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Precision of CVMI in Assessing Skeletal Maturity between Class II and Class III Post-Pubertal Indian Population: A Comparative and Cross-Sectional Study

Authors
Dr Neha Deshmukh, Dr Sunilkumar Pulluri, Dr Shrinivas Ambarkar, Dr Akash Lavate, Dr Sneha Hoshing, Dr Sneha Shinde, Dr Kalyani Chatla

Abstract
Introduction: *Treatment of skeletal malocclusions with dentofacial orthopaedics greatly depends on identification of patients' residual growth as well as skeletal maturation. One of the most widely used methods of growth assessment is the cervical skeletal maturation indicator. Though helpful in growing patients, its reliability in adult population is questionable, mainly due to lack of sufficient literature. Hence, the aim of this study was to assess and compare the cervical maturation stages in postpubertal nongrowing individuals showing different skeletal jaw bases.*
Material and Method: *Lateral cephalograms of 150 adult patients (age: 20-45 years) were selected and divided into 2 groups, A with Class II and B with Class III skeletal bases. Cervical vertebrae C2, C3, C4 were analysed visually using Hassel and Farman method and using metric analysis by Baccetti, studying their morphology, concavities, base to anterior height ratio (BAR) and posterior to anterior height ratio (PAR). Data were tabulated and statistically analyzed.*
Result: *The occurrence of stage 6 was least as compared to stages 4 and 5. CVMI stage 4 and BAR for C4 was greater in Group B. Group A showed increased concavities of C2, C3, C4 compared to Group B.*
Conclusion: *CVMI stage 6 was present least in adults. Skeletal Class II individuals showed higher stages of maturation than Class III individuals.*
Keywords: *Class II, Class III, Cervical vertebral maturation, skeletal growth.*

Introduction

For years, Orthodontists have catered to malocclusions in all age groups, ranging from young individuals with extreme growth potential to adults with no residual skeletal growth. Treatment timing plays a significant role in the outcome of nearly all dentofacial orthopaedic treatments for combined dental and skeletal disharmonies in growing patients[1,2]. Hence, it proves imperative for clinicians to achieve accurate identification of different phases of skeletal maturation for superior orthodontic diagnosis and relevant treatment planning. Since chronological age is not a valid indicator of skeletal maturity[1,3,4], various other parameters have been proposed for assessment of skeletal maturation like an increase in stature height[5], dental maturation[6,7], measurement of hormone concentrations[8,9], frontal sinus development[10], radiographic analysis of bones of hand and wrist[3,11,12] and assessment of cervical vertabrae[2,13].

Amongst these, two most commonly used methods of skeletal age assessment are with hand wrist radiographs and cervical vertebral maturation (CVM). Initially, hand wrist radiographs were adopted as the sequential ossification of bones of hand and wrist could be significantly correlated to different stages of an individual's growth. However, the hassle of an extra radiograph and unnecessary exposure lead to a need of another method that was simpler and more convenient. This lead to the rise of cervical vertebral maturation indicators (CVMI) which gained popularity amongst orthodontists as cervical vertebrae could be assessed in lateral radiographs itself.

The cervical vertebral maturation was first introduced by Lamparski in 1975[14] and was later modified by Hassel and Farman in 1995[13]. Both the methods involved correlating morphological changes seen in cervical vertebrae C2, C3 and C4 with the pubertal growth. Christ B et al suggested that CVMI could be a better predictor of mandibular growth as both cervical vertebrae and mandible shared the same area and time of embryological development[15]. The craniofacial region develops from the mesenchyme that is derived from the paraxial mesoderm, which later gives rise to the vertebral column[16]. The formation of the face, neck and spine occurs during the 4th month of intrauterine life[15]. A good correlation has been observed between skeletal age assessments using hand wrists and cervical vertebrae[17,18].

In 2002, Baccetti et al gave a new improved version of the cervical vertebral maturation method for the assessment of mandibular growth[19]. As opposed to former methods, Baccetti et al gave only 5 stages of maturation which could be assessed by 2 methods: visual and metric analysis. The metric analysis was an improved and more precise quantitative method of assessing morphological changes in C2, C3 and C4.

The accuracy, reproducibility and credibility of CVMI has been a topic of controversy amongst clinicians since it was ever introduced[20,21]. Though it shows a superior correlation with skeletal changes in growing individuals, its reliability in non-growing, post pubertal patients is still a mystery. Inconsistencies in the method was found when it was observed that the lateral cephalograms of adult orthodontic patients revealed lower levels of cervical vertebral maturations i.e. CVMI 4 and 5[16]. Dilemma arises when treatment plan of such post pubertal patients has to be formulated. Skeletal growth assessment becomes crucial to decide if functional appliances or orthognathic surgery might be required for correction of underlying dentoskeletal discrepancies.

Another important consideration is the variation in levels of skeletal maturation with different growth patterns. While this may not have any effect of Class I skeletal growers, this variation can greatly impact patients with Class II and Class III skeletal patterns since growth modulation plays a major role in treating their malocclusions and hence, skeletal age assessment becomes necessary to identify if a patient is a candidate for using and benefitting from such appliances or instead, a surgical approach is required. Hence, the aim of this study was to assess whether all post pubertal non-growing adults achieve complete skeletal maturation and to compare the level of maturation achieved in Class II and Class III skeletal patterns.

Materials and Method

The study was carried out at the Department of Orthodontics and Dentofacial Orthopaedics of the institute. Lateral cephalograms of 150 adult patients undergoing orthodontic treatment between the age group of 20 to 45 years were selected for the study from the records of our institution. Out of these, 77 were males and 73 were females.The mean age group of patients included was 22.76.

Inclusion criteria was complete root formation of all four third molars visible in the orthopentamograms and presence of either Class II (ANB > 4°) or Class III (ANB < 0°) skeletal jaw bases. Exclusion criteria involved patients with any craniofacial anomalies, systemic diseases or neuromuscular discrepancies. The lateral cephalograms were divided into two groups with Group A consisting of 75 patients with Class II skeletal jaw bases and Group B consisting of 75 patients with Class III skeletal jaw bases. Outlines of C2, C3 and C4 were traced for all the lateral cephalograms on0.03” thick acetate paper and CVMI of all patients was assessed using visual and metric analysis.

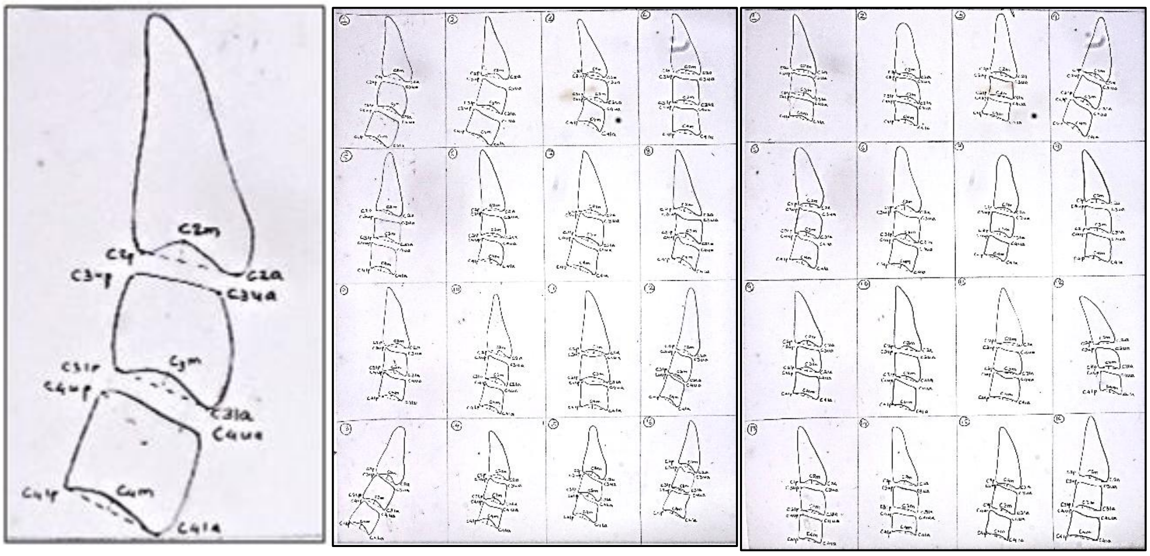
CVMI assessment with Visual Analysis

Visual Analysis was done using the Hassel and Farman method[13]. All the CVMI scores were assessed by the primary investigator. However, to avoid bias, 10 tracings were reassessed by a secondary investigator and interexaminer variability was checked with Kappa correlation statistics. The correlation was 0.061 indicating substantial agreement.

CVMI assessment with Metric Analysis

Metric Analysis was done using Baccetti’s method[19]. The landmarks were marked as shown in Table no. 2 and Figure no. 1 and measurements were calculated as shown in Table no. 3.

Figure No.1: Landmarks on C2, C3 and C4 for Metric Analysis



The base to anterior height ratio (BAR) was measured to calculate whether out of C3 and C4, a vertebra had a horizontal or vertical rectangular shape. BAR value greater than 1 would mean that the base of the vertebra was wider than its height i.e. a horizontal rectangle, whereas a value less than 1 meant base is shorter than its height i.e. a vertical rectangle. BAR value of 1 indicated a square vertebra. The posterior to anterior height ratio (PAR) was measured to determine if the anterior and posterior heights of C3 or C4 vertebrae were equal. A ratio less than 1 would indicate anterior height more than posterior height i.e. a trapezoid. A ratio of 1 would mean heights i.e. a square. Thus, the BAR and PAR ratios determined the shapes of vertebrae and were divided into 3 categories:

< 0.96

0.96 – 1.045

> 1.045

Thus, BAR ratio less than 0.96 indicated a vertical rectangle as seen in CVMI stage 6. Ratio between 0.96 – 1.045 would mean a square shape corresponding to CVMI stage 5. Ratio > 1.045 indicated a horizontal rectangle denoting CVMI stage 4. PAR ratio of < 0.96 would indicate posterior height smaller than anterior height. Ratio between 0.96 – 1.045 would indicate a square shape and ratio > 1.045 would mean posterior height more than anterior like a trapezoid. Each measurement was made with a metal scale with the smallest measurement of 1 mm. The measurements were made with a primary examiner followed by reassessment by a secondary examiner to avoid bias. The values were tabulated and results were calculated.

Statistical Analysis

The data was tabulated and analyzed by Statistical Product and Service Solutions (SPSS) version 21 for Windows (Armonl NY-IBM corp software). Tools of descriptive statistics such as Mean and Standard deviation were used to represent quantitative data. The Chi Square test was used to compare the percentage distribution of study participants according to CVMI stages assessed by Hassel and Farman's visual method, percentage distribution of study participants according to BAR and PAR ratios of C3 and C4 vertebrae and to determine gender distribution amongst both groups. Unpaired t-test was used for intergroup comparison of mean BAR and PAR ratios of C3 and C4 vertebrae. P value of <0.05 was set with α error of 5% and confidence interval of 95%.

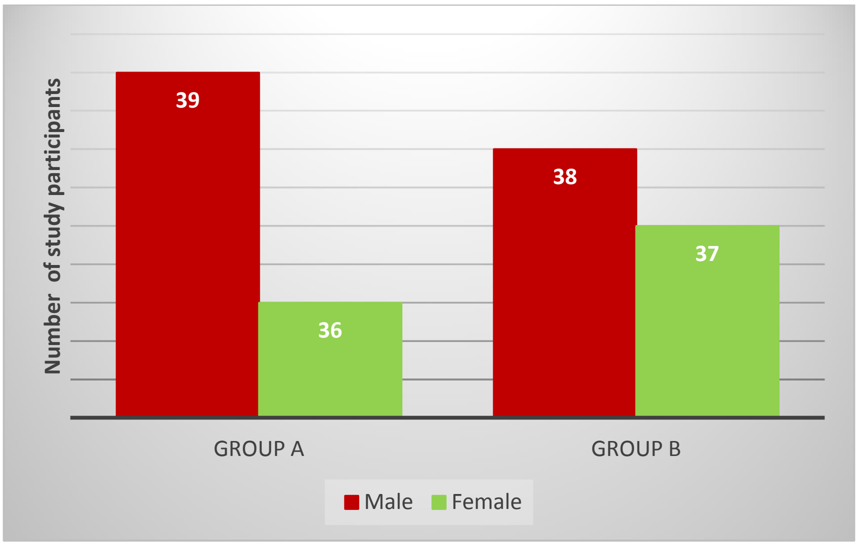
Results

The gender difference in the distribution of CVMI stages in both the groups was statistically insignificant as shown in Table I and Graph no. 1.

Table I: Frequency distribution of study participants according to Gender in Class II and Class III groups

Groups	Gender	Frequency (n)	Percent (%)	P value
Class II	Male	39	52.0	0.914
	Female	36	48.0	
Class III	Male	38	50.6	0.899
	Female	37	49.3	

Graph no. 1: Gender distribution of study participants in both groups



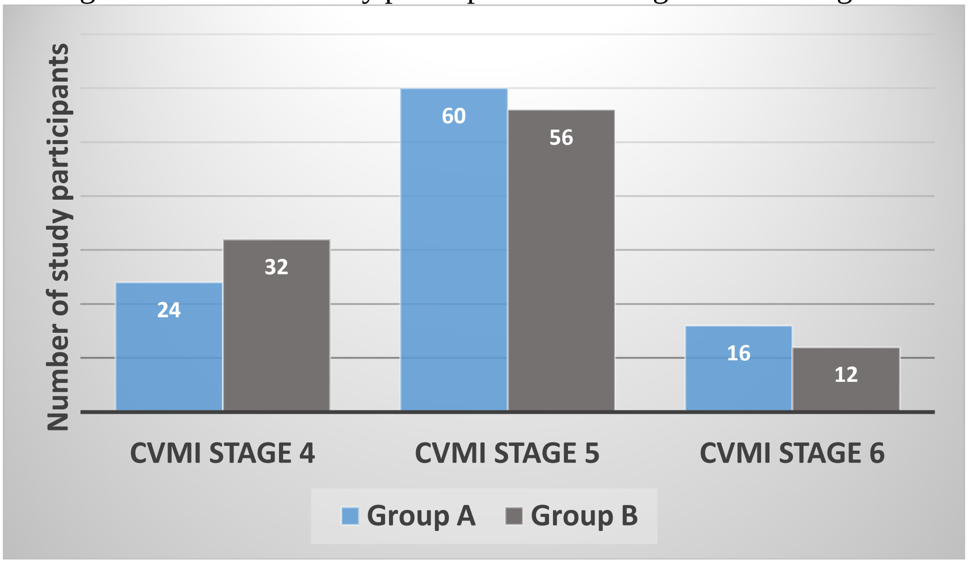
Percentage distribution of patients in various stages of CVMI by Hassel and Farman's visual method showed that out of all 150 lateral cephalograms assessed, 28% of patients showed CVMI stage 4, 58% patients showed CVMI stage 5 and only 14% patients showed CVMI stage 6 (Table II, Graph no. 2). Greater distribution of CVMI stage 4 was seen in Group B (32%) as compared to Group A (24%). CVMI stage 5 showed maximum distribution amongst all three stages for both the groups with a higher distribution in Group A (60%) as compared to Group B (56%). Least distribution was seen with CVMI stage 6 for both the groups with a higher distribution in Group A (16%) as compared to Group B (12%). The percentage distribution among both the groups was clinically significant (P = 0.018).

Table II: Frequency distribution of study participants according to Hassel Farman CVMI stages

Groups	CVMI Stage 4		CVMI Stage 5		CVMI Stage 6		P value
	n	%	n	%	n	%	
Group A	18	24	45	60	12	16	0.011*
Group B	24	32	42	56	9	12	0.026*
Total	**42**	**28**	**87**	**58**	**21**	**14**	**0.018***

*p value <0.05 statistically significant

Graph no. 2: Percentage distribution of study participants according to CVMI stages



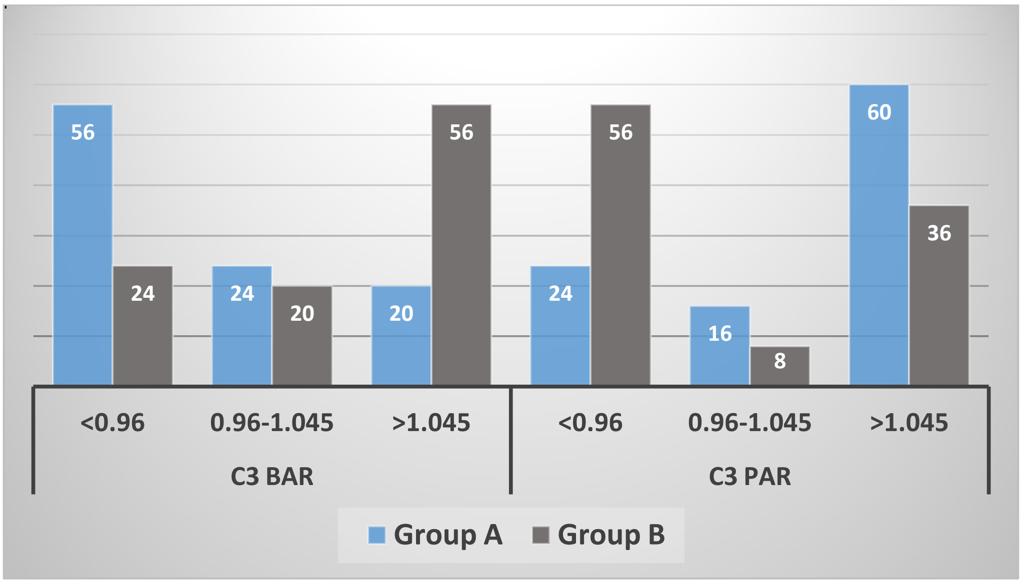
Percentage distribution of BAR and PAR ratios of C3 and C4 vertebrae for Groups A and B are shown in Table III, Graph no. 3 and 4. Considering BAR values, it was found that the maximum distribution was seen with C3 BAR < 0.96 (40%) and C4 BAR > 1.045 (42%) for C3 BAR and C4 BAR, respectively. Under PAR values, overall distribution was greatest for C3 PAR > 1.045 (48%) and C4 PAR 0.96 – 1.045 (48%) for C3 PAR and C4 PAR, respectively.

The BAR and PAR values for both C3 and C4 vertebrae were all statistically significant (P < 0.05). The distribution of C3 BAR < 0.96 was higher in Group A compared to Group B. Percentage distribution of C4 BAR > 1.045 was higher in Group B as compared to Group A. The distribution of C3 PAR > 1.045 was higher in Group A as compared to Group B. However, the distribution of C3 PAR between 0.96 and 1.045 was the least for both the groups. Lastly, C4 PAR between 0.96 and 1.045 was high for both groups with higher distribution in Group B.

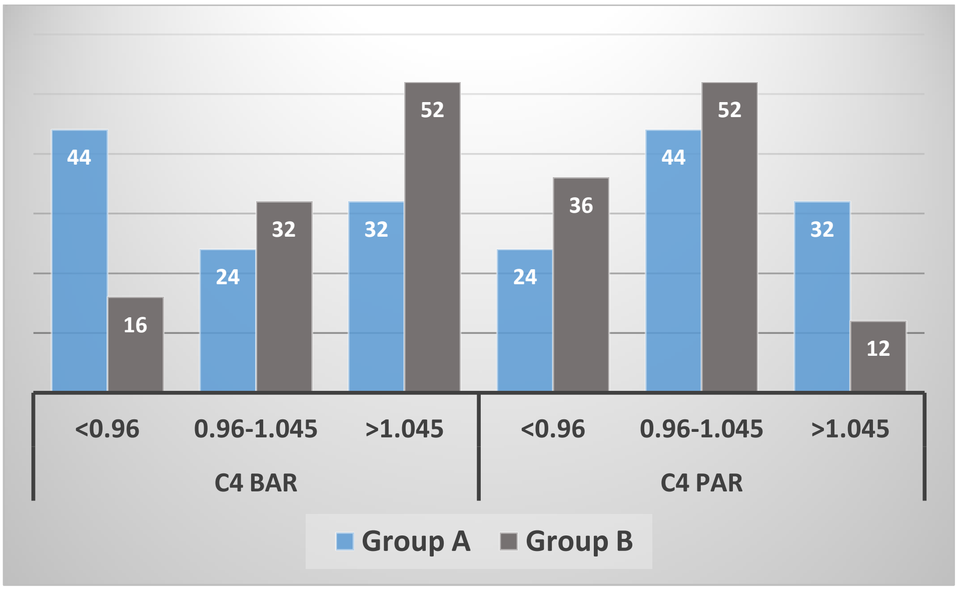
Table III: Percentage distribution of BAR and PAR ratios of C3 and C4 vertebrae

		PERCENTAGE		p VALUE
		Group A (%)	Group B (%)	
C3 BAR	**< 0.96**	56	24	0.015*
	0.96 – 1.045	24	20	
	> 1.045	20	56	
C4 BAR	**< 0.96**	44	16	0.033*
	0.96 – 1.045	24	32	
	> 1.045	32	52	
C3 PAR	**< 0.96**	24	56	0.009*
	0.96 – 1.045	16	8	
	> 1.045	60	36	
C4 PAR	**< 0.96**	24	36	0.040*
	0.96 – 1.045	44	52	
	> 1.045	32	12	

Graph no. 3: Percentage distribution of study participants according to C3 BAR and C3 PAR range in both groups



Graph no. 4: Percentage distribution of study participants according to C4 BAR and C4 PAR range in both groups

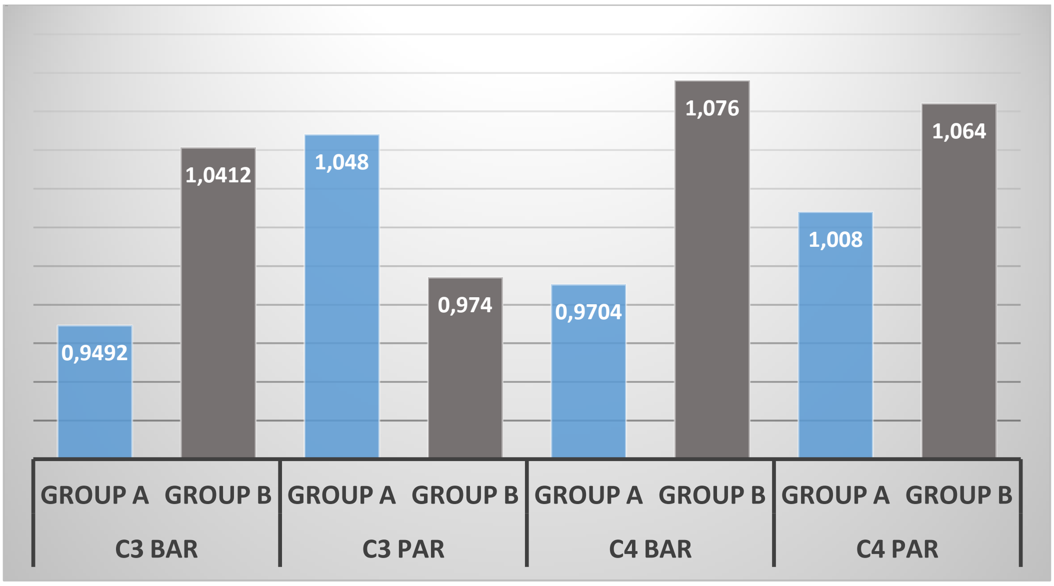


The mean ratios of C3 and C4 BAR and PAR values in both the groups were statistically significant when compared within the groups (P > 0.05) as shown in Table IV and Graph no. 5.

Table IV: Descriptive statistics of C3 and C4 BAR and PAR values in both group

	Groups	Mean	Standard Deviation	P value
C3 BAR	**GROUP A**	0.94	0.12	0.015*
	GROUP B	1.04	0.13	
C3 PAR	**GROUP A**	1.04	0.11	0.033*
	GROUP B	0.97	0.12	
C4 BAR	**GROUP A**	0.97	0.15	0.009*
	GROUP B	1.07	0.11	
C4 PAR	**GROUP A**	1.00	0.09	0.046*
	GROUP B	1.06	0.32	

Graph no. 5: Intergroup comparison of mean of C3 and C4 BAR and PAR - Unpaired t-test used – p value is statistically significant (<0.05) between both groups



Discussion

Since ages, a vast range of maturation predictors have been known to orthodontists and have gained tremendous popularity as a potent aid in treatment planning. However, these indicators are known to overestimate a child's developmental stage and consequently, underestimate growth potential[22]. On the other hand, comparing one's growth status with standard norms of different countries can also can also lead to misinterpretation. Racial variations in the relationships between skeletal maturity established by hand-wrist radiographs and cervical vertebrae were previously reported[23]. Hence, it was important to carry out a study estimating the relation between skeletal jaw bases and growth assessors in local population.

For a very long time, hand wrist radiographs were considered as a gold standard for estimation of skeletal growth. However it had certain drawbacks like extra radiation exposure as well as presence of sexual dimorphism and polymorphism[24]. This lead to the discovery of Cervical Vertebral Maturation Indicator. CVMI has been a part of a long standing debate regarding its validity and predictability, where some studies prove it to be reliable[25] while others show poor correlation of CVMI with growth prediction[16]. The reproducibility of this method has also been a topic of controversy with equivocal thoughts in both directions[26–29] with a wide range of inter-observer and intra-observer agreement[16].

Most of the literature on use of CVMI for growth assessment has emphasized its efficacy in the pubertal period i.e. when stages 3 or 4 are more prevalently seen. Seldom has there been a discussion about its use in patients whose growth phase is about to end or has ended already. In such patients, CVMI stages 5 or 6 are evident with the vertebrae appearing squarish or vertical rectangular in shape, respectively. Stage 5 represents a deceleration phase while stage 6 represents completion phase which should be expected in full grown adults.

The current study evaluated if later stages of CVMI were observed in adults having Class II or Class III skeletal jaw bases. This assessment was done using the visual method with Hassel and Farman's classifications[13] and the metric method using Baccetti's ratios[19] describing vertebral morphology. With both the methods, it was observed that CVMI stage 6 was seen in only 14% of the samples marking it to be the least prevalent, followed by stage 4 with 28%. Highest prevalence of 58% was seen with CVMI stage 5 amongst samples of Class II and III skeletal bases combined.

C3 BAR ratio < 0.96 showed greatest distribution in both groups combined suggesting that for most samples, C3 vertebrae showed increased height compared to base i.e. a vertical rectangle. The distribution of C3 PAR amongst all samples was highest for the ratio > 1.045 suggesting posterior height more than anterior height i.e. a trapezoid shape. As against that, C4 BAR ratio > 1.045 showed highest distribution in both groups combined indicating C4 vertebrae for most samples had height shorter than the base i.e. a horizontal rectangle. C4 PAR ratio between 0.96 and 1.045 indicated equal posterior and anterior heights that is a square shaped vertebrae. This inferred that C3 vertebrae showed more maturity than C4 vertebrae in all individuals.

A similar study by Baccetti et al(2) suggested that the body of C3 was square in 50% cases and a vertical rectangle in 50% cases, whereas C4 body was found square in 53% cases whereas it was a vertical rectangle in the remaining 47% cases. However, in this study, maturity was assessed only at two points of time post puberty and further follow up was also not done. It also said that the ideal time for correction of Class II skeletal malocclusion was at the peak of puberty whereas Class III skeletal malocclusion correction should be commenced in the pre pubertal phase.

Within the groups, there was 14% distribution of CVMI stage 6 with a greater distribution in Group A compared to Group B. Stage 5 had the greatest distribution of 58% with an increased distribution in Group A as well. Lastly, stage 4 showed 28% distribution with a higher distribution in Group B. This inferred that stages 5 and 6 were seen more commonly in Class II cases as compared to stage 4 which was more prevalent in Class III subjects.

C3 BAR and C4 BAR ratio of < 0.96 was significantly greater in Group A whereas a ratio of > 1.045 was significantly greater in Group B. This indicated that maximum subjects with Class II jaw bases showed vertical rectangular shaped or more matured C3 and C4 bodies, but maximum subjects with Class III jaw bases showed horizontal rectangular shaped or less matured C3 and C4 bodies.C3 PAR ratio between 0.96 and 1.045 was significantly the least for both groups indicating that both groups had trapezoid shaped C3 bodies. However, C4 PAR ratio between 0.96 and 1.045 was significantly greater for both groups suggesting the anterior and posterior heights of C4 body were equal. Another study by S Padmanabhan et al(16) found that with C3 and C4 vertebral bodies being more matured in Class III skeletal cases as compared to Class II. The reason for this contradiction can be attributed to a difference in demography of the subjects involved in the study.

It can be observed that different CVMI stages are seen more predominantly in different skeletal bases, suggesting that various skeletal cases mature at their own individual pace questioning the reliability of this method. Also, while all adults were expected to show CVMI stage 6, most showed earlier stages of skeletal maturation compared to their chronological age. These issues can cause potential ambiguity in deciding if a post pubertal patient has ceased to grow and is fit to undergo orthognathic surgery. A chronologically adult patient with a CVMI stage 4 or 5 suggests presence of some residual growth, which can alter a surgically corrected maxilla mandibular relation in sagittal, vertical or transverse direction over the course of time. This can jeopardize the functional efficiency and aesthetic balance of patient’s hard and soft tissues(16,30). This study had subjects with a mean age of22.76, which is years after puberty ends. Hence, presence of CVMI stages 4 or 5 suggests in these subjects directs towards lack of consistency.

This study had certain limitations. Firstly, use of only CVMI for skeletal maturity assessment cannot give us a complete picture of maturation levels in patients with different skeletal jaw bases. Hence, a combination of other skeletal as well as non-skeletal methods along with clinical correlation should be used to get a superior judgement of levels of maturation amongst all patients. Further studies must be carried out with a long follow up of patients throughout their entire period of growth to study skeletal growth even better, and to efficiently assess variations in various skeletal patterns.

Conclusions

1) The reliability of CVMI for skeletal age assessment is ambiguous, hence it should be used carefully and in accompaniment of other available methods.
2) Adult population showed the least prevalence of CVMI stage 6.
3) Remarkable variation was seen in levels of maturation amongst different skeletal bases.
4) There is an increased prevalence of higher degree of maturation in individuals with skeletal Class II jaw bases as compared to individuals with skeletal Class III jaw bases.

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