An Improved Version of the Cervical Vertebral Maturation (CVM) Method for the Assessment of Mandibular Growth in Deutero-Malay Sub Race

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Abstract. In this paper, Cervical Vertebral Maturation method was used to assess the mandibular growth in Deutero-Malay sub race. Twenty eight laterals Cephalometric radiographs of Deutero-Malay sub race aged 9-15 were observed. The observation used stratified random sampling by measuring the quantitative and qualitative assessment of the 2nd through 4th cervical vertebra of the subjects. It produced the diagram of developmental stages of cervical vertebrae for Deutero-Malay sub race. The diagram can be used to determine mandibular growth in term of qualitative by matching the shape of cervical vertebrae. It was obtained that the Cervical Vertebral Maturation method can be used to assess mandibular growth in Deutero-Malay sub race by matching the shape of cervical vertebrae to the diagram of developmental stages of cervical vertebrae. In addition, Cervical Vertebral Maturation method can be used to identification person’s age.
1. Introduction
Recent studies have shown that cervical vertebral growth is linked intimately to the maturation and growth of mandibular. To determine the normal growth rate, some clinical studies identified that during the circumpubertal growth period is when it shows greatest response. With this lead in research, the subject target for this thesis are male and female subjects aged 9 to 15 [1].

In the study of forensic odontology, determination of normal growth rate is essential to aid in identifying a person’s credibility to optimal growth rate. By determining the normal growth of a person, it can aid other researches to estimate the age of a certain subject using various types of age estimation methods.

An improved version of Cervical Vertebral Maturation (CVM) method, a maturational index that have been proposed to evaluate skeletal maturity in patient has proven to be effective in determining growth rates in terms of changes in mandibular size and body height. The CVM method comprises of 6 stages (Cvs 1 - Cvs 6), each stage shows the different stages of cervical vertebral growth throughout the pubertal years provided by an analysis which will be carried out in two ways that is visual analysis and cephalometric analysis [2].

The motive of choosing this title is to understand and to provide an understanding of how the cervical vertebral maturation method can be used to determine mandibular growth for deutero-Malay sub race ethnics in Indonesia by using the CVM method.

The main reason of choosing deutero-Malay sub race as the subject of this thesis is because there are no data or researches that have been carried out on this race before in Indonesia. Since the research is to be done in Indonesia, it’s vastest ethnic currently populating this country is the deutero-Malay sub race and it is only wise to choose this race as my thesis subject.

2. Materials and Methods
The morphology of the bodies of second (odontoid process, C2), third (C3), and fourth (C4) cervical vertebrae were analysed in 6 consecutive observations. The analysis comprised of visual and cephalometric appraisals of morphological characteristics of the cervical vertebrae.

Visual analysis will be the assessment through shape evaluated by visual inspection. Two sets of variables were analysed: (1) presence of a concavity at the lower border of the body of C2, C3, and C4; and (2) shape of the body of C3 and C4. The following explains the assessment of shape [3]:

1. Trapezoid (the superior border is tapered from posterior to anterior);
2. Rectangular horizontal (the heights of the posterior and anterior borders are equal; the superior and inferior borders are longer than the anterior and posterior borders);
3. Squared (the posterior, superior, anterior and inferior borders are equal);
4. Rectangular vertical (the posterior and anterior borders are longer than the superior and inferior borders).

Cephalometric analysis is by measuring the percentage of increase and decrease in concavity of C2 through C4. The cephalometric analysis is carried out by plotting several points on the digitalized cervical vertebral bodies from the cephalogram and is traced and digitized for the description of morphological characteristics. From the 13 points that were plotted and measured from the same lateral cephalogram, three liner and four ratio measurements which is adopted partially from Hellsing [4, 5] are made.

The subjects of this research are 28 deutero-Malay sub race patients age 9 to 15 who come to the Dentomaxillo facial Radiology Installation of Dental Hospital, Faculty of Dentistry, Padjadjaran University. The sampling method of this research is stratified random sampling and the research method is observational analytical study.

3. Results and Discussion
Table 1 shows the visual analysis of the morphologic characteristic of cervical vertebrae (C2, C3, C4). The features of examined vertebrae at the seven observations can be summarized as follows:
T9. A concavity is evident at the lower border of C2 in 50% of the subjects. Concavity is absent in C3 and C4 in 100% of subjects. The bodies of C3 and C4 are trapezoid in shape for all subjects.

T10. A concavity is not observed in all the lower borders of C2, C3, and C4 in all subjects. Both C3 and C4 are still trapezoid in shape in 100% of subjects.

T11. A concavity is present at the lower border of C2 in 75% of subjects and only 25% of subjects on C3. No concavity is present at the lower border of C4. 75% of subjects have trapezoid shaped body in C3 and C4 and only 25% of subjects have rectangular horizontal shaped body in C3 and C4.

T12. A concavity is present at the lower border of C2 and C3 in 50% of the subjects, but only 25% of subjects have concavity at the lower border of C4. The shape of both C3 and C4 can either be trapezoid or rectangular horizontal.

T13. This stage is characterized by the presence of concavity in all the lower border of C2, C3, and C4. 50% of subjects have concavity at the lower border of C2 and C4, and an astonishing 75% of subjects with concavity at lower border of C3. There is also a presence of squared shaped C3 and C4 body with 50% of subjects carrying squared shaped body in C4 and the remaining with the shape of rectangular horizontal.

T14. By this stage, a concavity can be observed in all the lower borders of C2, C3, and C4 in all the subjects except for a non-significant 25% of subject with no concavity at the lower border of C2. Evidence of rectangular vertical shaped body indicates the starting of maturation peak even though there is only 25% of subjects with rectangular vertical shaped body in C3 and C4 with the remaining body shaped in square.

T15. A concavity is present in all the lower borders of C3, and C4 in 100% of the subjects and 75% of subjects in C2 with an exception of a non-significant 25% of subject with no concavity at the lower border of C2. The body of C3 is rectangular vertical in 50% of subjects and the remaining with trapezoid and square shaped body. The body of C4 is also rectangular vertical in 50% of subjects and squared in the remaining 50%. This indicates the happening of mandibular growth peak.

Table 2 shows the descriptive statistics for cephalometric measurements of vertebral morphologic characteristics, together with statistical comparisons between observations.

There are no significant differences for any of the measurements assessed between T9 and T10. The depth of concavities at the lower border of the second (C2Conc) and third (C3Conc) cervical vertebra was significantly greater at T13 when compared to T12.

In the transition from T10 to T11, the height of anterior border of both C3 and C4 increases significantly, leading to significant decrements in the ratio between the heights of the posterior and anterior borders of the vertebral bodies (C3PAR and C4PAR).

At T12, the depth of concavity at the lower border of C4 (C4Conc) becomes significantly greater than at T11. In the transition from T11 to T12, the height of the anterior borders of both C3 and C4 have increase significantly again, thus leading to significant decrements both in the ratio between the heights of the posterior and anterior borders of the vertebral bodies (C3PAR and C4PAR) and in the ratio between the length of the base and the anterior height of the vertebral bodies (C3BAR and C4BAR). On average, C3PAR and C4PAR now have a ratio of approximately 1:1, an indication that both C3 and C4 vertebral bodies are rectangular horizontal in shape.

At T13, the depth of concavity at the lower border of C2 and C3 has the greatest and most significant increase when compared to T12. This indicates the peak of mandibular growth is greatest during this transition. Decremnts of the ratio between the length of the base and the anterior height of the vertebral bodies (C3BAR and C4BAR). The mean values for these measurements indicate that the vertebral bodies become progressively more squared in shape.

At T14 and T15, the depth of concavity at the lower border of C2, C3, and C4 remain greatly significant than the earlier stages. One-third of the cases show a rectangular vertical shape of one or both C3 and C4 vertebral bodies.
4. Conclusion

The objective of the present investigation was to aid in determining the condition of a patient if the growth rate is normal, and more specifically, a direct appraisal of the skeletal maturity of the mandible in relation to the changes in morphological features of the cervical vertebrae.

Secondly, an evaluation of the morphological features of the cervical vertebra bodies restricted to those that are visible on the lateral cephalogram even when a protective collar is worn, as originally proposed by Hassel and Farman [3]. Third, a description of the cervical vertebral morphology at each developmental stage which will allow the clinician to apply the method based on the information derived from a single cephalogram, and lastly, an evidence to support and prove if a subject has a normal growth rate by comparison of the morphological changes of the cervical vertebrae with the length of the mandibular growth.

The weakness of the research is that the subjects used are not consecutive as there are no available consecutive radiographs in the radiology installation. In addition to that, the research is conducted by merging the measurements from male and female subjects which may have reduced the accuracy by a little. Third and lastly, the capturing of the cephalometric radiographs is performed by different operators which may have produced a difference in radiograph in terms of technique of capturing and positioning of the patient.

In Figure 1, the diagram of developmental stages of cervical vertebrae guidance is as such. Stage DS1 is accounted for T9 and T10 showing no presence of concavity on all lower borders of cervical vertebrae. Shape of C3 and C4 is trapezoid. T11 is categorised into stage DS2 where C2 shows concavity at the lower border. The length of C3ua-C3la on the anterior border of C3 and C4 shows increase in length however, still not long enough to change the shape of C3 and C4 therefor remain as trapezoid shape.

DS3 is marked with concavity at the lower border of C2 and C3. The shape change in C3 from trapezoid shape to rectangular horizontal in shape which in this case is seen in stage T12. Stage T12 is included in the DS4 because of the presence of shape change in C4 from trapezoid to rectangular horizontal in shape while C2, C3 and C4 remain to have concavity present at the lower borders. DS5 includes the change in both C3 and C4 in terms of shape. Transitioning from rectangular horizontal to square shaped, T13 shows the distinctive changes thus is grouped in this category.

Stage DS6 can be said as the starting of a static shape change stage as it marks the starting of shape transition from square to rectangular vertical in C3 and C4 in which will remain unchanged in the upcoming stages and this characteristic is observed in T14. T15 has similar characteristics as seen in T14 but with a higher prevalence showing rectangular vertical shape in C3 and C4 vertebraes.

By applying the knowledge and referring to the Figure 1 and Table 3 of developmental stages of cervical vertebral growth, a physician will be able to determine if a deuto-Malay sub race individual has a normal growth rate by comparing his or her cephalometric radiograph to the references above.

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References

[1] O'Reilly M T, Yanniello G J. 1988. Mandibular growth changes and maturation of cervical vertebrae—a longitudinal cephalometric study. Angle Orthod., 58(2):179-184. doi:10.1043/0003-3219(1988)058<0179:MGCMAM>2.0.CO;2.

[2] Franchi L, Baccetti T, McNamara J A. 2000. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofac Orthop., 118(3):335-340.

[3] Hassel B, Farman A G. 1995. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofac Orthop., 107(1):58-66. doi:10.1016/S0889- 5406(95)70157-5.

[4] Hellsing E. 1991. Cervical vertebral dimensions in 8-, 11-, and 15-year-old children. Acta Odontol Scand., 49(4):207-213. doi:10.3109/00016359109005909.
[5] Flores-Mir C, Burgess C A, Champney M, Jensen R J, Pitcher M R, Major P W. 2006. Correlation of skeletal maturation stages determined by cervical vertebrae and hand-wrist evaluations. Angle Orthod., 76(1):1-5. doi:10.1043/0003-3219(2006)076[0001:COSMSD]2.0.CO;2.

| Table 1 Results of Qualitative Analysis of Cervical Vertebral (C2-C4) Characteristics at the Six Consecutive Observations (T9-T15) |
|---------------------------------------------------------------|---------------|---------------|---------------|---------------|
| Concavity at the lower border of C2 | Yes | No | Yes | No |
| 2 | 2 | 0 | 4 | (50%) | (50%) | (0%) | (100%) | (75%) | (25%) |
| 3 | 1 | 2 | 2 | (50%) | (50%) |
| Concavity at the lower border of C3 | Yes | No | Yes | No |
| 0 | 4 | 0 | 4 | (0%) | (100%) | (0%) | (100%) | (25%) | (75%) |
| 1 | 3 | 2 | 2 | (50%) | (50%) |
| Concavity at the lower border of C4 | Yes | No | Yes | No |
| 0 | 4 | 0 | 4 | (0%) | (100%) | (0%) | (100%) | (25%) | (75%) |
| 0 | 4 | 1 | 3 | (50%) | (50%) |
| C3 shape: trapezoid | Yes | No | Yes | No |
| 4 | 0 | 4 | 0 | (100%) | (0%) | (100%) | (0%) | (100%) | (25%) | (75%) |
| 3 | 0 | 2 | 0 | (50%) | (0%) |
| C4 shape: trapezoid | Yes | No | Yes | No |
| 4 | 0 | 4 | 0 | (100%) | (0%) | (100%) | (0%) | (100%) | (25%) | (75%) |
| 1 | 0 | 1 | 0 | (50%) | (0%) |
| C3 shape: rectangular horizontal | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (25%) | (0%) | (25%) | (0%) |
| C4 shape: rectangular horizontal | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (25%) | (0%) | (25%) | (0%) |
| C3 shape: squared | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) |
| C4 shape: squared | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) |
| C3 shape: rectangular vertical | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) |
| C4 shape: rectangular vertical | Yes | No | Yes | No |
| 0 | 0 | 0 | 0 | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) | (0%) |
Table 1 Extended

|                  | T13 |     | T14 |     | T15 |     |
|------------------|-----|-----|-----|-----|-----|-----|
|                  | Yes | No  | Yes | No  | Yes | No  |
| Concavity at the lower border of C2 | 2   | 2   | 3   | 1   | 3   | 1   |
|                  | (50%) | (50%) | (75%) | (25%) | (75%) | (25%) |
| Concavity at the lower border of C3 | 3   | 1   | 4   | 0   | 4   | 0   |
|                  | (75%) | (25%) | (100%) | (0%) | (100%) | (0%) |
| Concavity at the lower border of C4 | 2   | 2   | 4   | 0   | 4   | 0   |
|                  | (50%) | (50%) | (100%) | (0%) | (100%) | (0%) |
| C3 shape: trapezoid | 1   | 0   | 2   | 0   | 1   | 0   |
|                  | (25%) | (0%) | (50%) | (0%) | (25%) | (0%) |
| C4 shape: trapezoid | 1   | 0   | 2   | 0   | 0   | 0   |
|                  | (25%) | (0%) | (50%) | (0%) | (0%) | (0%) |
| C3 shape: rectangular horizontal | 2   | 0   | 0   | 0   | 0   | 0   |
|                  | (50%) | (0%) | (0%) | (0%) | (0%) | (0%) |
| C4 shape: rectangular horizontal | 1   | 0   | 0   | 0   | 0   | 0   |
|                  | (25%) | (0%) | (0%) | (0%) | (0%) | (0%) |
| C3 shape: squared | 1   | 0   | 1   | 0   | 1   | 0   |
|                  | (25%) | (0%) | (25%) | (0%) | (25%) | (0%) |
| C4 shape: squared | 2   | 0   | 1   | 0   | 2   | 0   |
|                  | (50%) | (0%) | (25%) | (0%) | (50%) | (0%) |
| C3 shape: rectangular vertical | 0   | 0   | 1   | 0   | 2   | 0   |
|                  | (0%) | (0%) | (25%) | (0%) | (50%) | (0%) |
| C4 shape: rectangular vertical | 0   | 0   | 1   | 0   | 2   | 0   |
|                  | (0%) | (0%) | (25%) | (0%) | (50%) | (0%) |

Table 2 Results of Quantitative Analysis: Descriptive Statistics and Statistical Comparisons (ANOVA for Repeated Measurements with post-hoc Scheffe’s test) on the Measurements at the Six Consecutive Cephalometric Observations (T9-T15) *

|                  | T9  |     | T10 |     | T11 |     | T12 |     |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|
|                  | M   | SD  | SEM | M   | SD  | SEM | M   | SD  | SEM |
| Age (months)     | 101.75 | 3.30 | 0.16 | 111.25 | 3.86 | 0.18 | 126.50 | 1.73 | 0.07 | 138.50 | 1.29 | 0.05 |
| Co-Gn (mm)       | 195.79 | 17.72 | 0.63 | 193.90 | 16.08 | 0.57 | 198.46 | 9.26 | 0.32 | 193.91 | 12.58 | 0.55 |
| C2Conc (mm)      | 1.655 | 0.063 | 0.035 | 0.00 | 0.00 | 0.00 | 1.53 | 0.18 | 0.08 | 1.37 | 0.81 | 0.49 |
| C3Conc (mm)      | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 1.25 | 0.92 | 0.58 |
| C3PAR (ratio)    | 1.12 | 0.88 | 0.83 | 1.11 | 0.60 | 0.57 | 1.22 | 0.60 | 0.54 | 1.06 | 0.30 | 0.29 |
| C3BAR (ratio)    | 1.37 | 0.91 | 0.78 | 1.53 | 0.25 | 0.20 | 1.94 | 0.32 | 0.46 | 1.67 | 0.84 | 0.65 |
| C4PAR (ratio)    | 1.20 | 0.60 | 0.55 | 1.31 | 1.18 | 1.04 | 1.42 | 1.49 | 1.24 | 1.26 | 1.47 | 1.37 |
| C4BAR (ratio)    | 1.62 | 0.45 | 0.35 | 1.47 | 1.00 | 0.82 | 1.93 | 0.21 | 0.15 | 1.67 | 1.41 | 1.08 |

|                  | T13 |     | T14 |     | T15 |     |
|------------------|-----|-----|-----|-----|-----|-----|
|                  | M   | SD  | SEM | M   | SD  | SEM |
| Age (months)     | 149.75 | 1.70 | 0.06 | 162.50 | 4.20 | 0.16 | 173.75 | 3.30 | 0.12 |
| Co-Gn (mm)       | 205.36 | 14.25 | 0.49 | 209.27 | 8.37 | 0.28 | 221.43 | 7.36 | 0.24 |
| C2Conc (mm)      | 2.54† | 0.21 | 0.09 | 1.90 | 0.63 | 0.26 | 2.49 | 0.67 | 0.24 |
| C3Conc (mm)      | 2.92† | 0.92 | 0.31 | 1.60 | 0.87 | 0.34 | 2.54 | 0.93 | 0.29 |
Table 3 Table of Developmental Stages of Cervical Vertebral Growth

| Developmental Stages | Explanation                                                                 | Observation Stages |
|----------------------|-----------------------------------------------------------------------------|--------------------|
| DS1                  | No concavity on lower border of C2, C3 and C4. C3 and C4 trapezoid shape.  | T9 and T10         |
| DS2                  | Concavity at lower border of C2. C3 and C4 trapezoid shape.                 | T11                |
| DS3                  | Concavity at lower border of C2 and C3. C3 rectangular horizontal shape, C4 trapezoid shape. | T12                |
| DS4                  | Concavity at lower border of C2, C3 and C4. C3 and C4 rectangular horizontal shape. | T12                |
| DS5                  | Concavity at lower border of C2, C3 and C4. C3 and C4 square shape.         | T13                |
| DS6                  | Concavity at lower border of C2, C3 and C4. C3 and C4 rectangular vertical shape. | T14                |
| DS7                  | Concavity at lower border of C2, C3 and C4. C3 and C4 remain rectangular vertical shape. | T15                |

*M indicates mean; SD indicates standard deviation; and SEM indicates standard error of mean.
† Statistically significant with respect to preceding observation.

Figure 1. The diagram of developmental stages of cervical vert