ORIGINAL ARTICLE

Effectiveness of the cervical vertebral maturation method to predict postpeak circumpubertal growth of craniofacial structures

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Introduction: Our aim was to assess effectiveness of the cervical vertebral maturation (CVM) method to predict circumpubertal craniofacial growth in the postpeak period. **Methods:** The CVM stage was determined in 176 subjects (51 adolescent boys and 125 adolescent girls) on cephalograms taken at the end of treatment (T2; mean ages, 15.75 years [boys] and 15.23 years [girls]) in subjects from the postretention database at the University of Washington in Seattle. Craniofacial growth was evaluated from the following measurements on cephalograms at T2 and end of follow-up (T3) (mean ages, 29.01 years [men] and 28.08 years [women]): condylion to gnathion, condylion to gonion, gonion to gnathion, sella to gnathion, nasion to menton, anterior nasal spine to menton, and sella to gonion. The change of each variable from T2 to T3 was assessed with paired *t* tests. Parametric (*t* tests or analysis of variance [ANOVA]) or nonparametric (Mann-Whitney or Kruskal-Wallis) tests were used to detect intergroup differences. **Results:** One hundred eight subjects (35 boys, 73 girls) demonstrated CVM stage 3, 56 (16 boys, 40 girls) were in CVM stage 4, and 12 (all girls) were in CVM stage 5 at T2. Intrasex comparisons showed that boys in CVM stages 3 and 4 could be differentiated regarding changes of all variables. In the girls, only those in CVM stages 3 and 4 could be differentiated based on the amount of changes of 2 measurements: condylion to gonion and sella to gonion. Intersex comparisons showed that boys in CVM stage 3 had significantly more changes than girls ($P < 0.01$). Boys in CVM stage 4 showed significant differences compared with girls in CVM stage 4 for only 2 variables (sella to gonion and condylion to gonion; $P < 0.001$ and $P = 0.012$, respectively). **Conclusions:** The CVM method was modestly effective in determining the amount of postpeak circumpubertal craniofacial growth. (Am J Orthod Dentofacial Orthop 2010;137:59-65)

Data from randomized, controlled clinical studies on Class II treatment suggested that skeletal effects with various protocols carried out in prepubertal children are of minor importance in the correction of Class II molar relationships.[1-3] However, the frequently observed improvement of a profile during treatment is directly related to the size or the position of the mandible. Findings of the investigations that aimed to elucidate this disparity implied that, when treatment of Class II malocclusion starts just before the pubertal growth spurt, skeletal effects are larger and lasting compared with treatment completed before the circumpubertal growth peak.[4,5] Cozza et al[6] in their systematic review found that the amount of supplementary mandibular growth appeared to be significantly larger if the functional treatment was performed at the pubertal peak in skeletal growth. Baccetti et al[5] compared mandibular morphology in patients treated early vs late and concluded that the optimal timing for Twin-block therapy for a Class II disharmony was during or slightly after the pubertal peak in growth velocity.

On the contrary, treatment of some orthodontic problems necessitates little or no craniofacial growth. A planned camouflage in Class III subjects will be successful if facial growth is complete. If the mandible outgrows the maxilla during treatment, achievement of stable correction is questionable. In children with congenitally missing lateral incisors, an implant-based restoration is often the method of choice. Since implants behave like ankylosed teeth,[7,8] early implantation could lead to submergence of the implant crown and cause an esthetic disaster.[9] Coming of age is often recommended as the suitable time to start treatment. Nevertheless, chronologic age was shown to be poorly correlated with development.[10] Cessation of craniofacial growth in early maturers is probably complete a few years

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earlier than in late maturers.[11] Consequently, starting treatment according to chronologic age irrespective of the patient's maturity is not always appropriate.

Among methods for assessment of craniofacial maturity, the cervical vertebral maturation (CVM) method has recently gained popularity because of its ease and postulated accuracy.[12-14] The most frequently used modification of the CVM method[15-18] was based on the cephalometric analyses of longitudinal records of 9 boys and 15 girls.[14] Through discriminant analysis, several CVM stages were established that were intended to correspond to skeletal maturity and, hence, future facial growth. Although an objective of the CVM method is to predict the peak velocity of growth, it should indirectly point to how much postpeak growth change is expected. However, the small sample size used to devise the CVM method and the lack of validation raise doubts about its effectiveness, especially in the later stages of development when growth tapers off.[14] These reservations are supported by the findings of Baccetti et al,[18] who examined growth changes in a cross-sectional sample of 1091 Class III subjects and found that the CVM method detected between-stage growth alterations only in approximately 25% of the performed measurements. Moreover, some children go through a prolonged period of accelerated growth without a distinct growth peak.[11] It is unclear whether the CVM method can be an effective predictor in these subjects.

Therefore, our aim in this study was to assess the effectiveness of the CVM method to predict circumpubertal craniofacial growth in the postpeak period.

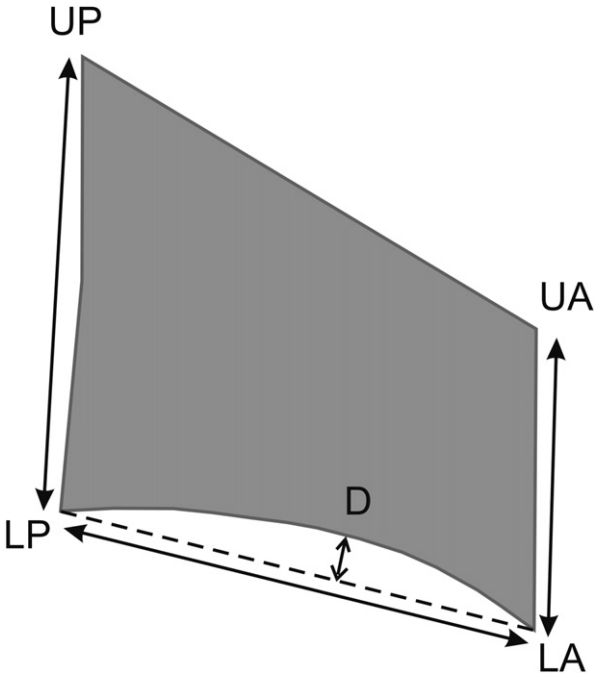

Fig 1. Schematic representation of landmarks identified and traced on the cervical vertebral body: *LP, D,* and *LA,* the most posterior, deepest, and most anterior points on the lower border of the body of C2, C3, or C4; *UP* and *UA,* the most superior points of the posterior and anterior borders of the body of C3 or C4; *Conc,* distance from the line connecting and LA to D on the lower border of C2, C3, or C4. Calculations: BAR, the ratio between the length of the base (LP-LA) and the anterior height (UA-LA) of the body of C3 or C4; and PAR, the ratio between the posterior (UP-LP) and anterior (UA-LA) heights of the body of C3 or C4.

MATERIAL AND METHODS

A sample from a study on incisor stability was used in this investigation;[19] 83.7% of the subjects from the original sample comprising 301 subjects from the postretention collection in the Department of Orthodontics at the University of Washington in Seattle had their CVM status established. Only those with a CVM status that met the following supplementary inclusion criteria were chosen: good-quality lateral cephalograms made at the end of orthodontic treatment (T2) and at least 10 years out of retention (T3), no orthognathic surgery, and no additional orthodontic treatment between T2 and T3. The enlargement factor of most cephalograms could not be determined, so, to minimize the influence of enlargement, only subjects with cephalograms taken at T2 and T3 in the same cephalostat were finally included.

The length of follow-up was calculated by subtracting the T2 date from the T3 date. Patient information and treatment history for all subjects were obtained from the database. Age at the end of treatment and sex were recorded.

Lateral cephalograms taken at T2 were used to determine the CVM stage. The assignment of the CVM stages is described elsewhere.[19] To summarize, on each cephalogram, the second, third, and fourth cervical vertebrae (C2, C3, and C4) were identified. The landmarks and measurements we used are presented in Figure 1. The CVM stages are shown in Table I.

Craniofacial growth was evaluated on lateral cephalograms taken at T2 and T3. The landmarks identified and the measurements made according to the study that described the CVM method are given in Figure 2.[14]

Statistical analysis

Descriptive statistics (means and standard deviations) were computed for age and length of follow-up in each

Table I. Classifications of CVM stages according to the shape of the bodies of C2, C3, and C4

CVM stage	*Vertebral body shape*
1	C3 and C4 flat
2	C3 concavity ≥1 mm; C4 flat
3	C2, C3, and C4 concavity ≥1 mm; C3 and/or C4 tapered or horizontal rectangular
4	C3 and/or C4 square; if C3 or C4 are not square, then horizontal rectangular
5	C3 and/or C4 vertical rectangular

Flat: concavity <1 mm.
Tapered: C3 UP-C3 LP (or C4 UP-C4 LP) to C3 UA-C3 LA (or C4 UA-C4 LA) ratio (PAR) >1.20.
Square: C3 UP-C3 LP (or C4 UP-C4 LP) to C3 UA-C3 LA (or C4 UA-C4 LA) ratio (PAR) of 0.80-1.20; C3 LA-C3 LP (or C4 LA-C4 LP) to C3 UA-C3 LA (or C4 UA-C4 LA) ratio (BAR) of 0.85-1.15.
Horizontal rectangular: C3 LA-C3 LP (or C4 LA-C4 LP) to C3 UA-C3 LA (or C4 UA-C4 LA) ratio (BAR) >1.15.
Vertical rectangular: C3 LA-C3 LP (or C4 LA-C4 LP) to C3 UA-C3 LA (or C4 UA-C4 LA) ratio (BAR) <0.85.

CVM group. For the craniofacial measurements, means, standard deviations, and 95% confidence intervals were calculated.

Paired *t* tests were used to assess craniofacial growth in each group. Shapiro-Wilks tests were used to evaluate normality of distribution in each group. In case of normal distribution, independent *t* tests or analysis of variance (ANOVA) were run. If distribution was not normal, nonparametric tests, Mann-Whitney for 2-group comparisons or Kruskal-Wallis for 3-group comparisons, were carried out. The Dunn multiple comparison procedure with the Bonferroni adjustment was used for intergroup differences.

At $P < 0.05$, the difference was considered significant. At $P < 0.1$, the difference was considered marginally significant.

The reproducibility of the measurements was assessed by statistically analyzing the difference between double measurements taken 1 week apart on 25 cephalograms selected at random. The error of the method was calculated from the equation:

$$S_X = \sqrt{\frac{\sum D^2}{2N}}$$

with *D* representing the difference between the corresponding first and second measurements and *N* the number of double determinations.

Intraobserver agreement for the CVM stage assignment was calculated as the Pearson correlation coefficient and proportionally weighted kappa coefficient based on 2 assignment sessions a week apart.

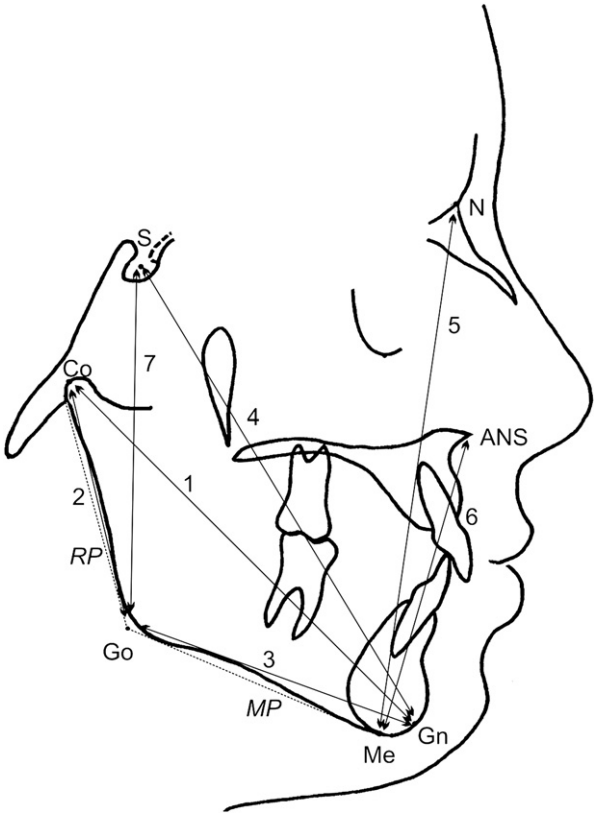

Fig 2. Craniofacial measurements: *1,* mandibular length (Co-Gn); *2,* posterior ramus height (Co-Go); *3,* mandibular body length (Go-Gn); *4,* sella to gnathion distance (S-Gn); *5,* anterior facial height (N-Me); *6,* lower anterior facial height (ANS-Me); *7,* posterior facial height (S-Go). Gonion (Go) is located at the intersection of the mandibular (MP) and ramus (RP) planes.

RESULTS

A total of 252 subjects were initially identified; 61 were excluded for lack of good-quality cephalograms taken in the same cephalostat at T2 and T3, and 15 of the remaining 191 subjects were in CVM stages 1 and 2 (7 and 8 children, respectively), indicating prepubertal development, and were excluded. The final sample included 176 subjects: 29% male and 71% female. The sample characteristics are presented in Table II.

Boys in the CVM stage 3 group were older than the girls in the same stage at the beginning of follow-up by 0.72 years; the difference was significant ($P = 0.017$). No intersex difference was found regarding age in the CVM stage 4 group ($P = 0.412$).

Age at the start of follow-up was similar in boys in CVM stages 3 and 4 ($P = 0.589$). Analogous comparisons in girls showed difference between CVM stages 3

Table II. Age at the beginning and length of follow-up in groups in various CVM stages

	Males					*Females*					*Males + females*				
		Age (y)		*Follow-up length (y)*			*Age (y)*		*Follow-up length (y)*			*Age (y)*		*Follow-up length (y)*	
CVM stage	*n*	*Mean*	*SD*	*Mean*	*SD*	*n*	*Mean*	*SD*	*Mean*	*SD*	*n*	*Mean*	*SD*	*Mean*	*SD*
3	35	15.68	1.29	13.31	4.60	73	14.96	1.52	12.92	4.06	108	Not pooled*		13.05	4.23
4	16	15.92	1.07	12.31	5.29	40	15.62	1.25	12.73	2.99	56	15.71	1.20	12.60	3.76
5	0	–	–	–	–	12	15.55	1.20	12.83	4.28	12	15.55	1.20	12.83	4.28
	51	$P = 0.589$		$P = 0.924$		125	$P = 0.016^{\dagger}$		$P = 0.970$		176			$P = 0.996$	

*Ages for boys and girls in CVM stage 3 were significantly different ($P = 0.017$); †Dunn multiple comparison tests with the Bonferroni adjustment showed statistically significant differences in age between the CVM stages 3 vs 4 groups.

Table III. Error of measurements

Variable	*Error*	*Variable*	*Error*
Co-Gn	1.40	C2 Conc	0.33
Co-Go	2.14	C3 Conc	0.30
Go-Gn	0.52	C4 Conc	0.28
S-Gn	0.67	C3 PAR	0.05
N-Me	0.69	C3 BAR	0.07
ANS-Me	0.74	C4 PAR	0.09
S-Go	0.71	C4 BAR	0.07

Conc, distance from the line connecting and LA to D on the lower border of C2, C3, or C4. Calculations: *BAR,* the ratio between the length of the base (LP-LA) and the anterior height (UA-LA) of the body of C3 or C4; *PAR,* the ratio between the posterior (UP-LP) and anterior (UA-LA) heights of the body of C3 or C4.

and 4 ($P = 0.016$). No differences between the CVM stages 3 and 5 groups, and the CVM stages 4 and 5 groups were found.

The length of follow-up in the various CVM groups did not differ in the sexes ($P = 0.924$ and 0.970, respectively) and approximated 13.0 years.

Error of the method is shown in Table III. For most variables, errors did not exceed 0.75 mm. Condylion to gonion and condylion to gnathion had errors in excess of 1 mm (2.14 and 1.40 mm, respectively).

The Pearson correlation coefficient between the first and second assignments of CVM stages in 25 subjects was 0.67 (95% CI = 0.39-0.84; $r^2 = 0.45$), and the weighted kappa coefficient was 0.55.

During follow-up, most variables showed significant changes at $P < 0.01$ (Table IV). However, mandibular length (Co-Gn) increased in the male CVM stage 4 group by 2.25 mm ($P = 0.015$), and 2 variables, anterior facial height (N-Me) and lower anterior facial height (ANS-Me) in males in CVM stage 4, had marginally significant differences ($P = 0.096$ and 0.060, respectively). All measured structures in females showed statistically significant changes ($P < 0.01$) during the follow-up.

Comparison between males in various CVM stages showed that craniofacial structures in the CVM stage 3 group grew significantly more than in the CVM stage 4 group. Length of the mandible (Co-Gn) increased by 5 mm more in the CVM stage 3 compared with the CVM stage 4 group ($P < 0.001$). Also, posterior ramus height (Co-Go), sella-gnathion distance, and posterior facial height (S-Go) increased in the CVM stage 3 boys by more than 4 mm than in the CVM stage 4 group ($P < 0.01$). The least difference between male groups—1.7 mm—was observed for lower anterior facial height (ANS-Me) ($P = 0.038$).

Females in various CVM stages demonstrated only a few significant differences. Although most craniofacial variables increased more in the CVM stage 3 than in the CVM stage 4 or 5 group, the only statistically significant differences between the CVM stages 3 and 4 groups were posterior ramus height (Co-Go) and posterior facial height (S-Go) ($P = 0.016$ and 0.021, respectively). No difference was found between females in the CVM stage 3 vs 5, or CVM stage 4 vs 5.

When males and females in the same CVM stage were compared, a few significant distinctions were found (Table V). All measured craniofacial structures in boys from the CVM stage 3 group increased at least twice as much as in the girls in the same CVM stage ($P = 0.002$ for lower anterior facial height [ANS-Me] and $P < 0.001$ for the remaining variables). Fewer differences were observed between the CVM stage 4 boys and girls. Only posterior ramus height (Co-Go) and posterior facial height (S-Go) differed significantly between the sexes ($P = 0.012$ and < 0.001, respectively).

DISCUSSION

The observation that cervical vertebrae undergo consistent morphologic changes during growth led to the development of a method relating the vertebral alterations to craniofacial growth. Originally, the CVM

Table IV. Intrasex comparisons of the variables during follow-up in subjects in various CVM stages

		Co-Gn			*Co-Go*			*Go-Gn*			*S-Gn*		
	CVM stage	*Mean*	*SD*	*95% CI*	*Mean*	*SD*	*95% CI*	*Mean*	*SD*	*95% CI*	*Mean*	*SD*	*95% CI*
Males	3	7.26	6.02	5.19-9.32	7.89	4.89	6.21-9.56	4.54	3.85	3.22-5.87	7.34	5.48	5.46-9.27
	4	2.25	3.30	0.49-4.01	3.75	2.67	2.33-5.17	2.38	2.13	1.24-3.51	2.94	3.47	1.09-4.79
			P <0.001			P = 0.003			P = 0.041			P = 0.005	
Females	3	3.16	2.91	2.49-3.84	3.08	2.60	2.48-3.69	2.26	2.28	1.73-2.79	2.73	2.39	2.17-3.28
	4	1.85	2.76	0.97-2.73	1.60	2.84	0.69-2.51	1.78	1.62	1.26-2.29	1.65	1.75	1.09-2.21
	5	3.00	2.70	1.29-4.71	3.08	3.12	1.10-5.06	2.08	1.38	1.21-2.96	2.42	2.43	0.87-3.96
			P = 0.063			P = 0.016; 3 vs 4			P = 0.530			P = 0.057	

		N-Me			*ANS-Me*			*S-Go*		
	CVM stage	*Mean*	*SD*	*95% CI*	*Mean*	*SD*	*95% CI*	*Mean*	*SD*	*95% CI*
Males	3	4.77	4.15	3.35-6.20	2.51	2.98	1.49-3.54	8.48	4.74	6.83-10.09
	4	1.25	2.82	–0.25-2.75	0.81	1.60	–0.04-1.67	4.38	2.92	2.82-5.93
			P = 0.003			P = 0.038			P = 0.002	
Females	3	2.41	2.60	1.80-3.02	1.07	1.81	0.65-1.49	2.84	2.38	2.28-3.39
	4	1.90	1.97	1.27-2.53	1.08	1.53	0.59-1.56	1.55	1.87	0.30-0.95
	5	2.50	2.20	1.11-3.89	2.17	2.33	0.69-3.65	2.50	2.68	0.80-4.20
			P = 0.503			P = 0.174			P = 0.021; 3 vs 4	

Follow-up was the time from T2 (end-of-treatment records) to T3 (long-term out-of-retention records).

Table V. Intersex comparison of the measured variables during follow-up

CVM stage		*Co-Gn*	*Co-Go*	*Go-Gn*	*S-Gn*	*N-Me*	*ANS-Me*	*S-Go*
3	Male	7.26	7.89	4.54	7.34	4.77	2.51	8.46
	Female	3.16	3.08	2.26	2.73	2.41	1.07	2.84
	Difference (male – female)	4.10‡	4.81‡	2.28‡	4.61‡	2.36‡	1.44†	5.62‡
	P	0.000	0.000	0.000	0.000	0.000	0.002	0.000
4	Male	2.25	3.75	2.38	2.94	1.25	0.81	4.38
	Female	1.85	1.60	1.78	1.65	1.90	1.08	1.55
	Difference (male – female)	0.40	2.15*	0.60	1.29	–0.65	–0.27	2.83‡
	P	0.645	0.012	0.259	0.070	0.331	0.569	0.000

Follow-up was the time from T2 (end-of-treatment records) to T3 (long-term out-of-retention records).
*Statistically significant at P = 0.05; †P = 0.01; ‡P = 0.001.

method distinguished 6 stages that corresponded to different developmental phases. A recent modification limited the number of stages to 5: from CVM stage 1 indicating that a peak of craniofacial growth will occur not earlier than 1 year after this stage, to CVM stage 5 indicating that a growth spurt occurred at least 2 years before this stage.[20] A growth peak, according to this method, should occur between the second and third stages in 95% of adolescents. Hassel and Farman[13] stated that 65% to 85% of adolescent growth is expected in a child in CVM stage 1, as opposed to 5% to 10% of growth in a stage 4 person. A person in CVM stage 5 should demonstrate little to no craniofacial growth.

Our findings suggest that the CVM method is only modestly effective in discriminating between subjects with various amounts of circumpubertal craniofacial growth in the later stages of development. Although a focus of the CVM method is prediction of the pubertal growth peak, the assumption that adolescents at a more advanced CVM stage will grow less seems to be valid. However, the CVM method could differentiate between boys in only CVM stages 3 and 4 of development. The detection ability of the CVM method in girls was much poorer. Of the 7 craniofacial variables measured, only 2 (posterior ramus height and posterior facial height) were discriminating for girls between CVM stages 3 and 4, and the levels of statistical significance (P = 0.016 and 0.021, respectively) were not high. Moreover, the CVM stages 4 and 5 did not predict different amounts of craniofacial growth. These findings generally agree with the results of Franchi et al,[14] who reported average changes of craniofacial structures during transition from lower to higher CVM stages. Mandibular length (Co-Gn) increased accordingly from CVM stages 4 to 5

(equivalent to passage from CVM stages 3 to 4 in this study, since they used the CVM stages 1 to 6 scale) by about 2.9 mm in a pooled sample of 9 boys and 15 girls ($P < 0.05$). Elongation amounts of the mandible (Co-Gn) in males and females between the corresponding stages in our study were 5.01 and 1.31 mm, respectively, and the change was statistically significant only in males. The disparity of absolute values of mandibular length increase between our findings and those of Franchi et al[14] most likely results from a longer observation period in this investigation: 13.1 years rather than about 1.5 years. Also, pooling the data for both sexes might have influenced the results.

Intersex comparisons demonstrated significant differences regarding all measured parameters solely in CVM stage 3. Mandibular length (Co-Gn), as well as other variables, increased at least twice as much in males than females during follow-up. In CVM stage 4, 2 variables—posterior ramus height (Co-Go) and posterior facial height (S-Go)—increased significantly more in male subjects compared with females. These findings suggest that the data of the sexes should not be combined when the aim is to present mean changes of particular variables over time. Perhaps, if the data for males and females had been separated by Franchi et al,[14] a statistically significant change of mandibular length between CVM stages 3 and 4 would have been found only for boys.

Surprisingly, chronologic ages in the CVM stages 3, 4, and 5 groups were similar and equaled about 15 years for both sexes. Only girls in CVM stage 3 and 4 showed a significant difference of approximately 7 months. This similarity can be explained by large variations in chronologic ages for each CVM stage. Possibly, more subjects in the groups would allow detection of more differences. Our results partially confirm the findings of Hassel and Farman,[13] who attempted to correlate 2 methods of assessment of skeletal maturity: the hand-wrist evaluation[21] and the CVM. They indirectly reported the ages of boys in CVM stages 3 and 4 to be 14.8 and 15.8 years, respectively. Girls in the analogous CVM stages, however, were approximately 1.3 to 2 years younger when compared with our group. The disagreement between the findings of Hassel and Farman and ours might be because they did not give directly the age of the subject with the same CVM stage, but reported what stage of the skeletal maturity index of Fishman[21] corresponded to the appropriate CVM stage. Thus, the subjects' ages might be only indirectly obtained from Fishman's study. However, correlation between the CVM and the skeletal maturity index methods, although high ($r^2 = 0.89$), was not perfect. Subjects in CVM stages 3 and 4 in the samples of Franchi et al[14] and Baccetti et al[20] were 2 to 3 years younger than were our subjects. The possible explanation for the disagreement is the small sample sizes in those studies, especially when the distinctiveness of the sexes is considered.

The difficulty in assigning CVM stage 3, 4, or 5 to a subject might also explain the lack of substantial differences in age at the postpeak CVM stages. CVM stages 1 and 2 are not difficult to distinguish, since an easily recognizable concavity at the lower border of C2 or C3 differentiates them from more advanced stages. As Baccetti et al[20] recommended, CVM stage 3 is recognized when "concavities at the lower borders of C2, C3, and C4 are present, and the bodies of both C3 and C4 are rectangular horizontal in shape." In case of conflict between the CVM staging assumptions—eg, lack of concavity at the base of C4 and the rectangular horizontal shape of C3 and C4 in some subjects in our sample—assigning the CVM stage is problematic. Similarly, CVM stage 4 should be characterized by the square shape of at least 1 body of C3 and C4. If not square, the body of the other cervical vertebra still ought to be rectangular horizontal.[20] By definition, a square shape is equal length and height of the vertebral body. The application of such a strict criterion does not seem right for at least 2 reasons: error of the method should be considered, and positional changes of the cervical vertebral column are possible during cephalometric x-ray exposure. Instead, an arbitrarily set border of what is considered square must be applied. So, the difference between horizontally rectangular, square, and vertically rectangular depend on the researcher's arbitrary decisions.

Ideally, to assess the ability of the CVM method to detect craniofacial growth alterations in CVM stages 3 through 5, the longitudinal records taken annually until the age of 18 to 20 on large samples of both sexes should be evaluated. The availability of such records is limited. Baccetti et al[20] found only 18 boys and 12 girls with records 3 years before and 3 years after the pubertal growth peak of the 706 subjects with records at the University of Michigan. Hassel and Farman[13] and San Roman et al[22] used cross-sectional samples. We attempted to use longitudinal posttreatment lateral headfilms to find an association between craniofacial growth and CVM stage. A weakness of this mixed longitudinal study design is the unknown amount of late postadolescent growth. According to many investigations, late growth changes, however, are small.[23-27] To additionally restrict the influence of late growth alterations, groups with various CVM stages had similar follow-up times.

When craniofacial growth is assessed on the postorthodontic sample, the influence of posttreatment rebound is difficult to measure. Driscoll-Gilliland et al[28]

attempted to examine the difference between craniofacial growth in untreated and treated subjects. They evaluated craniofacial growth in untreated (ages, 14.3-23.2 years) and treated subjects (ages, 15.2-28.9 years) and found that facial growth continued during follow-up. They demonstrated that both skeletal and dental changes were similar in both groups, and the few statistically significant differences between groups were small.

A possible shortcoming of this study was that enlargement of each cephalogram could not be entirely controlled. Visual inspection and subsequent exclusion of the images taken in different cephalostats were probably only partially effective. Also, including subjects with various malocclusions might have affected the results.

CONCLUSIONS

1. The CVM method was only modestly effective in detecting the amount of postpeak circumpubertal craniofacial growth.
2. The CVM method discriminated only CVM stage 3 from CVM stage 4 in boys for all measured variables.
3. The ages of the boys and girls in various CVM stages were about 15 years and 1 to 2 years older than the ages reported in other studies.

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