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The Cervical Vertebrae Maturation Stage Method

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Abstract: *Determining growth stage for effective implementation of certain orthopedic treatment modalities is paramount; further determining if there is residual growth in a prospective patient is of equal importance. Surprisingly, many orthodontic clinicians lack sufficient knowledge in this area to confidently implement certain aspects of orthodontic treatment, consequently carrying out many treatment modalities in an untimely and ineffective manner. Age, dental development, sexual maturation or increases in height are all means that have been used to determine stages of skeletal development. However, a more predictable and reliable method for helping establish skeletal maturity is the CVMS (Cervical Vertebrae Maturation Stage) Method. This article will try to help determine the stage of skeletal maturity using the CVMS method since using it may also help determine the best timing for maxillo-mandibular orthopedic treatment.*

Keywords: skeletal maturity, dental age, chronological age, growth.

Chronologic age is a poor predictor of skeletal development: relying on it to implement orthodontic treatment is not recommended.[13,19] Since dental development, sexual maturation or increases in height are particular to the individual patient, orthodontic treatment planning needs to have a more reliable method for assessing skeletal maturity and growth stage. It has been well documented that during growth and development all bones in the body undergo a predictable sequence of morphologic changes, in particular, the seven cervical vertebrae. The first two vertebrae, Atlas and Axis have their own particular anatomic appearance, the rest C3-C7 have morphologic similarities.[2]

The CVMS Method has been established as reliable as the Hand Wrist Method for evaluation of growth stage of skeletal development.[1,5,13,19,16,24,10,18,15,12,6,11,2] The additional benefit of the CVMS Method is that this valuable information can be drawn from the single cephalometric radiograph which is a normal part of the basic pre-treatment orthodontic record; thus avoiding any further exposure to ionizing radiation to a prospective growing patient.[19,9,7] Further, the hand-wrist method requires identifying complex landmarks that have led to inaccurate predictions.[16] The above reasons, in this author's view, make the hand-wrist method for assessing skeletal maturity a practice of the past.

The CVMS is a systematic method of evaluating the maturational changes in cervical vertebrae with regard to skeletal growth and appears to be first attributed to Lamparski's thesis in 1972. This thesis is an atlas of vertebral age related maturational/ morphologic changes. It demonstrated that the human vertebra undergo consistent predictable developmental changes in their morphology.[1] The more salient consistent changes that have been well documented,[1,10] are the development of a concavity on the lower border, change from wedge shape to rectangular and increase in vertebral height as the patient matures.[7]

Of all of the anatomic changes, starting with C2, the progressive development of a concavity on lower borders of the cervical vertebrae is where the clinician should first focus; generally the deeper the concavity of CV2-CV4 the greater the maturation stage.[7] Therefore, the first part ofthe CVMS technique is to look for the presence or absence of curvature in the lower border of C2-C4 to determine the stage of development. For example, if curvature is present on CV2 but not on CV3 then patient is in a CVS 2 Stage of development. Presence of curvature on CV3 would correspondingly suggest that this patient is in the third stage of development.

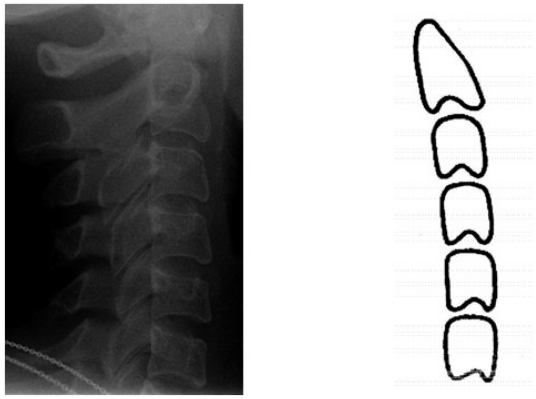
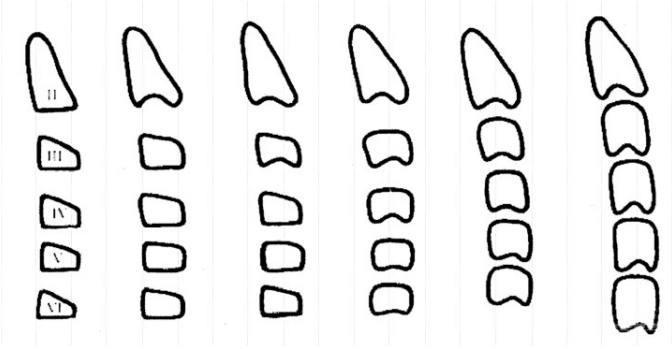


Figure 1 (Cephalometric radiograph of a mature individual, C2-C6 visible).

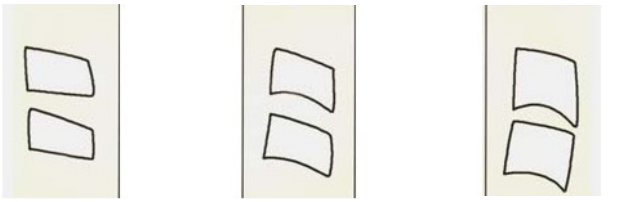
The original CVM method encompassed six stages of development (CVS 1-6), but recently[21] has been revised to only five stages; basically CVS1 and CVS2 have been combined since it's difficult to effectively tell these stages apart.



CVS 1 CVS2 CVS3 CVS 4 CVS5 CVS6

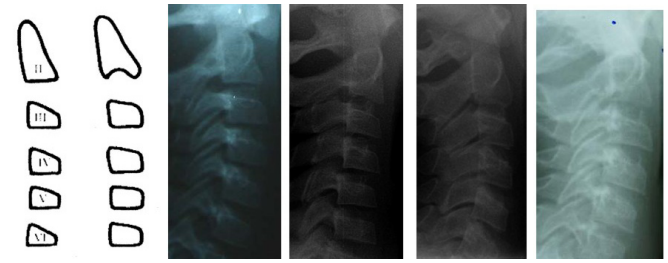
The diagram that follows graphically demonstrates the developmental morphologic changes in CV3 and CV4 from early stage to peak development to maturity. This method of evaluating has been simplified to evaluate the morphologic changes in these two vertebrae only, CV2 is difficult to measure and it shows little change and CV5-7 usually are not seen due to the thyroid collar and also that the last two vertebrae are difficult to image.[23] Therefore, skeletal maturation stage can be established by simply evaluating CV3-CV4.[5] The second important aspect of the CVMS technique is to focus on the general shape of the vertebrae; that is from "wedge" to "rectangular" to "square."

Figure 2: (CV3 and CV4)



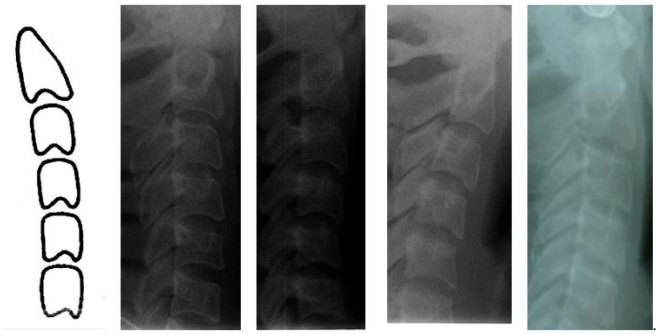
PRE-PUBERTAL ("wedge") GROWTH PEAK ("rectangular") POST-PEAK ("square")

CVMS I: Refers to a stage of development where all three vertebrae (CV2, 3 and 4) have FLAT lower borders (except CV2 in 50% of cases), and CV3 and 4 are tapered from anterior to posterior (shorter anteriorly, "wedge" shape); this stage also suggests that peak craniofacial growth will NOT occur earlier than one year away (± 6 months).[5,13]



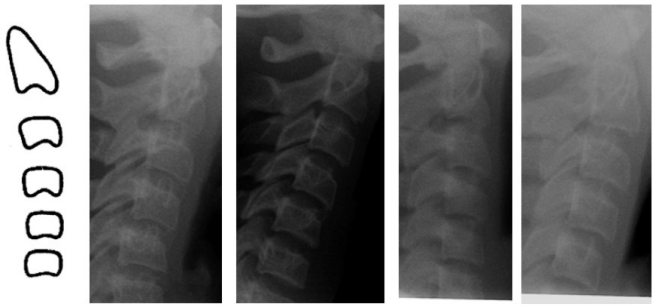
("wedge") Figs (Illustrating CVMS I)

CVMS II: Concavities present on C2 and C3 and the bodies of C3 and C4 may begin to change shape to more rectangular. This stage marks the onset of mandibular growth; peak mandibular growth will take place within one year in 90% of patients.[5,13]



(becoming "rectangular") (Illustrating CVMS II)

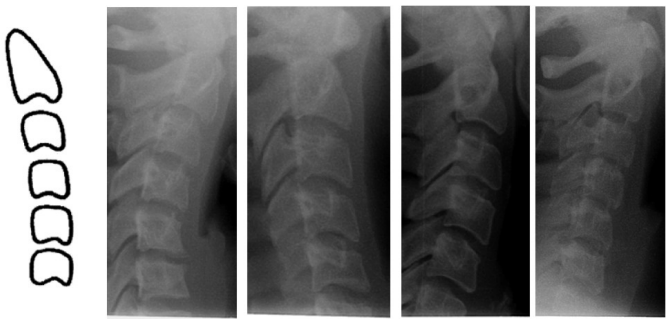
CVMS III: Lower borders of C2, 3 and 4 manifest concavities and they have become more rectangular-horizontal in shape. This stage marks the end of maximum growth spurt. Peak growth has just passed.[5,13]



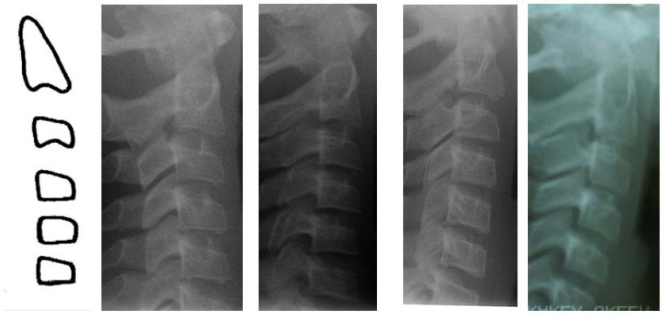
("Rectangular") (Illustrating CVMS III)

Peak growth stage should occur in 96% of patients between CVMS II and CVMS III.[21] However, detecting stages CVMS 3 and CVMS 4 of development is easier in males than in females.[19]

CVMS IV: Concavities present on C2-4 with at least one of C3 or C4 becoming more "square" in shape; mandibular peak growth has occurred not more than a year ago before this stage.[5,13]



(becoming "square") (Illustrating CVMS IV, note differences)



("square") (Illustrating CVMS V)

CVMS V: Concavities evident on C2-4 with at least one of C3 or C4 becoming horizontal-vertical in shape. Peak growth has taken place no more than two years before this stage and thus little to no craniofacial growth expected.

Hassel and Farman describe these growth stages similarly, through the morphologic change in the vertebrae from a "wedge" shape (initiation of growth) to a progressive increase in anterior height and a more "rectangular" shape (growth acceleration); further height increase both anteriorly and posteriorly, a more "square" shape, would indicate a deceleration and finalization of growth. They have simply used descriptional terms for these stages.

Thus the **initiation** stage, as they reference it, would be characterized by a lack of concavities on CV2-CV4 (flat lower borders, wedge shape, lower taper anterior to posterior) and an expected 80-100% of adolescent growth still anticipated. The growth **acceleration** stage would be characterized by concavities evident on C2 and C3 with a flat lower border on C4. Additionally, the vertebral bodies of C3 and C4 would now have changed from wedge to more "rectangular." The third stage is called **transition**; growth at this stage is moving toward peak velocity and 25-65% of growth still expected; the other visible evidence is a concavity developing on C4 and continued development of this "rectangular" shape. What follows is the **deceleration** stage. At this point only 10-25% of growth is still expected with a marked slowing down of growth rate, a deepening of the concavity on C4 is evident with the appearance of more "square" cervical vertebrae appearance. A fifth stage is termed **maturation**; this is marked by significantly more pronounced concavities on C2-C4 and only about 5-10% of growth is still expected with the bodies becoming more "square" (taller than wider). The last stage is **completion**. Little or no growth is expected and deep concavities seen on C2-C4 with a further height increase (taller than wider) in the vertebral shape.[2]

The importance of understanding when our orthopedic treatment plan will be most effective clearly is a challenge when faced with a young patient that already demonstrates some kind of developmental problem or growth tendency. How and when can growth modification be a real treatment possibility for such a patient?[17] How early should we attempt correction of a severe Class II or Class III skeletal problem? The literature is clear that any pre-pubertal treatment of the Class II skeletal type will not have a significant corrective result. Therefore, timing our orthopedic treatment just before and during the pubertal growth spurt will have a more significant therapeutic result.[4,19] As mentioned already, it is unreliable to use chronologic age to determine skeletal maturity. However, the CVMS method for growth stage determination has now been well correlated with age. This investigation found that peak mandibular growth in females is (concavities evident on both CV3 and CV4) between the age of 10-13 years and between 12-15 years in males.[22]

Functional appliances, such as the Twin-Block, will have a further positive lengthening of a retrusive mandible through the growth stimulation in a supero-posterior direction of the condylar cartilage. Treatment during or slightly after the pubertal growth period will have a further lengthening of the mandible of 4.75mm per year opposed to only 1.88mm per year to the pre-pubertal treated group.[4]

The other population of patients with a different growth concern is the Skeletal Class III patient. Questions that require good answers: 1) How early should we intercept a patient with either a maxillary deficiency and/or a prognathic mandible? 2) When treatment is completed in a male at age ~14, how much residual growth remains? 3) How much overcorrection should be attempted? It has been suggested that protraction is best initiated prior to peak growth when protraction of the maxilla can be more effective.[4] We know that males begin their pubertal growth spurt later than females and also that this growth lasts longer. Both of these patient populations require a more accurate prediction of mandibular growth potential.[6] If the mandible outgrows the maxilla during treatment, success will be compromised.[19]It is also well recognized that different individuals mature differently; thus it is important to know if a patient is early or a more delayed in maturation rate.[19]

Acceleration of growth begins when a developing concavity is seen on both CV2 and CV3, but "peak" pubertal growth stage is when a concavity is visible on both CV3 and CV4 and both bodies are becoming "rectangular" (anterior border increasing in height) in both sexes. Therefore, maximum mandibular and maxillary growth is taking place during this peak stage in 93.5% of individuals.[2] There is also agreement that concavities on CV 4-5 marks the period of growth rate deceleration.[2,3] However, one of the challenges of this method is that

borderline cases are difficult to tell them apart. Another is that a patient is being evaluated by a single cephalogram at one point in time.[3]

In conclusion, the orthodontic clinician needs to remember that there is no single infallible method for the determination of skeletal growth stage. Our patients are not simply skulls with growing faces but whole beings that are not developing linearly but in their own individual 3-dimensional growth spurts.[14,26]

References

1. Lamparski, D.G., Skeletal age assessment utilizing cervical vertebrae (dissertation). Pittsburgh, PA, The University of Pittsburgh; 1972.
2. Hassel B, Farman A. Skeletal maturation evaluation using cervical vertebrae. *AJODO* 1995; 107:58-66.
3. Franchi L, DDS, PhD, et al, Mandibular growth as related to cervical vertebral maturation and body height, *AJODO*, September 2000, pp 335-40.
4. Baccetti, T. DDS, PhD, et al, Treatment timing for Twin-block therapy, *AJODO*, August 2000, pp 159-69.
5. Baccetti, T. DDS, PhD, et al, An Improved Version of the Cervical Vertebral Maturation (CVM) Method for Assessment of Mandibular Growth, *Angle Orthodontist*, August 2002, vol 72, No4, pp 316-23.
6. Mito, T., DDS, et al, Cervical vertebral bone age in girls, *AJODO*, October 2002, pp380-84.
7. San Roman, Paloma, DDS, et al, Skeletal maturation determined by cervical vertebrae development, *EJO*, 24 (2002) pp303-311.
8. Baccetti, T. DDS, PhD, et al, The cervical vertebral maturation method: some need for clarification, *AJODO*, January 2003, pp 19A-20A.
9. Mito, T., DDS, et al, Predicting mandibular growth potential with cervical vertebral bone age, *AJODO*, August 2003, pp173-77.
10. Kamal M, Ragini, Goyal S. Comparative evaluation of hand wrist radiographs with cervical vertebrae for skeletal maturation in 10-12 years old children. *J Indian Soc Pedod Prev Dent* 2006;24:127-35.
11. 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 Fall;24(1):47-52.
12. Ozer T, Kama JD, Ozer SY. A practical method for determining pubertal growth spurt. *Am J Orthod Dentofacial Orthop*. 2006 Aug;130(2):131.e1-6.
13. Gandini P, Mancini M, Andreani F.A comparison of hand-wrist bone and cervical vertebral analyses in measuring skeletal maturation. *Angle Orthod*. 2006 Nov;76(6):984-9.
14. Damian MF, Cechinato F, Molina RD, Woitchunas FE. Relationship between cranial and mandibular growth and the stages of maturation of the cervical vertebrae. *J Appl Oral Sci*. 2007 Apr;15(2):115-9.
15. Lai EH, Liu JP, Chang JZ, Tsai SJ, Yao CC, Chen MH, Chen YJ, Lin CP. Radiographic assessment of skeletal maturation stages for orthodontic patients: hand-wrist bones or cervical vertebrae? *J Formos Med Assoc.* 2008, Apr;107(4):316-25.
16. Soegiharto BM, Cunningham SJ, Moles DR. Skeletal maturation in Indonesian and white children assessed with hand-wrist and cervical vertebrae methods. *Am J Orthod Dentofacial Orthop*. 2008 Aug;134(2):217-26.
17. Soegiharto BM, Cunningham SJ, Moles DR. Discriminatory ability of the skeletal index in the cervical vertebrae maturation index in detecting peak pubertal growth in Indonesian and white subjects with receiver operating characteristics analysis, *Am J Orthod Dentofacial Orthop*. 2008 Aug;134(2):227-37.
18. Sun Y, You QL, Liu HH. [Correlation of adolescents' skeletal maturation determined by cervical vertebrae and hand-wrist in Shanghai region], Shanghai Kou Qiang Yi Xue. 2007 Aug;16(4):365-9.
19. Fudalej P, Bollen AM. Effectiveness of the cervical vertebral maturation method to predict postpeak circumpubertal growth of craniofacial structures. *Am J Orthod Dentofacial Orthop*. 2010 Jan;137(1):59-65.
20. Gabriel DB, Southard KA, Qian F, Marshall SD, Franciscus RG, Southard TE. Cervical vertebrae maturation method: poor reproducibility. *Am J Orthod Dentofacial Orthop*. 2009 Oct;136(4):478.e1-7; discussion 478-80.
21. Baccetti T, Franchi L, McNamara JA Jr. Reproducibility of the CVM method: a reply. *Am J Orthod Dentofacial Orthop*. 2010 Apr;137(4):446-7; author reply 447
22. Caldas Mde P, Ambrosano GM, Haiter Neto F. New formula to objectively evaluate skeletal maturation using lateral cephalometric radiographs. *Braz Oral Res*. 2007 Oct-Dec;21(4):330-5.
23. Chen F, Terada K, Hanada K. A new method of predicting mandibular length increment on the basis of cervical vertebrae. *Angle Orthod*. 2004 Oct;74(5):630-4.
24. Wong, W.K. Ricky, et al, Use of cervical vertebral maturation ot determine skeletal age, AJODO, 2009, 136: 484-5.
25. Chatzigiani, Athina, DDS, Halazonetis, Demetrios, DDS, Geometric morphometric evaluation of cervical vertebrae shape and its relationship to skeletal maturation, *AJODO*, 2009, 136: 481-483.
26. Generoso, Rodrigo, DDS, MS, et al, Evaluation of mandibular length in subjects with Class I and Class II skeletal patterns using the cervical vertebral maturation, *Braz. Oral Res.,* 2010, Jan-March: 24(1): 46-51.

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