Professor / HOD Orthodontics, Islamic International Dental College, Islamabad

[3] Senior Registrar, Sardar Begum Dental College, Peshawar.

Correspondence: Dr Ghulam Rasool, House 238, Street 4, Sector J-1, Phase 2, Hayatabad, Peshawar, Tel: 091-5830083, Cell: 0333-9126029, E-mail Address: malaika-_bh@yahoo.com

sis performed by radiograph.[3,8] The hand has received most attention in literature, both because it is easy to radiograph, and because it includes a wide range of bones suitable for study. Validity of the hand-wrist bone analysis has been confirmed by numerous studies. In 1950s, Greulich and Pyle, with the aid of radiograph updated an atlas and reported a precise sequence of hand and wrist bone ossification.[9,10] Fishman[11] developed a system for assessment of skeletal maturation on the basis of eleven discrete Skeletal Maturity Indicators (SMI) covering the entire period of adolescent development. Bjork[12,13], Grave[14] and Brown utilized certain anatomical sites located on the phalanges, abductor sesamoid, carpal and radius bone, which have predictable and consistent time of onset of ossification. The ossification sequence and timing of the skeletal maturity within the hand wrist area show polymorphism and sexual dimorphism, which can limit their clinical use.[15] An important consideration is that the same pattern of skeletal growth can be found in almost every individual. However, initiation, duration and amount of growth vary considerably during the growth spurt.[16]

The evaluation of changes in size and shape of the cervical vertebrae in growing subjects have gained increased interest in the last decades as a biological indicator of individual skeletal maturity. One of the main reasons for the rising popularity of the method is that the analysis of Cervical Vertebral Maturation (CVM) is performed on the lateral cephalogram of the patient, a type of film used routinely in orthodontic diagnosis. It is well known that the morphology of the cervical vertebral bodies change with growth.[17] Skeletal maturity can be evaluated in a detailed and objective manner on the cephalometric radiograph by determining the cervical vertebral bone age.[18]

In the past many studies have been carried out to assess the relationship between the CVM method and hand-wrist skeletal maturity method. Racial variations in the relationship between skeletal maturity established by hand-wrist and cervical vertebrae have been reported in previous studies. Unfortunately little is known of this relationship in Pakistani population. For that reason this study was carried out to investigate the relationship in cervical vertebrae and hand-wrist skeletal maturation in local population. This might be helpful in determining the validity of cervical vertebrae to evaluate skeletal maturity and provide the orthodontist with an additional tool to assess growth potential in adolescent patients without exposure to additional radiation.

METHODOLOGY

The study was conducted on 100 patients (36male, 36female) with the age range of 9-15 years, who reported to orthodontic department of Islamic International Dental Hospital Islamabad. Subjects with gross deformity and history of trauma and previous orthodontic treatment were excluded. After getting written informed consent of the patients, both the hand wrist X-ray and lateral cephalogram were exposed and developed on the same day, by the same operato,r using the same machine, at the same distance (X-ray source – film and film – subject distance) and intensity.

Hand-Wrist Radiograph

PA view of the hand-wrist of left hand was taken with Toshiba TL-6 TL-3 at 50 kvp, 100ma and exposure time of 0.2 seconds using kodak green film 8×10 inch. The center of the tube was half way between the tips of the fingers and distal end of the radius, perpendicular to the film.

Lateral Cephalogram

The Lateral cephalogram of the patients were taken with Rotograph Plus at 80 kvp, 10 ma and 0.8-second exposure time using 8 ×10 inch Kodak green film. To standardize the spinal position all radiograph were obtained with the patient positioned at the Frankfurt horizontal plane parallel to the floor and the X-ray beam was perpendicular to the head. The patient was instructed to stand erect and looking straight into his / her own eyes in a mirror on the wall and keep the teeth in centric occlusion and the lips relaxed. Distance from X-ray source to the subject's mid sagital plane was fixed at 5 feet.

Method of tracing the films

Tracing was performed in a darkened room with a radiographic illuminator to ensure contrast enhancement of the bone images. All the phalanges of the fingers and thumb were drawn along with the carpals, metacarpals and outline of the radius and ulnar bone in the hand wrist radiographs on .003" acetate tracing paper using 4H pencil. In the lateral cephalograms, three parts of the cervical vertebrae were traced; these entities include the dens odontoid process – C2, body of the third cervical vertebrae – C3 and the body of the fourth cervical vertebrae – C4.

SKELETAL MATURATION ASSESSMENT

Hand wrist

Skeletal maturation was assessed according to Bjork's method of assessment. The following nine stages of Björk[12,13], Grave and Brown[14] were utilized (Fig 1).

Stage 1 (PP2): Epiphysis of proximal phalanx of index finger (PP2) is same width as diaphysis.

Stage 2 (MP3): Epiphysis of middle phalanx of middle finger (MP3) is same width as diaphysis.

Stage 3 (Pisi - H1 - R): Pisi; Visible ossification of pisiform; H1: ossification of hamular process of hamatum: R same width of Epiphysis and diaphysis of Radius.

Stage 4 (S-H2): S, first mineralization of ulnar sesamoid bone of metacarpophalangeal joint of hamatum; H2, progressive ossification of hamular process of hamatum.

Stage 5 (MP3cap - PP1cap - Rcap): Diaphysis is covered by cap shaped epiphysis; in MP3cap, process begins at middle phalanx of third finger; in PP1cap, at proximal phalanx of thumb; in Rcap, at radius.

Stage 6 (DP3u): Visible union of epiphysis and diaphysis at distal phalanx of middle finger (DP3).

Stage 7 (PP3u): Visible union of epiphysis and diaphysis at proximal phalanx of middle finger (PP3).

Stage 8 (MP3u): Union of epiphysis and diaphysis at middle phalanx of middle finger is clearly visible (MP3).

Stage 9 (Ru): Complete union of epiphysis and diaphysis of radius.

Bjork nine stages of skeletal maturation were reduced to five intervals to relate to five stages of CVM method and ranked 1 to 5 according to growth completion.

1. **Interval A:** → Bjork stage 1-3 (growth preceding acceleration)
2. **Interval B:** → Bjork stage 4 (stage of growth acceleration)
3. **Interval C:** → Bjork stage 5 (peak of growth stage)
4. **Interval D:** → Bjork stage 6-7 (deceleration stage of growth)
5. **Interval E:** → Bjork stage 8-9 (growth completion)

Cervical Vertebral Maturation Stages (CVMS)

Lateral cephalogram was assessed for skeletal maturation according to the improved modified version of Bacetti,[19] who merged Cvs1 and Cvs 2 into a single stage. Thus five maturational stages (CVMS I - CVMS V) were as follow (Fig 1).

1. **CVMS I:** The inferior border of C2 exhibit concavity and the bodies of C3 and C4 are trapezoidal in shape.
2. **CVMS II:** Presence of concavities at lower border of C2 and C3 and Bodies of C3 and C4 are trapezoidal or rectangular horizontal in shape.
3. **CVMS III:** Presence of concavity at the lower border of C2, C3, C4 and bodies of C3, C4 are rectangular horizontal in shape.
4. **CVMS IV:** Presence of concavity at the lower border of C2, C3, C4. At least one of C3 and C4 is square in shape.
5. **CVMS V:** Presence of concavity at the lower border of C2, C3, C4. At least one of C3 and C4 is rectangular vertical.

Five stages of CVMS method were compared with Bork's five intervals of growth to find the strength of relation between the two methods as

CVMS I with interval A (Bjork stage 1-3).

CVMS II with interval B (Bjork stage 4) .

CVMS III with interval C (Bjork stage 5) .

CVMS IV with interval D (Bjork stage 6-7).

CVMS V with interval E (Bjork stage 8-9) .

Statistical analysis

Statistical analysis was performed with the help of SPSS (Version 13). Frequency and percentage were presented for discrete variable like gender and means ± SD were calculated for age, height and weight. The stages in hand-wrist radiograph were ranked in five intervals (A-E) in hand wrist radiograph and in five CVM stages (CVMI I-CVMI V) in lateral cephalogram. The outcome of data for radiographic assessment was ordinal and Spearman rank order correlation coefficient test was used to judge the strength of the relationship between the maturation stages of hand-wrist and cervical vertebrae. $P \leq 0.05$ was taken as statistically significant.

RESULTS

This study was conducted on 100 orthodontic patients (36 males and 64 females). The means, minimum, maximum and standard deviation of age, height

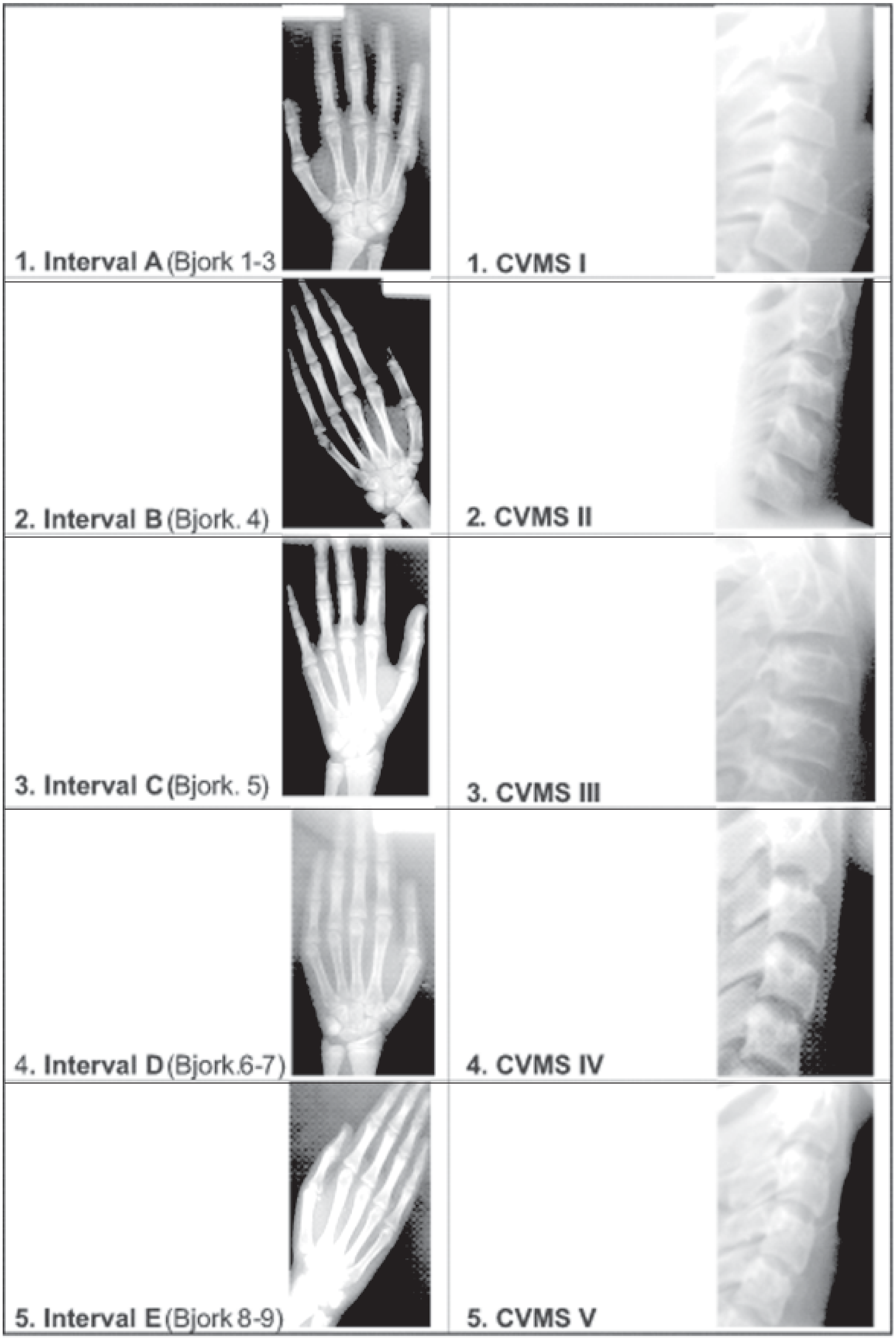

Fig 1: Five growth intervals in hand-wrist radigraph and CVMS stages in lat cephalogram

and weight is shown in table 1. Frequency distribution of gender by age is given in (Fig 2).

There was a high correlation between hand-wrist maturation and cervical vertebral evaluation method for skeletal maturation. Table 2 shows that the highest frequency of skeletal maturation intervals and cervical vertebral maturation stages was found in principle diagonal, some border line cases blend into each other. In interval A of hand-wrist 82% were in CVMS I. In interval B 87% were in CVMS II. In interval C of hand-wrist maturation 89% were in CVMS III. In interval D 83% were in CVMS IV and in growth interval E of skeletal maturation 70% were in CVMS V.

Spearman rank correlation between hand-wrist and cervical vertebrae maturation was 0.944 with standard error .017, P< .001 (highly significant). Frequency distribution of cervical vertebral maturation stages (CVMS) in hand-wrist maturation intervals by gender is shown in Table 3. The ranking of the growth was in the same order in two genders separately. Spearman rank correlation in two genders separately suggested a better correlation in males (r=0.936, P<.001) than female subjects (0.912, P<.001).

Frequency distribution of cervical vertebral maturation stages (CVMS) in hand-wrist maturation intervals in different age groups was also plotted (Table 4). The correlation in hand-wrist and cervical vertebral maturation in 9-11 years was 0.938 (P<.001), in 12-13 years was 0.923 (P<.001), in 14-15 years was 0.711 (P<.001), statistically significant. So a higher correlation was found in relatively younger age group than older.

DISCUSSION

In dentofacial orthopedics, each patient's skeletal maturation period is important in order to better exploit the growth potential by using functional appliances. The issue of optimal timing for dentofacial orthopedic is linked to the identification of period of accelerated or intense growth that can contribute significantly to the correction of skeletal imbalance in a patient. Chronological age is not a valid predictor of skeletal growth velocity or skeletal maturity.[15, 20 21] Skeletal maturity among all is the most commonly used index in routine clinical work and is closely related to the sexual and somatic maturity. The hand-wrist radiograph has been used conventionally to de-

TABLE I: DESCRIPTIVE STATISTICS OF AGE, HEIGHT AND WEIGHT

	N	Minimum	Maximum	Mean	Std. Deviation
Age	100	9.00	15.00	12.77	1.54
Height	100	129.00	169.00	153.42	9.73
Weight	100	28.00	50.00	41.90	5.35

TABLE 2: COMPARISON OF CERVICAL MATURATION AND SKELETAL MATURATION INTERVAL CERVICAL MATURATION * SKELETAL MATURATION INTERVAL CROSS TABULATION

Cervical maturation	Skeletal maturation interval					Total
	Interval A	Interval B	Interval C	Interval D	Interval E	
CVMS I	14	0	0	0	0	14
CVMS II	3	13	1	0	0	17
CVMS III	0	2	24	2	1	29
CVMS IV	0	0	2	15	6	23
CVMS V	0	0	0	1	16	17
Total	17	15	27	18	23	100

Symmetric Measures

		Value	Std. Error(a)	Approx. Sig.
Ordinal by Ordinal	Spearman Correlation	0.944	0.017	0.000(c)
No of Valid Cases		100		

Spearman correlation 0.944
P< 0.001 (highly significant)

TABLE 3: COMPARISON OF CERVICAL MATURATION (CVMS) AND SKELETAL MATURATION INTERVAL BY GENDER
CERVICAL MATURATION* SKELETAL MATURATION INTERVAL* GENDER CROSSTABULATION

Count

Gender			Skeletal maturation interval 1	2	3	4	5	Total
Male	Cervical maturation	1	10	0	0	0	0	10
		2	2	8	1	0	0	11
		3	0	2	5	0	0	7
		4	0	0	1	4	1	6
		5	0	0	0	0	2	2
	Total		12	10	7	4	3	36
Female	Cervical maturation	1	4	0	0	0	0	4
		2	1	5	0	0	0	6
		3	0	0	19	2	1	22
		4	0	0	1	11	5	17
		5	0	0	0	1	14	15
	Total		5	5	20	14	20	64

Symmetric Measures

Gender			**Value**	**Asymp Std Error**[a]	**Approx T**[b]	**Approx Sig**
Male	Interval by Interval	Pearson's R	.940	.023	16.081	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.936	.028	15.439	.0000[c]
	Measure of Agreement	Kappa	.745	.086	8.285	.000
	N of Valid Cases		36			
Female	Interval by Interval	Pearson's R	.927	.027	19.427	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.912	.036	17.473	.000[c]
	Measure of Agreement	Kappa	.771	.063	11.090	.000
	N of Valid Cases		64			

a Not assuming the null hypothesis

b Using the asymptotic standard error assuming the null hypothesis

c Based on normal approximation

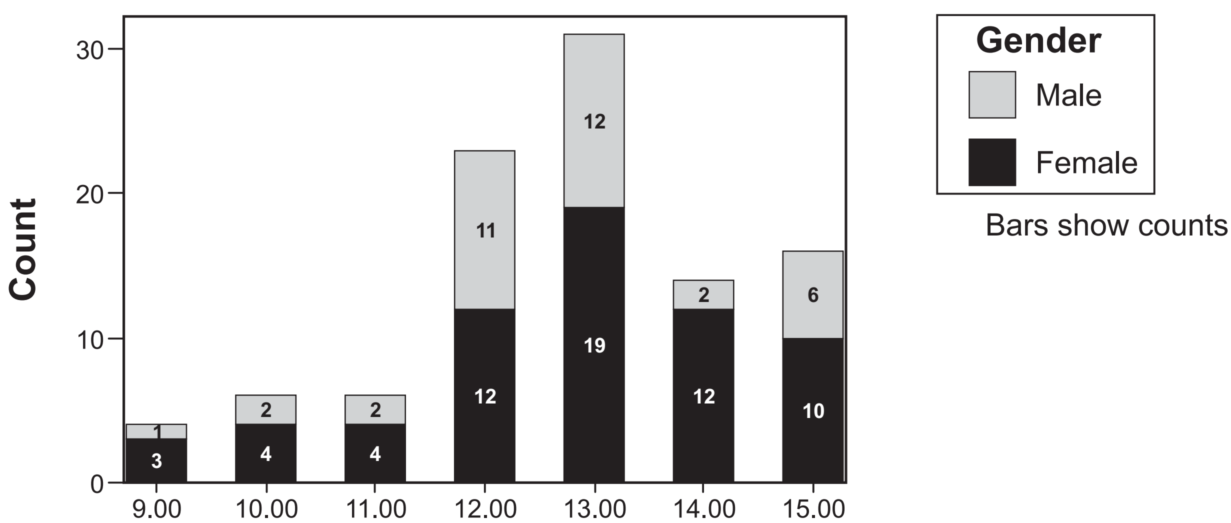

Fig 2: Frequency distribution of Age by Gender

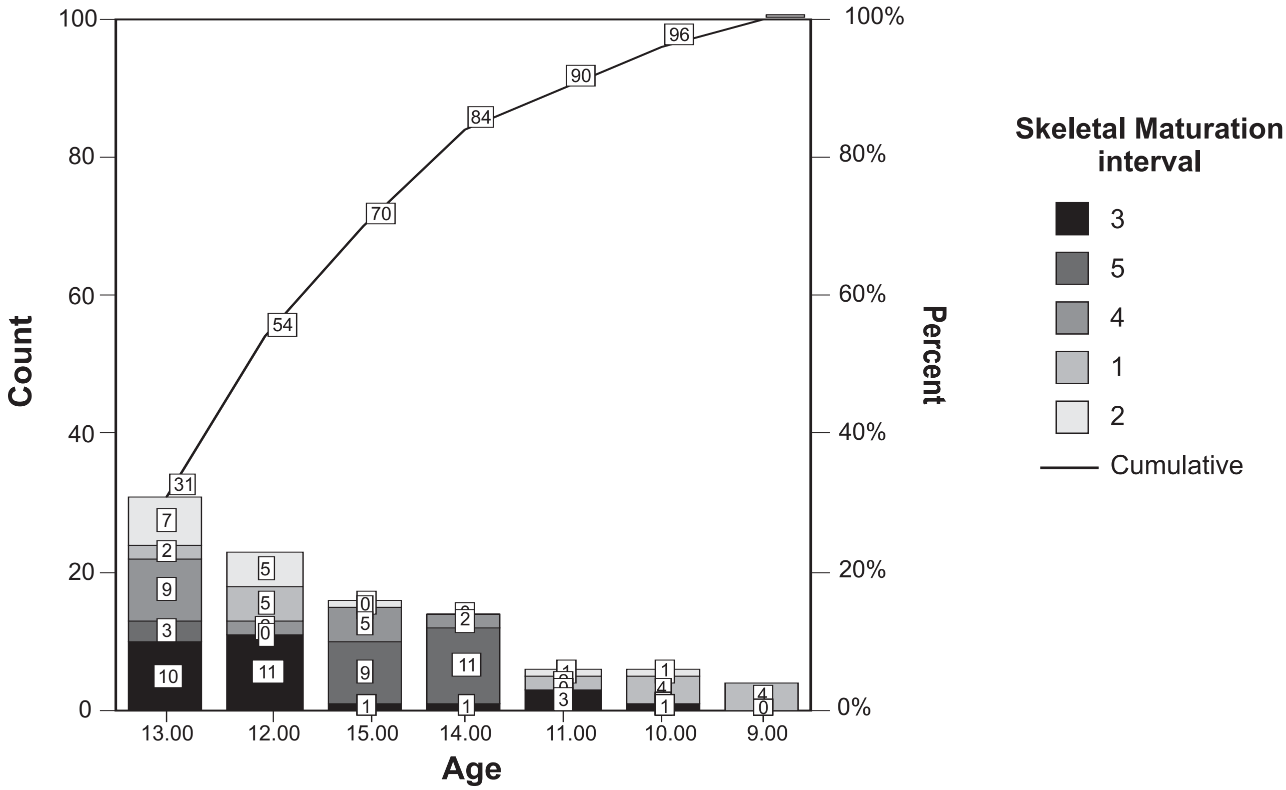

Fig 3: Plot skeletal maturation interval against Age

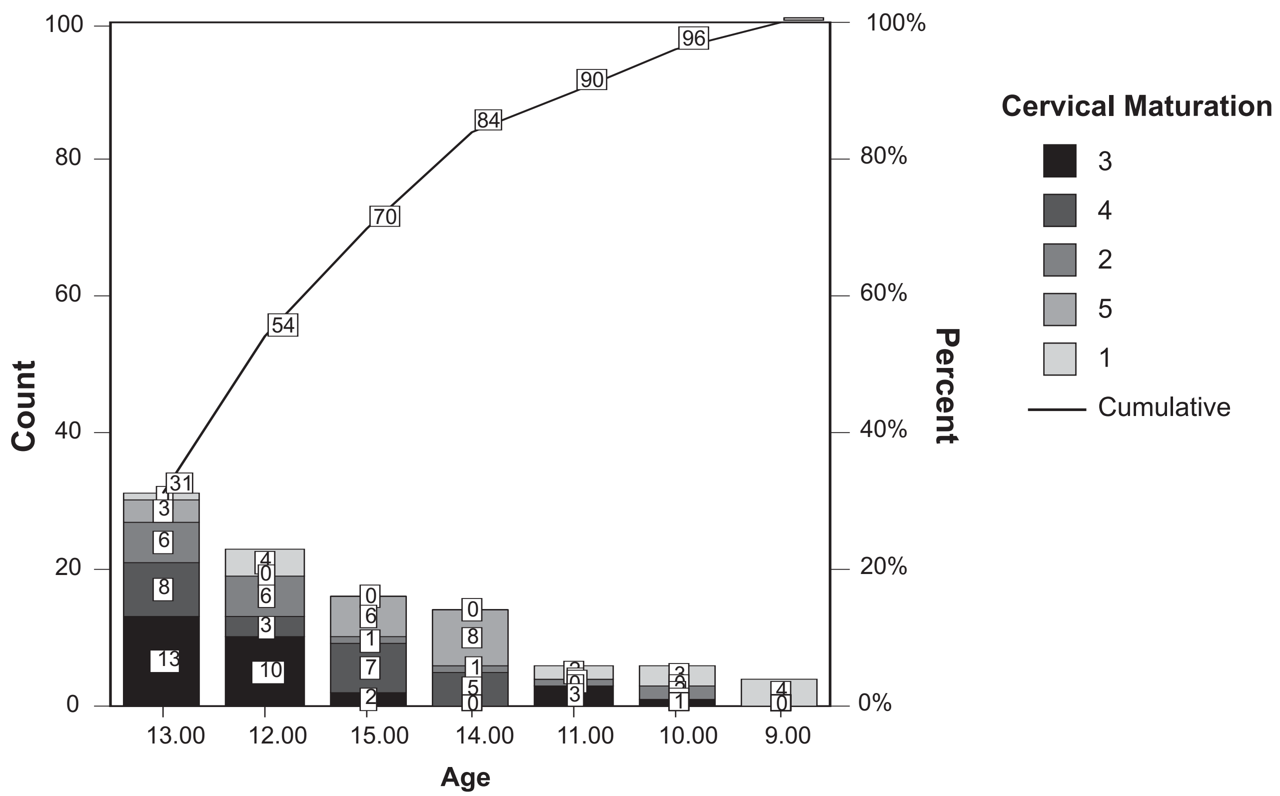

Fig 4: Plot cervical maturation interval against Age

TABLE 4: COMPARISON OF CERVICAL VERTEBRAL MATURATION (CVMS) AND HAND-WRIST SKELETAL MATURATION INTERVALS IN DIFFERENT AGE GROUP INTERVALS CERVICAL MATURATION* SKELETAL MATURATION INTERVAL CROSSTABULATION

Count

Age Interval			Skeletal maturation interval 1	2	3	4	5	Total
9–11	Cervical maturation	1	9	0	0			9
		2	1	2	0			3
		3	0	0	4			4
	Total		10	2	4			16
12–13	Cervical maturation	1	5	0	0	0	0	5
		2	2	10	0	0	0	12
		3	0	2	19	2	0	23
		4	0	0	2	8	1	11
		5	0	0	0	1	2	3
	Total		7	12	21	11	3	54
14–15	Cervical maturation	2		1	1	0	0	2
		3		0	1	0	1	2
		4		0	0	7	5	12
		5		0	0	0	14	14
	Total			1	2	7	20	30

Symmetric Measures

Age Interval			**Value**	**Asymp Std Error[a]**	**Approx T[b]**	**Approx Sig**
9–11	Interval by Interval	Pearson's R	.960	.039	12.770	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.938	.062	10.115	.000[c]
	Measure of Agreement	Kappa	.889	.107	4.811	.000
	N of Valid Cases		16			
12–13	Interval by Interval	Pearson's R	918	.025	16.695	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.923	.029	17.279	.000[c]
	Measure of Agreement	Kappa	.746	.072	9.723	.000
	N of Valid Cases		54			
14–15	Interval by Interval	Pearson's R	.805	.094	7.181	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.711	.109	5.346	.000[c]
	Measure of Agreement	Kappa	.604	.121	4.757	.000
	N of Valid Cases		30			

a Not assuming the null hypothesis

b Using the asymptotic standard error assuming the null hypothesis

c Based on normal approximation

termine the level of maturation in a child. The validity of hand-wrist skeletal maturity in the evaluation of craniofacial growth has been questioned. Moore[22] pointed out that most of the bones of the body were preformed in cartilage and develop by endochondral ossification. The bones of the face are formed by intramembranous ossification without cartilaginous precursor. Therefore growth of the face may be regulated by factors other than those responsible for the growth of the long bones.

Recently the use of cervical vertebrae maturation has been suggested as a valid replacement to the hand-wrist evaluation. The CVM method describes the entire circumpubertal period by covering all significant phases in craniofacial growth during adolescence and it is valid for both sexes.[23,24] The main advantage of the CVM evaluation is that it can be obtained from a conventional lateral cephalogram, which would avoid an extra radiation exposure of patients. In the past many studies have been carried out to assess the relationship between the CVM method and hand-wrist SMI method. Racial variations in the relationship between skeletal maturity established by hand-wrist and cervical vertebrae have been reported in previous studies.[25-27] Unfortunately little is known of this relationship in Pakistani population. For that reason this study was carried out to investigate the relationship in cervical vertebrae and hand-wrist skeletal maturation in local population to provide the orthodontist with an additional tool to help determine growth potential in adolescent patients.

The CVM method described by Franchi and Bacetti[19,28,29] was adopted in the present study because of its wide utilization in the current literature and the demonstrated applicability for several populations.[30] In the present study, the validity and reliability of CVM method to assess skeletal maturity level in local population was evaluated against the well organized Bjork's standards of hand-wrist skeletal maturity.[13] Bjork's method is commonly used in related studies because of its simplicity, popularity and reliability. Bjork's nine stages were reduced to five intervals (A-E) to relate the five stages of CVM method to nine stages of a Bjork hand-wrist bone analysis. This reduction from nine to five stages did not entail the loss of significant data, as the goal was not represented by the identification of each single stage but by the interval of growth. Because growth is a continuous phenomenon, either the hand-wrist or the cervical vertebral indicators can present both non-well defined patients and some whose growth is intermediate between two stages, what matters is not a rigid classification but the identification of a growth interval, which was closely associated with the growth interpretation of five cervical vertebral maturation stages.

The validity and reliability of the cervical vertebral maturation method in predicting the skeletal maturity level in Pakistani children have been demonstrated in the present study by high correlation value (0.944, P<0.001) between the cervical vertebral maturation stages and hand-wrist maturity stages (table 3). Previous studies have reported variable correlation values (from 0.45 to 0.98) between skeletal maturity stages determined by two methods.Similarly with the previous reports, the hypothesis that there is no significant difference between the hand-wrist and cervical vertebrae technique of assessing skeletal maturation in this population can not be rejected. This agrees with the findings in other population groups.

Hassel and Farman[31] compared SMI with CVMI in 1995 and found correlation value (r=0.89). Similar study conducted by Kamal et al[32] in Indian population (r=0.892), Sun Y et[33] al in Chinese population (r=0.918), Uysal[34] in Turkish population (r=0.86), Lee[35] in Korean subjects (r=0.91-0.93), Minars et al[36] (r=0.98) and Al Hadlaq[27] in Saudi male subjects (r=0.89) supported our sample result in Pakistani population. Similar results were reported by Zhang and Wang[37] and Chang[38] in Chinese population.

While the correlation values obtained by Flores-Mir[39] in Canadian (r=0.72), Gandini[40] in Italian (r=0.783), Roman[41] in Spanish (male/female r=0.77/0.84), Grippaudo et al[42] in Italian (r=0.795), and Caltabiano[43] in Italians (male/female r=0.450/0.564) were less than reported in this study. The difference in correlation in the present study and other international studies might due to difference in racial and ethnic background, sample selection technique and criteria, sample size, gender and the methodology used for skeletal maturation assessment.

When the correlation was observed separately in the two genders a better correlation was observed in males (r= 0.936 P<.001) than females (r=0.912, P<.001) as in table IV. Regarding the sex our findings were supported by Kamal[32] (male r=0.892, female r=0.858). In contrast to the present study females in the study of Roman[41] (male r=0.77, females r=0.84) Caltabino[43] (male r=0.450, females r=0.564), Uysal[34] (males r=0.78, females r=0.88) Grippaudo[42] (male-0.70, females=0.84) and Sun Y et al[33] (male r=0.858, females r=0.882) presented higher correlation values than males. Lamparski[25] suggested that cervical vertebral maturation was more reliable in female than males. However Hassel and Farman did not distinguish between males and females. The difference in the results of present study and the previous studies may be due to uneven distribution of the males and females and relatively smaller sample size of males in the present study. Another reason may be explained by different ages of the patients. In this study only children between 10 and 15 years were included. However many males still have growth potential at 15 years of age, and Hellsing[44] demonstrated differences between 15 years old and adult males in the height and size of vertebral bodies. Gabriel[45] et al showed poor reproduceability of CVM stages. In contrast Chen[46] 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

Grave and Townsend[47] observed that particular combinations of hand-wrist and cervical maturation events occurred consistently before, during and after the adolescent growth spurt. In contrast the result of the statistical analysis on the present sample in three different age groups showed disagreement with Grave and Townsend reports. In 9-11 years age group correlation in hand-wrist and cervical maturation was 0.936 ($p<.001$). In 12-13 years correlation value was 0.923 ($p< .001$), and in 14-15 years the correlation coefficient decrease markedly ($r=0.711$, $p< .001$). Correlation in hand-wrist and cervical maturation was statistically significant in all the three age groups but the correlation decreased with age (table 4). Our report is supported by Kamal[32] who found the maturity indicators less reliable in female subjects during the later stages than the initial stages. Our results in three different age groups are also supported by Sun Roman[41], who evaluated the cervical vertebral maturation by studying the changes in the concavity of the lower border, height and shape of the vertebral body. He found highest correlation of concavity with hand-wrist maturation ($r=0.82/0.75$) than shape ($r=0.74/0.67$) and height ($r=0.70/0.60$). Concavity was demonstrated to be the best of the three parameters and height of the vertebral bodies had a lower correlation with the hand-wrist. Interpreting the results of the present study, the poor correlation of cervical vertebrae with hand-wrist in late age group (late maturation stages) might be due to poor correlation of height of vertebrae with hand-wrist, which is the only parameter for labeling the late maturation stages. The sample distribution in three age groups was not uniform, relatively low percentage of subjects participated in 9-11 years age group. In the present study the sample selection criteria, regarding the sample size and gender distribution in each age interval was not strictly followed. This might be biased in the results obtained. Thus, results related to this group should be considered with caution until sample size in this category is increased in future studies.

The use of cervical vertebrae maturation has been suggested as a valid replacement to the hand-wrist evaluation. The main advantage of the cervical vertebrae maturation evaluation is that it can be obtained from a conventional lateral cephalogram, which would avoid an extra radiation exposure for the patients and cost to the clinician, and can be obtained more readily during the treatment progress in the lateral cephalometric radiograph. The techniques simplicity and ease of use should encourage more orthodontists to use this method to assess skeletal maturation.

CONCLUSION

Basic results of the present study can be summarized as:

- A high correlation was found between hand-wrist skeletal maturation and vertebral maturation in Pakistani subjects according to the statistical evaluation.
- A better correlation was found in male subjects than females.
- Correlation in hand-wrist and CVM was higher in earlier than late age.
- Skeletal maturity stages can be effectively determined from cervical vertebrae on lateral cephalogram for dentofacial orthopedics.
- The girls were advanced in skeletal maturation as compared to boys.

Further Recommendations

- Skeletal maturity levels should also be considered when taking decisions regarding dentofacial orthopedics, thus eliminating the factor of gender dimorphism.
- A larger sample size should be studied to verify the correlation on broader base.
- The subjects should be uniformly distributed in future studies to find the correlation in different age groups in both the genders.

REFERENCES

1 Baccetti T, Franchi L, McNamara JA. The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment Timing in Dentofacial Orthopedics. Semin Orthod 2005; 11:119-29.

2 Beker L. Principles of growth assessment. Pediatr Rev 2006, 27:196-97.

3 Ozer T,Kama JD, Ozer SY. A practical method for determining pubertal growth spurt. Am J Orthod Dentofac Orthop 2006;130: 131.e1-e64

4 Ochoa KB, Nanda RS. Comparison of maxillary and mandibular growth. Am J Orthod Dentofac Orthop. 2004; 125:148-59.

5 Turchetta BJ, Fishman LS, Subtelny JD. Facial growth prediction: A comparison of methodologies. Am J Orthod Dentofac Orthop 2007; 132:439-50

6 Šidlauskas A, •ilinskaite L, Švalkauskiene V. Mandibular Pubertal Growth Spurt Prediction. Part One: Method Based on the Hand-Wrist Radiographs. Baltic Dent and Maxillofac J 2005; 7:16-20.

7 Bilgili Y, Hizel S, Kara SA, Sanli C, Erdal HH, Altinok D. Accuracy of skeletal age assessment in children from birth to 6 years of age with ultrasonographic version of the Greulich-Pyle Atlas. J Ultrasound Med 2003; 22:683-90.

8 Mir CF, Nebbe B, Major PW. Use of Skeletal Maturation Based on Hand-Wrist Radiographic Analysis as a Predictor of Facial Growth: A Systematic Review: Angle Orthod 2004; 74:118-24.

9 Shamsher RM, Ijaz A. Age of High Growth Rate in Adolescent period of development. Pak Oral Dent J 2005; 25: 53-58.

10 Bacetti T, Franchi L, De Toffol L, Ghiozzi B, Cozza p. The diagnostic performance of chronologic age in the assessment of skeletal maturity. Prog Orthod 2006; 7:176-88

11 Fishman LS. Radiographic evaluation of skeletal maturation. Angle Orthod. 1982; 52: 88-112

12 Björk A, Helm S. Prediction of the age of maximum puberal growth in body height. Angle Orthod. 1967; 37:134-42.

13 Björk A. Timing of interceptive orthodontic measures based on stages of maturation. Trans Eur Orthod Soc 1972; 61-74.

14 Grave KC. Timing of facial growth: a study of relations with stature and ossification in the hand around puberty. Aus Orthod J 1973; 3:117-22.

15 Fishman LS. Chorological versus skeletal age, an evaluation of craniofacial growth. Angle Orthod 1979; 49:181-89.

16 Mito T, Sato K, Mitani H. Predicting mandibular growth potential with cervical vertebral bone age. Am J Orthod Dentofac Orthop 2003; 124:173-77.

17 Mito T, Sato K, Mitani H. Cervical vertebral bone age in girls. Am J Orthod Dentofac Orthop 2002; 122:380-85.

18 Chapman SM. Ossification of the adductor sesamoid and the adolescent growth spurt. Angle Orthod 1972; 42:236-44.

19 Baccetti T, Franchi L, McNamara JA. An Improved Version of the Cervical Vertebral Maturation (CVM) Method for the assessment of Mandibular Growth. Angle Orthod 2002; 72: 316-23.

20 Fudalej P, Rothe L, Bollen AM. Effects of posttreatment skeletal maturity measured with the cervical vertebral maturation method on incisor alignment relapse. Am J Orthod Dentofacial Orthop.2008;134:238-44.

21 Hagg U, Taranger J. Maturation indicators and the pubertal growth spurt. Am J Orthod 1982; 82:299-309.

22 Moore RN. Principles of dentofacial orthopedics. Semin Orthod 1997; 3:212–21

23 Franch L, Baccetti T, McNamara JA Jr. The Cervical vertebral maturation method some need for clarification. Am J Orthod Dentofacial Orthop 2003; 123:19A-20A.

24 Fudalej P, Bollen A M. Effectiveness of the cervical vertebral maturation method to predict postpeak circumpubertal growth of craniofacial structures Am J Orthod Dentofacial Orthop 2010;137:59-65.

25 Lamparski DG. Skeletal age assessment utilizing cervical vertebrae. (Unpublished master's thesis). Pittsburgh, PA: Department of Orthodontics, University of Pittsburgh; 1972.

26 Garcia-Fernandez P, Torre H, Flores L, Rea J. The cervical vertebrae as maturational indicators. J Clin Orthod. 1998; 32:221-25

27 AL Hadlaq A, AL Qarni, AL Khatani A, AL Obaid A. Comparative study between hand-wrist and cervical vertebral maturation method for evaluation of skeletal maturity in Saudi boys. Pak Oral Dent J 2007; 27:187-92.

28 Franchi L, Bacetti T: The use of maturational indices for the identification of optimal treatment timing in dentofacial orthopaedics, in Mc-Namara JA Jr Kelly KA(eds): Treatment Timing: Orthodontics in Four Dimension. Craniofacial Growth Series, Vol 39. An Arbor, MI, Center for Human Growth and Development, University of Michigan, 2002, pp 151-70.

29 Baccetti T, Reyes BC, McNamara JA Jr. Craniofacial changes in Class III malocclusion as related to skeletal and dental maturation. Am J Orthod Dentofacial Orthop 2007;132: 171-78.

30 Seedat AK, Forsberg CD. An evaluation of the third cervical vertebra (C3) as a growth indicator in Black subjects. SADJ 2005; 60: 156, 158-60.

31 Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofac Orthop.1995 107: 58-66.

32 Kamal M, Ragini, Goyal S. Comparative evaluation of hand wrist radiograph with cervical vertebrae for skeletal maturation in 10-12 years old children. J Indian Soc Pedod Prev Dent 2006;24:127-35

33 Sun Y, You OL, Liu HH. Correlation of adolescent skeletal maturation determined by cervical vertebrae and hand-wrist in Shanghai region. Shanghai Kou Qiang Yi Xue.2007;16: 365-69.

34 Uysal T, Ramoglu SI, Basciftci FA, Sari Z. Chronological age and skeletal maturation of the cervical vertebrae and hand wrist: Is there a relationship? Am J Orthod Dentofac Orthop 2006; 130: 622-28.

35 Lee YM, Kim KW, Yoon YJ. Correlations between dental and skeletal maturity. *Korean J Orthod*. 2000 Apr; 30:143-157.

36 Minars M, Burch J, Masella R, Meister M. Predicting skeletal maturation using cervical vertebrae. Today's FDA 2003; 15: 17-19.

37. Zhang Y, Wang B. Observation of cervical vertebrae and estimation of their bone age (Article in Chinese) Zhonghua Kou Qiang Yi Xue Za Zhi. 1997; 32: 152-54.

38. Chang HP, Liao CH, Yang YH, Chang HF, Chen KC. Correlation of cervical vertebra maturation with hand-wrist maturation in children. Kaohsiung J Med Sci 2001; 17: 29-35.

39. Flores-MC, Burgess CA, Champney M, Jensen RJ. Pitcher MR, Major PW. Correlation of Skeletal Maturation Stages Determined by Cervical Vertebrae and. Hand-wrist Evaluations. Angle Orthod 2006; 76:1-5.

40 Gandini P, Mancini M, Andreani F. A Comparison of Hand-wrist Bone and Cervical Vertebral Analysis in Measuring Skeletal Maturation. Angle Orthod 2006; 76:984-89.

41 San Roman P, Palma JC, Oteo MD, Nevado E. Skeletal Maturation Determined by Cervical Vertebrae Development. Eur J Orthod 2002; 24: 303-13.

42 Grippaudo C, Garcovich D and Volpe G. Comparative evaluation between cervical vertebral morphology and hand-wrist morphology for skeletal maturation assessment. Minerva Stomatol. 2006; 55:271-80.

43 Caltabiano M, Leonardi R, Zaborra G. (Evaluation of cervical vertebrae for determination of skeletal age) [Article in Italian] Riv Ital Odontoiatr Infant. 1990; 1: 15-20

44 Hellsing E. Cervical vertebral dimensions in 8-11- and 15 year old children. Acta Odontol Scand 1991; 49(4): 207-13.

45 Gabriel et al. Cervical vertebrae maturation method: Poor reproducibility Am J Orthod Dentofacial Orthop 2009;136: 478-80.

46 Chen L, Xu T M, Jiang J H, Zhang Z, Lind J. Quantitative cervical vertebral maturation assessment in adolescents with normal occlusion: A mixed longitudinal study. Am J Orthod Dentofacial Orthop 2008;134:720.e1-720.e7.

47 Grave K, Townsend G. Hand-wrist and cervical vertebral maturation indicators: how can these events be used to time Class II treatments? Aust Orthod J. 2003; 19: 33-45.

48 Kucukkeles N, Acar A, Biren S, Arun T. Comparisons between cervical vertebrae and hand-wrist maturation for the assessment of skeletal maturity. J Clin Pediatr Dent 1999; 24: 47-52.