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DENTAL SCIENCE
Research Article

Correlation between Cervical Vertebral Maturation and Chronological Age in a Group of Saudi Arabian Females

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Received: February 04, 2016; **Published:** February 10, 2016

Abstract

One of the Important Factors in the Diagnosis and evaluation during clinical orthodontic practice is the Correlation between chronological age at different stages of cervical vertebral maturation (CVM). The goal and Benefit of this study is to evaluate the correlation between CVM stage and chronological age in a group of Saudi female patients, and to determine its importance clinically.

Keywords: *Cervical Vertebral; Chronological age; Maxillofacial Radiology; CVM stages; Cervical maturation*

Introduction

Optimum timing is an important issue in orthodontic planning and dentofacial orthopedic treatments [1]. Treatment timing is correlated to the severity and type of the malocclusion in addition to the maturational stage of the patient in which the most severe malocclusions are, usually, treated in younger ages [1,2]. Maturity of the patient is assessed by several developmental ages, including skeletal age that has been proven to be the most appropriate developmental age in management of skeletal discrepancies [3]. To assess skeletal age, sequence of ossification of bones of hand-wrist or more recently introduced cervical vertebra bones with the same level of accuracy have been used [4,5]. Cervical vertebral maturation (CVM) method first described by Lamparsky and then reintroduced by Baccetti has two outstanding advantages over hand-wrist method [4,6]. First, additional X-ray exposure is avoided and thus shortening the examination duration. Second, it is designed for the anticipation of the pubertal peak in mandibular growth with the same validity [7]. According to Baccetti, the peak in mandibular growth occurs during the year after cervical stage 3 when concavities at lower border of second and third cervical vertebra are present [8]. Although the chronological age is the least accurate indicator describing developmental maturation [9], it is the mostly used indicator of patient maturation by parents and or even clinicians. Therefore, many high ranked scientific reports still use it frequently to develop guidelines that can be used easily by clinicians in practice. For example, the results of a meta-analysis on the effectiveness of face mask therapy revealed that the orthopedic treatment of a deficient maxilla is less effective in patients who are older than 10 years of age [10].

Considering the difficulties in simultaneous usage of various skeletal age determination methods, correlation between all types of developmental ages and chronological age or age distribution of every stage of different developmental ages seems quite useful [11-13]. Mean chronological age at different stages of puberty is, usually, reported in Tanner stages for breast and pubic hair development, which does not seem applicable in clinical situations [14]. However, mean chronological age at different stages of CVM and correlation between them are more useful data in clinical orthodontic practice. Considering the possible racial variations that have been reported previously [15], the purpose of this study was to evaluate:

1. The intra and inter-observer agreements on determined stage of each subject in addition to the presence of concavities and the shapes of the C3 and C4;
2. The mean chronological age at each stage of CVM, specially mean age at growth spurts (CS3 and CS4); and
3. Correlation between chronological age and CVM in a group of Iranian females.

Materials and Methods

This descriptive cross-sectional study was performed on 196 female subjects of age range 9-14 years, (±2 years around circum-pubertal period) during 2011-2012 following the ethical approval of Science and Technology University at Jordan instead of Shahid University. The lateral cephalometry radiographic images assessed in this study were taken from patients referred to nine Oral and Maxillofacial Radiology Centers in Tehran equipped with digital cephalometric radiographs from the same manufacturer. Those images in which cervical vertebrae C2-C4 was not captured or captured with low quality or contrast were discarded.

Precise chronologic age of patients (years and months) was extracted from electronic files present in the database of the centers. Skeletal maturation of patients was determined based on the last version of CVM method of Baccetti., *et al*. [1] In this method, two sets of variables were used:

A. Presence or absence of concavity at the inferior border of C2, C3 and C4;
B. Morphologic shape of the body of cervical vertebral C3 and C4 (trapezoid, rectangular horizontal, square and rectangular vertical).

According to these two sets of variables, patients were divided into six stages of skeletal maturation, CS1 to CS6 (Figure 1 and Table 1). After precise application of written improved protocol by Baccetti., *et al.* [1] it was decided to augment the examiner's ability in making decision on the perceived stage of the subject with some distinct clinical guidelines stated as:

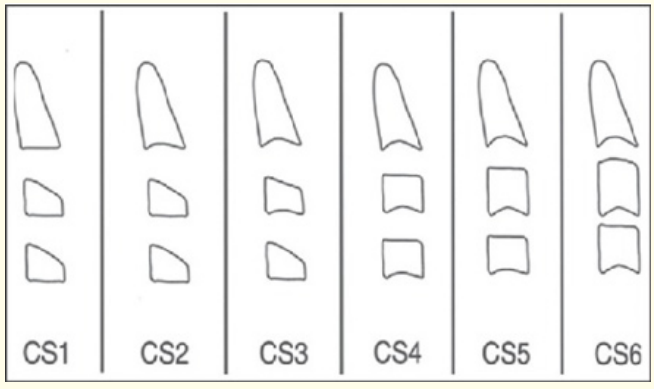

Figure 1: *Schematic illustration of developmental stages of cervical vertebrae.*

Concavity at the lower border of C2	Concavity at the lower border of C3	Concavity at the lower border of C4	C3 Shape/C4 Shape	Overall CS Stage
No	No	No	Trapezoid/trapezoid	CS 1
Yes	No	No	Trapezoid/trapezoid	CS 2
Yes	Yes	No	Trapezoid/horizontal rectangular	CS 3
		No	Horizontal rectangular/trapezoid	
Yes	Yes	Yes	Trapezoid/horizontal rectangular	CS 4
		Yes/No	Horizontal rectangular/ horizontal rectangular	

		Yes	Horizontal rectangular/trapezoid	
Yes	Yes	Yes	Horizontal rectangular/square	CS 5
		Yes	Square/square	
		Yes	Square/horizontal rectangular	
Yes	Yes	Yes	Square/vertical rectangular	CS 6
		Yes	Vertical rectangular/vertical rectangular	
		Yes	Vertical rectangular/square	

CS: Cervical Stage; CVM: Cervical vertebral maturational.

Table 1

CVM stages, developed by Baccetti., *et al.*

a. Considering non-significant reported exceptions at original Baccetti approach, in diagnosis of the first three stages, presence of the concavity is the major prioritized diagnostic characteristic over the shapes of the bodies of C3 and C4.
b. In the diagnosis of CS4, the presence or absences of the notch in the lower border of C4 is a less important characteristic than the necessity of horizontal rectangular shapes of both C3, C4.
c. In CS5, being at least one of the C3 or C4 in a square shape is enough to consider the subject in this stage. However, the other one must be in rectangular horizontal shape.
d. In CS6, being at least one of the C3 or C4 in a rectangular vertical shape is enough to consider the subject in this stage. However, the other one should be in rectangular horizontal shape.

Staging was performed by two calibrated examiners trained for this staging who were blind according to the real chronologic age of cases. To avoid a possible bias, instead of tracing, the lateral cephalograms were used, and the examiners did not participate in the statistical analysis of the project. In the case of disagreement between the observers, the third opinion was obtained from a university professor who was an expert for this staging.

As peak growth velocity occurs between stages 3 and 4 of Baccetti classification, mean age of cases in these stages were calculated to be growth spurts of skeletal maturation in our sample. To examine intra-observer reliability, 20 samples were chosen randomly and reassessed by both observers. The statistical analysis was performed with the help of statistical package for the social sciences (SPSS) (Version 21, SPSS Inc., Chicago, IL, USA). To evaluate the correlation between mean chronological age and cervical maturation stage, the Spearman rank-order correlation coefficient was used. The intra and inter-observer agreement was evaluated by weighted Kappa statistics in overall diagnosis of stages, in addition to determination of presence or absent of concavities at the lower border of second, third and fourth cervical vertebral and the shapes of the third and fourth vertebrae. This additional report would help the clinicians to determine the most challenging step of the diagnosis process by this protocol. A $P < 0.05$ was considered significant.

Results

The results of the study indicate a positive correlation between mean chronological age and CVM from CS1 through CS6 (Figure 2). The Spearman rank-order correlation coefficient between chronologic age and CVM stages was 0.62; this was statistically significant correlation and showed a moderate, but not high correlation. Mean chronological age for peak pubertal growth (CS3 and CS4 group) was about 11.48 years for this sample. The inter-examiner agreement on assessment of the cervical maturation stage was reported as 0.79, while the intra-examiner agreement was 0.74. The inter-examiner agreement coefficient for each separate step of diagnosis of concavities and the differential diagnosis of the third and fourth vertebrae shapes are demonstrated in Table 2.

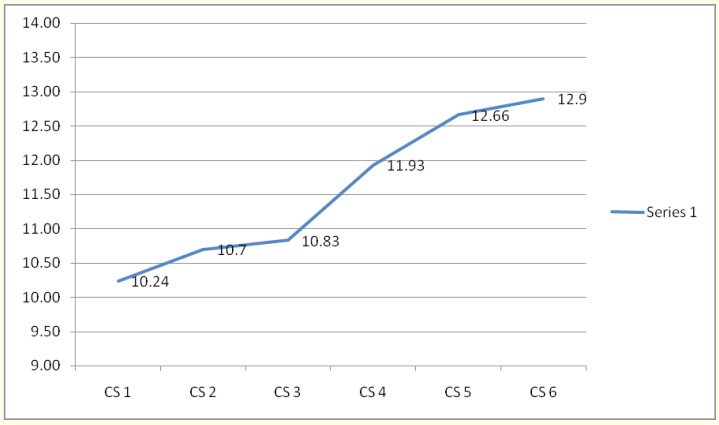

Figure 2: *Statistical indices of mean chronological age of the samples according to the cervical maturational stage.*

Different steps of diagnosis	Concavity at the lower border of C2	Concavity at the lower border of C3	Concavity at the lower border of C4	C3 Shape	C4 Shape	Overall CS Stage
Coefficient orrelation	0.74	0.71	0.78	0.63	0.42	0.79

CS: Cervical Stage;

Table 2: *The inter-examiner agreement on five step and overall assessment of the cervical maturation stage.*

Vertebral maturation in each age group is presented in Figure 3 and demonstrates that 42.3% of 9 years age group were in CS1, 31.4% of 10 years age group were in CS2, 34.2% of 11 years age group were in CS3, 28.6% of 12 years age group were in CS4, 41.0% of 13 years age group were in CS5 and 26.01% of 14 years age group were also in CS6. There was a positive but not high correlation between these two variables.

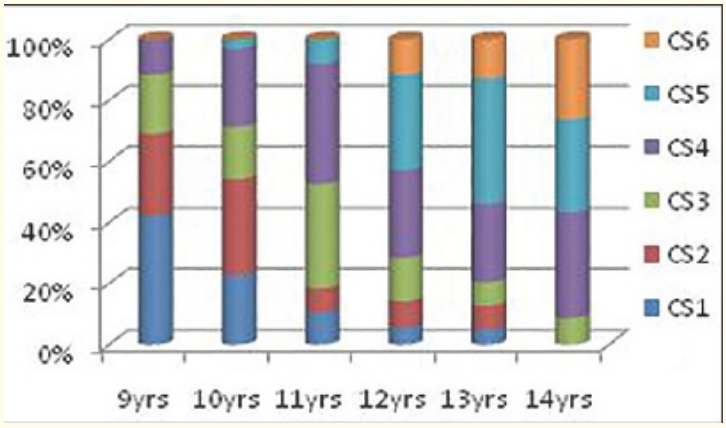

Figure 3: *Distribution frequency of cervical vertebral maturation stages in each age group.*

Discussion

The results of the present study indicate that mean chronological age of the present sample at pubertal growth spurts (CS3 and CS4) was 11.48 years. Considering the available variation that exists in this regard, several attempts have been made to achieve a more reliable and valid data on maturational changes during growth spurt period as CVM method was developed [16,17].

Maximum variation in maturation of cervical vertebra occurs during growth spurt period [18]. Mean chronological age of samples who were in CS3 was 10.8 years and demonstrated a high level of variation (standard deviation [SD] = 1.3 years). SD of the mean chronological age at CVM stages prior to peak growth velocity and after that indicate that minimum variation can be expected before 9 years of age and after 13 years of age. During chronological age range of puberty (9-13 years), we can see several 10 years old samples who are in CS4 or CS5 or 15 years old individuals who are in CS2.

On the other hand, one way of checking the accuracy of this reported mean age of the peak of growth spurt is to compare the age at menarche or considering the reported mean chronological age at peak mandibular growth in the same population. Regarding the available literature, menarche occurs 1 year after peak of the growth spurt in girls at the end of CS4 [19,20]. According to the published data, mean chronological age at menarche for Tehranian females is reported from 12 years to 12.6 years [21]. Therefore, it can be concluded that the peak of the growth spurt occurs at 11-11.5 years of age in named population. The mean chronological age at pre-pubertal stages (CS3 and CS4), in this study, was 11.48 years, which is very close to calculated age of the growth spurt. In other words, the time interval between the age at peak skeletal growth and the average age of the first menstruation is about 6-12 months in these subjects that seem logical.

The results of the present study indicate a moderate but not high correlation (62%) between CVM and chronological age in the named subjects. The calculated correlation between these two variables in similar studies was reported as 0.72-0.75%, which demonstrate a relatively high correlation [15,16,22,23]. Maximum variation in maturation of cervical vertebrae occurs during the growth spurt period. One possible explanation of this variation is that different age groups were considered in each study. A higher correlation can be expected between these two variables when age range expands from 9 to 14 years to a wider range of age [18]. It is obvious that a variation on maturational state of cervical vertebrae of the individuals at the growth spurt period is significantly more than any other time interval. During this period, the minimum correlation between CVM and chronological age can be detected simply due to a maximum variation of the second component. The correlation coefficient in our sample was minimum (48%) during puberty (CS3 and CS4, and if age groups were restricted to 11 years and 12 years of age). The greater the variations between the samples, the lesser the correlation between age and CVM. Variations in maturational status of cervical vertebrae will decrease during the years after puberty because nearly all subjects are in CS6 after 16 years of age.

On the other hand, to fully explain the underlying reason of the observed variety of coefficient between chronological age and cervical maturational status of the individuals, it should be highlighted that age at maximum craniofacial growth velocity is a complex trait and has a strong genetic component [24]. However, several environmental factors including civilization, nutrition and climate significantly affect mean chronological age during puberty [25]. According to the results of a recent national survey in China there is a significant difference between rural and urban Chinese girls in regards to the timing of menarche; menarche occurs at an earlier age in urban Chinese girls [20]. There is a significant difference in the pubertal age of girls living in various regions of Iran with different ethnicity and geographic characteristics. For example, the mean age at menarche for girls in Tehran is 11.99 ± 1.35, whereas it is about 13 years in Kordestan and Ilam provinces [21]. Recent data suggest that the growth spurt in girls in the 21st century takes place at younger ages [19]. Obesity is another recently proven factor that has a positive correlation with early onset of puberty [26]. Significant differences between obese subjects and control groups have been reported in CVM. It has been shown that obese subjects have a higher mean score of maturation compared to a control group [26].

Another reason of the observed variation of the correlation between the chronological age and cervical maturational status would be embedded within the applied technique as well. In this study, the inter-examiner agreements were assessed in two subgroups of

detection of the presence of the concavity in the lower border of each vertebrae and the shape of the C3 and C4. This agreement was also evaluated between the examiners on the overall reported stage of each subject. Similar to recent reported study, the minimum amount of inter-observer agreement measured by weighted Kappa agreement index was determined to be at the clinical decision of the shape of the fourth vertebra, followed by the shape determination of the third vertebra [27]. All measures of the kappa coefficient on the detection of the concavities in the lower border of all three vertebrae were below the 0.8, which indicate that the cervical maturation method is not precise enough to provide high consistency of interpreted data between calibrated examiners [28]. As it is stated in the literature, the high level of accuracy of the CVM protocol reported by several studies has been questionable following strict methodological shortcomings hidden in the study construction [28] or because of application of the protocol by means of "too much" calibrated examiners, which is advantageous in increasing the reliability regarding inter-examiner agreements, but conversely affect the validity of the method since these highly calibrated examiners do not reflect the real picture of the applied methodology. All in all, concomitant usage of different skeletal maturity indicators like CVM is recommended for precise estimation of skeletal age of the patients.

Conclusion

Chronological age has a moderate correlation with skeletal age (CVM method) during circumpubertal phase. The concomitant usage of other skeletal indicators seems necessary for precise determination of physiologic age of the patients. Considering a great variability of inter-observer agreement in different steps of Baccetti modified protocol, strict adherence to clearly explained diagnostic characteristics in each stage is highly recommended.

Financial support and sponsorship

Nil.

Conflicts of Interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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Volume 3 Issue 5 February 2016