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Relationship of Skeletal Age and Chronological Age Based on Lateral Cephalograms in the Treatment of Different Malocclusions

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Abstract

Background: Skeletal age has been suggested for the assessment of puberty in patients, as chronological age is not reliable for this purpose.
Objectives: This study aimed at determining chronological age based on the maturation stage of cervical vertebrae in the treatment of different malocclusions in a group of Iranian patients.
Methods: This cross- sectional analytical study was performed on 480 lateral cephalograms of patients aged 8 to 16 years (240 males and 240 females). The specimens were randomly selected from 480 patients who referred to a radiology center in Tehran. Patients were divided into 8 age groups. Cephalograms were traced by ViewBox software to determine the class of malocclusion. The cervical vertebral maturation stage (CVMS) was determined according to the Baccetti's classification. Data were analyzed using SPSS.
Results: The Pearson's correlation coefficient revealed a significant association between chronological age and CVMS in all patients with different classes of malocclusion ($P < 0.001$). Also, the correlation of CVMS and gender in class II ($P < 0.001$) and III ($P = 0.018$) malocclusions was statistically significant. However, there was no significant difference between CMVS and gender in class I. CS-1, CS-4, and CS-5 had the highest frequency percentage in the age range of 12 to 13, 13 to 15 and 15 to 16 years, respectively.
Conclusions: The CVMS and skeletal age significantly increased with an increase in chronological age. However, high variability of chronological age at each CVMS showed that chronological age is not a reliable index for planning treatment for different malocclusions.

Keywords: Cephalogram, Chronological Age, Skeletal Age, Cervical Vertebral Maturation, Malocclusion

1. Background

Malocclusion refers to misalignment and incorrect relationship of the teeth in the 2 dental arches (1). Malocclusion can result in unaesthetic appearance, psychological problems, impaired mastication, deglutition, and speech, and increased susceptibility to trauma (2-5).

Many orthodontic conditions should be ideally treated during the growth spurt. In some other cases, as in treatment planning for corrective surgeries or intraosseous dental implant placement, the clinician needs to ensure that the patient has passed his/her growth capacity (6).

Chronological age is an inaccurate index for determining patients' pubertal growth spurt. Several biological markers have been suggested for the assessment of biological maturity of individuals (7). Skeletal maturity can be determined by several biological indices, such as increased body height, skeletal maturity of the hand and wrist, menstruation, or voice change, and morphological changes in cervical vertebrae. The cervical vertebral maturation stage (CVMS) is a simple and available skeletal index for orthodontists, which does not require taking additional records and exposure, such as wrist radiography. Cervical vertebrae are visualized on lateral cephalograms, which are commonly requested by orthodontists (8, 9).

On the other hand, skeletal maturation is variable in different populations and races and is significantly influenced by the environmental factors (10). Variations in the speed and time of puberty in different communities are due to differences in nutritional habits, genetics, lifestyle, and socioeconomic status of individuals (11-13). The cervical vertebral maturation indices are the same in males and females, but changes appear sooner in females (14).

Several studies have assessed the association of chronological and physiological age in different populations (14). However, studies on this topic are limited in the Iranian population.

2. Objectives

Thus, this study aimed at determining the suitable chronological age for treatment of class I, II, and III malocclusions in the Iranian patients, based on CVMS.

3. Methods

This cross- sectional analytical study was conducted on 480 lateral cephalograms of patients presenting to a radiology center in Tehran. The cephalograms belonged to 240 males and 240 females in the age range of 8 to 16 years. Based on the type of malocclusion, the patients were divided into 8 age groups with one year intervals. All digital lateral cephalograms were traced using ViewBox software and SNA, SNB, and ANB angles and the Wits appraisal were measured and calculated to determine the type of malocclusion according to the Angle's classification (Figure 1).

Next, the CVMS was determined based on the lateral cephalograms according to the classification described by Baccetti. This classification is based on the morphology of the vertebral body of the second (C2), third (C3), and fourth (C4) vertebrae (5). This method is based on anatomical changes in these 3 vertebrae including (I) presence or absence of concavity (notch) in the inferior border of C2, C3, and C4; and (II) difference in the shape of vertebral body, such as trapezoidal, horizontal-rectangular, square-shaped, and vertical-rectangular, and has 6 stages as follow:

The first 3 stages are differentiated by the presence or absence of the concavity (15).

- In the first stage (CS-1), the inferior border of the body of C2 to C4 is smooth (or slightly convex). This stage often continues for 2 years before the skeletal growth spurt, and the main skeletal adaptation of the mid-face occurs in this stage.

- Thus, this stage is ideal for therapeutic interventions by use of face mask along with rapid maxillary expansion.

- The second stage (CS-2) is characterized by presence of a concavity in the inferior border of C2. The inferior border of C3 and C4 bodies remains smooth. The shape of C3 and C4 often remains trapezoidal. Peak interval starts 1 year after the onset of this stage (15).

- The third stage (CS-3) is characterized by development of a notch in the inferior border of C2 and C3. C4 remains smooth. At least, one of the C3 and C4 vertebral bodies remains trapezoidal, while the other one appears to be horizontal-rectangular. Maximum craniofacial growth is expected to happen at this stage. Thus, it would be better to assign a patient to late CS-3 or early CS-4, based on the deformation of C3 or C4 (15).

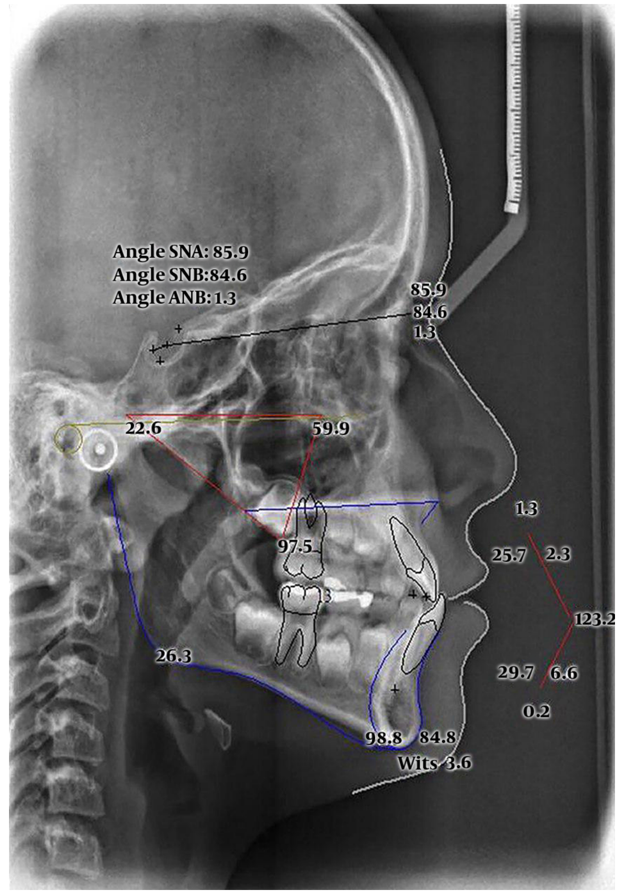

Figure 1. Tracing Cephalometry

- The fourth stage (CS-4) is characterized by the presence of a notch in the inferior border of all 3 cervical vertebrae. Thus, the shape of C3 and C4 vertebral bodies is a more important factor in this stage, which appears to be horizontal-rectangular rather than trapezoidal.

- The fifth stage (CS-5) can be differentiated from CS-4 by the shape of C3 and C4, such that the vertebral bodies are square-shaped. Presence of notch in this stage is not important for differential diagnosis. This stage indicates that the craniofacial growth has been mainly accomplished and the patient can be considered for corrective surgeries or intraosseous dental implant placement. Although CVMS is still important in this stage, the gold standard to determine the continuation or cease of growth is the assessment of 2 lateral skull radiographs taken by a minimum of 6-month interval.

- The sixth stage (CS-6) is the most difficult among all. In this stage, the body of at least one of the third or fourth vertebra is vertical-rectangular. Also, it appears that the cortical bone is better identifiable in CS-6.

Estimation of the maturation stage of patients based on the CVMS (C2-C4) provides the clinician with valuable information required for correct diagnosis and treatment planning. Timing of the therapeutic interventions is highly important in orthodontics, and the initiation time of treatment protocols varies for different types of malocclusions. For instance, tooth size/arch size discrepancies must be treated at the age of 8 to 9 years.

To increase the accuracy and reliability of the results, all measurements were made by one observer.

Data were analyzed using Spearman's correlation coefficient, chi square test, and Fisher's exact test in SPSS Version 16. $P < 0.05$ was considered statistically significant.

4. Results

A total of 480 lateral cephalograms were evaluated. Table 1 demonstrates the frequency distribution of patients in different age groups.

In type of malocclusion, the highest and the lowest frequency belonged to class II (59.58%) and class I (17.7%) malocclusion, respectively. Table 2 displays the frequency of each CVMS in each age group separately for each type of malocclusion. In patients with class I malocclusion, CS-1 had the highest frequency in the age range of 8 to 12 years, while CS-4 had the highest frequency in the age range of 13 to 16 years. In patients with class II malocclusion, CS-1 had the highest frequency in the age range of 8 to 13 years, while CS-4 had the highest frequency in the age range of 13 to 15 years and CS-5 had the highest frequency in the age range of 15 to 16 years. In patients with class III malocclusion, CS-1 had the highest frequency in the age range of 8 to 11 years, CS-2 had the highest frequency in the age range of 12 to 13 years, CS-3 had the highest frequency in the age range of 13 to 14 years, and CS-4 and CS-5 had the highest frequency in the age range of 14 to 16 years. Also, CS-1 had the highest frequency in females up to the age of 11 years and in males up to the age of 13 years. In the assessment of the correlation of skeletal and chronological age, based on the adaptation of skeletal growth and chronological age, age groups were divided into 2 categories of 8 to 12 and 13 to 16 years. Based on the chi square test, no significant association was noted between chronological age and skeletal age ($P > 0.1018$).

Chi square test revealed a strong and significant association between chronological age and skeletal age ($P < 0.001$). Table 3 shows the correlation of gender and skeletal age based on CVMS for the 3 classes of malocclusion in patients.

In all 3 classes of malocclusion in males and females, skeletal age of CS-1 had the highest frequency among patients followed by CS-4 in class I males and females, CS-2 in males with class II and III malocclusion and CS-4 in females.

In analytical studies by chi square test, no significant association was found between the skeletal age and gender in class I malocclusion patients ($P = 0.182$). However, significant associations were found between skeletal age and gender in class II ($P < 0.001$) and III ($P = 0.018$) malocclusions. Table 4 displays the mean age in each CVMS separately for class of malocclusion and gender.

Irrespective of the type of malocclusion, the mean age of females and males in each CVMS was as follows:

Females: CS-1: 8 - 11 years; CS-2: 9 - 12 years; CS-3: 10 - 13 years; CS-4: 13 - 14 years; CS-5: 1 - 15 years; and CS-6: 15 years

Males: CS-1: 8.5 - 12 years; CS-2: 9.5 - 13.5 years; CS-3: 12 - 15 years; CS-4: 13 - 15 years; CS-5: 14 - 15 years; and CS-6: 15 years

The correlation coefficient between the skeletal age and chronological age in females and males with class I malocclusion was 82% and 76%, respectively. These values were 78% and 50% for class II and 82% and 73% for class III malocclusion, respectively (Figure 2).

5. Discussion

This study aimed at determining the suitable chronological age for treatment of class I, II, and III malocclusion in a group of Iranian population; 480 lateral cephalograms of 8 to 16 year-old males and females were evaluated. CS-1 had the highest frequency in the age range of 12 to 13 years, CS-4 had the highest frequency in the age range of 13 to 15 years, and CS-5 had the highest frequency in the age range of 15 to 16 years. Irrespective of age, CS-1 had the highest frequency.

In this study, CS-1 had the highest frequency in the age range of 8 to 9, 9 to 10, 10 to 11, and 11 to 12 years in females. This result in the age range of 8 to 9 and 10 to 11 years was in agreement with that of Abesi et al. in 2015. However, in their study, most females in the age range of 9 to 10 and 11 to 12 years were in CS-2 stage (16). Baidas in 2012 in Saudi Arabia reported that most 8 to 9 year-old females were in CS-1 stage, while 9 to 10 year-old females were in CS-2, 10 to 11year-old females were in CS-3, and 11 to 12 year-old females were in CS-4 stage (7). Safavi et al. in 2015 reported that females in the age range of 10 to 11 years were mainly in CS-2 stage and females in the age range of 11 to 12 years were mainly in CS-3 stage (16). In our study, CS-3, CS-4, and CS-5 had the highest frequency in females in the age range of 12 to 13, 13 to 14, 14 to 15, and 15 to 16 years, respectively, while in the study by Abesi et al. CS-4, CS-5, and CS-6 had the highest

Table 1. Frequency Distribution of Patients Based on Gender and Chronological Age

Chronological Age		8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	Total
Gender	Female	30	30	30	30	30	30	30	30	240
	Male	30	30	30	30	30	30	30	30	240

Table 2. Frequency of Chronological Age and Skeletal Age Based on CVMS in Class I, II, and III Malocclusions

Chronological Age	Skeletal Age					
	1	2	3	4	5	6
8 - 9	47	12	1	0	0	0
9 - 10	46	12	2	0	0	0
10 - 11	42	12	6	0	0	0
11 - 12	35	18	7	0	0	0
12 - 13	20	15	16	8	1	0
13 - 14	12	12	15	18	3	0
14 - 15	7	10	12	21	10	0
15 - 16	0	5	7	17	24	7

Table 3. The Association of Gender and Skeletal Age Based on CVMS for the 3 Classes of Malocclusion

Malocclusion	Gender	Skeletal Age Based on CVMS						P Value
		1	2	3	4	5	6	
Cl I	Female	16 (37.2)	6 (14)	6 (14)	9 (20.9)	6 (14)	0 (0)	0.182
	Male	20 (47.6)	7 (16.7)	6 (14.3)	8 (19)	0 (0)	1 (2.4)	
Cl II	Female	58 (38.9)	22 (14.8)	25 (16.8)	28 (18.8)	15 (10.1)	1 (0.7)	< 0.001
	Male	70 (51.1)	40 (29.2)	18 (13.1)	5 (3.6)	4 (2.9)	0 (0)	
Cl III	Male	15 (31.3)	5 (10.4)	8 (16.7)	9 (18.8)	8 (16.7)	3 (6.3)	0.018
	Female	30 (49.2)	16 (26.2)	3 (4.9)	5 (8.2)	5 (8.2)	2 (3.3)	

frequency in the age range of 12 to 13, 13 to 14, and 14 to 15 years, respectively. The order was CS-3, CS-4, CS-5, and CS-6, respectively, in the study by Baidas and CS-4, CS-5, and CS-6 in the study by Safavi et al. (7, 16, 17).

Development of skeletal age was significantly lower in males than in females, such that CS-1 had the highest frequency in 8 to 14 year olds. Earlier development in females has also been reported in other studies, in line with ours, indicating that females reach the maturation phase of cervical vertebrae and subsequent skeletal growth sooner than males. In the study by Abesi et al. CS-1 had the highest frequency in males in the age range of 8 to 9 and 9 to 10 years, CS-2 had the highest frequency in the age range of 11 to 12 and 12 to 13 years, and CS-4 had the highest frequency in the age range of 13 to 14 and 14 to 15 years in males (16). In the study by Baidas, the highest frequency of CS-1, CS-2, CS-3, CS-4, and CS-5 was reported in the age range of 8 to 12, 12 to 13, 13 to 14, 14 to 15, and 15 to 16 years, respectively (7).

Based on the results of this study and those of previous ones, 8 to 12 year olds are mainly in CS-1 stage, and then maturity of cerebral vertebra continues with a steeper gradient. After 1 year of chronological age, cervical vertebras must develop by one stage; in other words, 1 year should be added to skeletal age. An important finding of our study, in line with previous ones, was earlier maturation of cervical vertebrae in females, which can help in estimation of the initiation time of treatment (15, 16, 18).

Regarding the frequency of malocclusion, class II malocclusion had the highest frequency (59.58%), followed by class III (22.7%) and class I (17.7%). This result was different from that of Shahri et al. in Isfahan, Khaneh Masjedi in Ahwaz, Ramazan Zadeh in Neyshabour, and Azarbaijani in Isfahan (19, 20), as they reported that class I malocclusion had the highest frequency followed by class II and class III;

Table 4. Mean Skeletal Age in Males and Females with Class I, II, and III Malocclusion

Skeletal Age		Females			Males		
		Mean ± SD	Maximum	Minimum	Mean ± SD	Maximum	Minimum
Cl I	CS-1	8 - 12	14	8	8 - 11	12	8
	CS-2	10.5 - 14	15	9	9 - 12.5	14	8
	CS-3	12 - 14.5	15	13	10 - 14	15	10
	CS-4	13 - 15	15	12	13 - 14	15	13
	CS-5	-	-	-	14 - 15	15	14
	CS-6	15	15	15	8 - 11	12	8
Cl II	CS-1	8 - 11	14	8	9 - 12	14	8
	CS-2	9 - 12	12	9	9 - 13	15	8
	CS-3	10 - 13	13	10	11.5 - 15	15	8
	CS-4	13 - 14	14	13	13 - 15	15	13
	CS-5	14 - 15	15	14	15	15	15
	CS-6	15	15	15	9 - 12	14	8
Cl III	CS-1	8 - 11	14	8	8 - 11.5	14	8
	CS-2	9 - 10	10	8	10 - 14	15	8
	CS-3	11 - 13	13	11	13 - 15	15	13
	CS-4	12 - 14	15	12	14 - 15	15	14
	CS-5	13 - 15	15	12	14 - 15	15	14
	CS-6	15	15	15	15	15	15

Abbreviation: SD, standard deviation.

this difference was probably due to the method of patient selection, such that a higher number of class II malocclusion patients were included. In our study, the correlation of skeletal age and CVMS was significant in all 3 classes of malocclusion. In association of gender and skeletal age estimation based on CVMS, the difference between males and females was not significant in class I malocclusion, which may be due to small sample size; however, this difference was statistically significant for class II and class III malocclusions.

The time of mandibular growth spurt is particularly important in orthodontic treatment. Commonly, growth spurt of the jaws occurs simultaneously with growth spurt of the height; however, significant inter-individual differences exist as well (2). Thus, treatment of mandibular growth deficiency is more effective if performed during the mandibular growth spurt. The CS-3 stage is the most ideal treatment time for growth modifications and the highest response to treatment can be expected. Growth modifications can still be performed for patients in CS-4 stage, but response to treatment may be low. For patients in CS-2 or lower stage, patient's height must be recorded every 3 months to determine the time of pubertal growth spurt, and growth modifications should be performed at a time close to the growth spurt (21, 22). In patients with transverse maxillary deficiency, maxillary expansion is more effective during the prepubertal stage (22). For maxillary protrusion in patients with maxillary deficiency, treatment is only effective before the growth spurt in CS-1 and CS-2 stages (21). In patients requiring correction of vertical facial problems due to the mandibular ramus deficiency, facial height can be controlled by treatment during the growth spurt of the mandible (21, 22).

Considering the most suitable time for treatment of each malocclusion, the most ideal stage for treatment of tooth size/arch size discrepancy (serial extraction) is CS-1. In our study population, the mean age in this stage of skeletal maturation was 8 to 12 years in females and 8.5 to 13.5 years in males.

If class II malocclusion is due to the mandibular retrusion, CS-3 would be the ideal time of treatment. In our study population, the mean age in the stage of skeletal maturation was 10 to 13 years in females and 11.5 to 15 years in males. If class II malocclusion is due to the maxillary

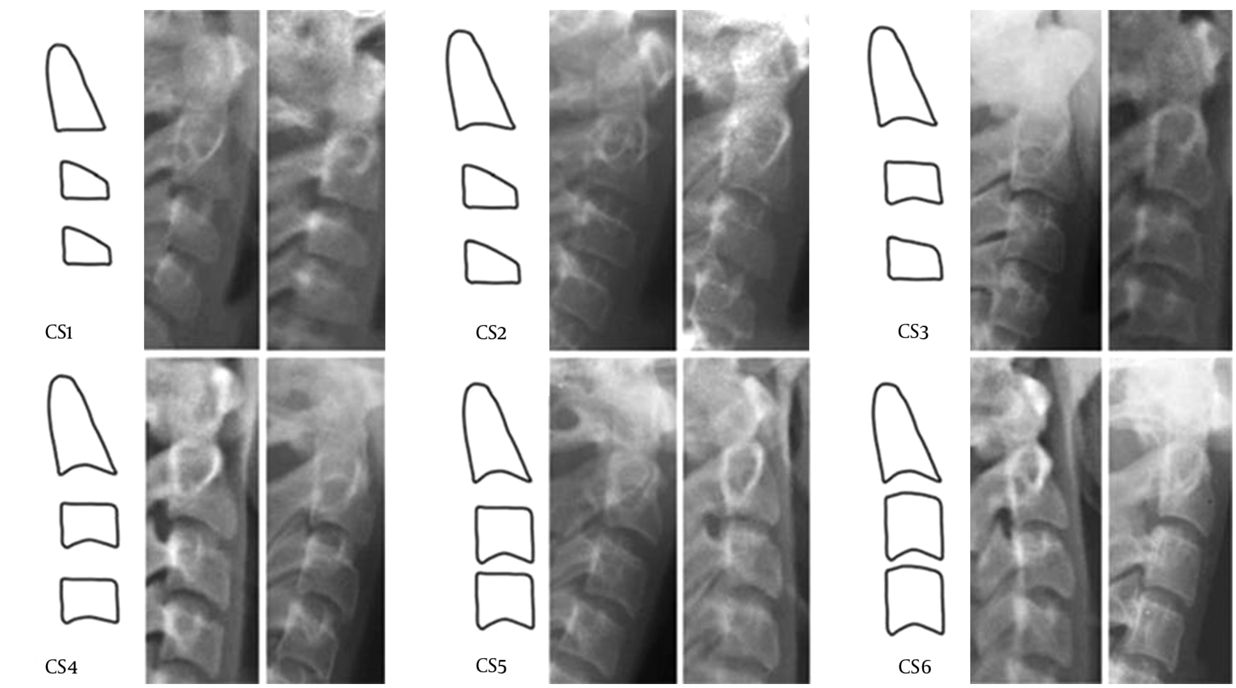

Figure 2. Cervical Vertebral Maturation Stages

prognathism, use of extra oral traction is effective in both the mixed and permanent dentition periods.

To treat class III malocclusion, 2 conditions exist, and each treatment needs to be performed at a different time in the course of skeletal maturation. If class III malocclusion is due to maxillary deficiency, CS-1 and CS-2 would be the ideal time of treatment. In our study, the mean age of females and males in this stage of skeletal maturation was 8 to 11 years and 8 to 14 years, respectively. If class III malocclusion is due to mandibular prognathism, since initiation of treatment during the growth period causes relapse of malocclusion, the treatment must be postponed after the termination of active growth period. Thus, the best time for treatment of such cases would be CS-5. The mean age of females and males in our study in this stage of skeletal maturity was 14 to 15 years.

Assessment of the pubertal characteristics in patients in CS-3 stage in a previous study (2) showed an agreement between the time of skeletal maturity determined based on CVMS and time of physical and sexual puberty in this population and confirmed that the patients in their study were at the onset of puberty.

5.1. Conclusions

The most important topic is the use of skeletal age instead of chronological age to estimate the time of initiation of orthodontic treatment in the Iranian population. In this study, maturity of cervical vertebra and skeletal age significantly increased by an increase in chronological age. However, high variability in chronological age of patients at each stage of cervical vertebral maturation revealed that chronological age is a poor index to decide the proper time of initiation of treatment of different malocclusions.

The mean age of males at each CVMS was higher than that of females, indicating that females enter into each stage of skeletal development sooner than males. Thus, growth modification in females must be started sooner than that in males because the growth spurt and puberty occur sooner in females. The correlation coefficient between skeletal age and chronological age in was higher in females than in males, which, perhaps, due was to the sooner initiation of puberty in females.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

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