Agreement of Tracing and Direct Viewing Techniques for Cervical Vertebral Maturation Assessment

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Objective: *This study aimed to evaluate agreement among three methods for cervical vertebral maturation (CVM) assessment, comprising direct viewing, tracing only, and tracing with digitized points.*
Material and Method: *Two examiners received training and tests of reliability with each CVM method before evaluation of agreement among methods. The subjects were 96 female-cleft lateral cephalometric radiographs (films of eight subjects for each age ranged from seven to 18 years). The examiners interpreted CVM stages of the subjects with four-week interval between uses of each method.*
Results: *The range of weighted kappa values for paired comparisons among the three methods were: 0.96-0.98 for direct viewing and tracing only comparison; 0.93-0.94 for direct viewing and tracing with digitized points comparison; and 0.96-0.97 for tracing only and tracing with digitized points comparison. The intraclass correlation coefficient (ICC) value among the three methods was 0.95. These results indicated very good agreement among methods.*
Conclusion: *Use of direct viewing is suitable for CVM assessment without spending more time for tracing. However, the three methods might be used interchangeably.*

Keywords: *Agreement, Cervical vertebral maturation, Tracing, Direct viewing*

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In orthodontic and dentofacial orthopedic growth modification procedures, pubertal growth status is an important tool for diagnosis and treatment planning, especially in children and teenagers. Due to variations on timing of growth and development among individuals, chronological age is not appropriate for growth assessment[1,2]. There are many biological indicators of pubertal growth status including physical growth status[3-5] dental development[6], secondary sexual characteristics[7,8], human blood[9] and skeletal maturation[10-19]. Among various growth assessment methods, the skeletal maturation, which is determined by level of maturation or markers in the skeletal system, is widely accepted due to its advantages over other methods.

Cervical vertebral maturation (CVM) assessment, which determines skeletal maturation by ossification events and morphological changes of cervical vertebra, has been increasingly used by clinicians[15-19], since the method is reliable, valid and correlates well with Hand-Wrist Radiograph (HWR) methods[19-21]. It is also important that CVM reduce additional radiation exposure on patients when compared to HWR method[14-16]. Among researches and clinical implications, CVM method enables assessment by direct inspection of a patient's lateral cephalometric radiograph[16,22,23] or tracing[15,24,25] of cervical vertebra morphology from patients' radiographs.

This study aimed to evaluate agreement of CVM assessment methods among direct viewing, tracing only, and tracing with digitized points.

Material and Method

This study was a cross-sectional analytical research design. Based on a pilot study, a total number of 96 lateral cephalometric radiographs were included as subjects. These radiographs belong to patients from the Department of Orthodontics, Faculty of Dentistry, Khon Kaen University. The x-ray films of female cleft patients, aged between seven and 18 years were only

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included. The radiographs with low contrast, artifacts and lack of sharpness or blurry were considered as low quality and omitted from the study. To distribute CVM stages of the subjects as equal as possible, quota-sampling technique was used to choose eight samples for each age ranged from seven to 18.

To prevent assessment bias, all lateral cephalometric radiographs were masked to hide ID, age and other non-relevant craniofacial structures, and were identified only by numbers from 1 to 96. All subjects were represented only cervical vertebra.

Raters and training process

Two examiners who were orthodontic postgraduate students involved in this research were intensively trained in the CVM method developed by Baccetti et al[16] involving three methods:

Direct viewing method

Each subject's masked radiograph was placed on a light box in a darkened room. The examiners directly inspected the radiograph and interpret the CVM stages according to Fig. 1 and Table 1.

Tracing only method

Each subject's masked radiograph was traced for morphological bodies of the second, third and fourth cervical vertebrae on acetate paper with 0.3 mm pencil and used this tracing picture to interpret CVM stage according to Fig. 1 and Table 1.

Tracing with digitized points method

Use the tracing from the tracing only method. Points were marked on each tracing as defined in Fig. 2.

This method interprets CVM stage based on measurements of the concavity depth and dimension of the second, third and fourth cervical vertebral bodies. The measurements listed in the Table 2 were determined. The criteria for CVM stage interpretation by tracing with digitized points method are listed in Table 3.

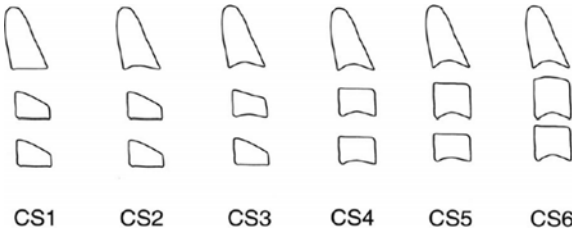

Fig. 1 Schematic of cervical vertebral maturation stages adapted from Baccetti et al (2005)[16].

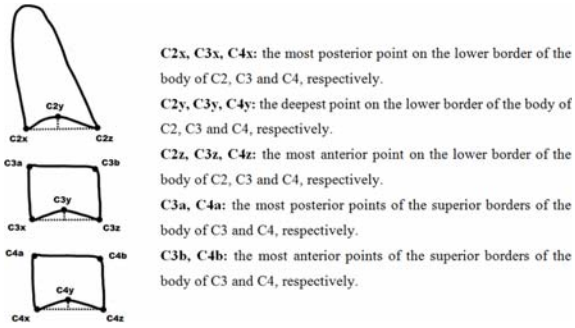

Fig. 2 Identifying points for distance measurements adapted from Baccetti et al (2005)[16].

Table 1. Assessment of CVM stages

CVM stage	Criteria
Cervical stage 1 (CS1)	The lower borders of all 3 vertebrae (C2-C4) are flat, and the bodies of C3 and C4 are trapezoid shaped
Cervical stage 2 (CS2)	Concavity presenting at the lower border of C2, and the bodies of both C3 and C4 are trapezoid shaped
Cervical stage 3 (CS3)	Concavities presenting at the lower borders of both C2 and C3, and the bodies of C3 and C4 are either trapezoid or rectangular horizontal in shape
Cervical stage 4 (CS4)	Concavities presenting at the lower borders of C2, C3, and C4, and the bodies of C3 and C4 are rectangular horizontal in shape
Cervical stage 5 (CS5)	Concavities presenting at the lower borders of C2, C3, and C4, and at least 1 of the bodies of C3 and C4 is square
Cervical stage 6 (CS6)	Concavities presenting at the lower borders of C2, C3, and C4, and at least 1 of the bodies of C3 and C4 is rectangular vertical

Adapted from Baccetti et al (2005)[16].

Intra-examiner's reliability testing for CVM assessment methods

After training, a sample of 30 subjects was used to test intra-examiner's reliability. The subjects were examined twice with a four-week interval between each examination. The guidelines for CVM assessment were available to the examiners throughout this research.

Agreement evaluation between methods

After receiving satisfied outcomes on intra-examiner's reliability, the examiners were allowed to interpret CVM stages of 96 subjects with a four-week interval between uses of each method to minimize the possible effect of memory bias on the results. The examiners were required to interpret only 20 to 30 radiographs per day for each of the three assessment methods to prevent fatigue. The guidelines for CVM assessment were given to the examiners throughout this research.

Data analyses

Agreements between pair comparison were analyzed by weighted kappa statistics. Agreement among the three methods was analyzed by intraclass correlation statistics. The interpretation of kappa value and ICC were based on data according to Altman[26].

Results

After training, the weighted kappa values of intra-examiner's reliability ranged from 90.9 to 96.8% (Table 4).

Interpretations of the CVM stage of 96 subjects by each method with a four-week interval were made independently by each examiner. The weighted kappa values for inter-examiner's agreement between two examiners were: 97.0% for direct viewing method; 95.5% for tracing only method; and 95.0% for tracing with digitized points method.

Considering agreement between two

Table 2. The measurements for CVM stage interpretation

Measurements	Definition
C2 Concavity depth	Distance from the line connecting C2x and C2z to the deepest point on the lower border of the vertebra, C2y.
C3 Concavity depth	Distance from the line connecting C3x and C3z to the deepest point on the lower border of the vertebra, C3y.
C4 Concavity depth	Distance from the line connecting C4x and C4z to the deepest point on the lower border of the vertebra, C4y.
C3 Base-anterior ratio (C3BAR)	Ratio between the length of the base (C3x to C3z) and the anterior height (C3b to C3z) of the body of C3.
C4 Base-anterior ratio (C4BAR)	Ratio between the length of the base (C4x to C4z) and the anterior height (C4b to C4z) of the body of C4.

Table 3. The criteria for CVM interpretation by tracing with digitized points method

CVM stages	Criteria
Cervical stage 1 (CS1)	C2, C3 and C4 Concavity depth are below 0.8 mm.
Cervical stage 2 (CS2)	C2 Concavity depth is equal or over 0.8 mm, but C3 and C4 Concavity depth are below 0.8 mm.
Cervical stage 3 (CS3)	C2 and C3 Concavity depth are equal or over 0.8 mm, but C4 Concavity depth is below 0.8 mm.
Cervical stage 4 (CS4)	C2, C3 and C4 Concavity depth are equal or over 0.8 mm, and C3BAR and C4BAR are over 1.2
Cervical stage 5 (CS5)	C2, C3 and C4 Concavity depth are equal or over 0.8 mm, andeither C3BAR or C4BAR is 1-1.2
Cervical stage 6 (CS6)	C2, C3 and C4 Concavity depth are equal or over 0.8 mm, andeither C3BAR or C4BAR is below 1

Table 4. Intra-examiner's reliability

Examiner	Weighted kappa values		
	Direct viewing (%)	Tracing only (%)	Tracing with digitized points (%)
1	96.2	96.3	96.8
2	95.4	95.2	90.9

Table 5. Weighted kappa value of agreement between methods calculated with 95% CI

Examiner	Direct viewing and tracing only % (95% CI)	Direct viewing andtracing with digitized points % (95% CI)	Tracing only andtracing with digitized points % (95% CI)
1	97.5 (95.0-99.1)	93.7 (88.8-97.3)	96.0 (91.8-98.2)
2	95.8 (91.0-98.3)	93.1 (87.6-96.7)	97.3 (93.2-99.4)

Table 6. Agreement among three methods

Examiner	Intraclass correlation coefficient	95%CI
1	0.95	0.94-0.97
2	0.95	0.93-0.96

methods, the weighted kappa values of examiner 1 ranged from 93.7% to 97.5%, and the values of examiner 2 ranged from 93.1% to 97.3% (Table 5). The intraclass correlation coefficient among the three methods was 0.95 for examiners 1 and 2 (Table 6).

There were some disagreements when interpreting CVM stage of the same subject by the different method. The percentage of disagreement of examiner 1 ranged from 10.4% to 19.8%. The percentage of disagreement of examiner 2 ranged from 9.4% to 24.0% (Table 7).

Discussion

The CVM methods have been developed to determine growth and development during puberty of an individual as with other growth prediction methods[14-19]. Therefore, this method aids orthodontic diagnosis and treatment planning, particularly relating growth modification and orthognathic surgery cases.

The pubertal growth spurt is usually between 10 to 15 years[1,3,4]. However, the subjects' age range in this study were from 7 to 18 years which is expected to cover both early and late onset of skeletal growth that are of concerns to orthodontists. Because the study had to determine CVM stages, quota-sampling technique using the 12-age groups from 7 to 18 years was chosen to distribute CVM stage of the samples as equally as possible. Despite within-sex variability[1], limiting the sample to one gender (in the present study, females) should provide a more consistent growth pattern as represented by CVM stages throughout the age range of the study sample. In addition, only subjects with oral clefts were studied because of the ready availability of their cephalometric radiographs covering the planned age range.

In the present study, there were very good intra-examiner's reliability and inter-examiner's agreement. This is consistent with other CVM studies[16,22-25,27,28].

There were very good agreements between all pair comparisons and among the three methods. These infer that the CVM methods can be interpreted by direct assessment on the lateral cephalometric film without tracing or any further procedures. Perinetti and colleagues[28] developed digitized points method based on objective analysis and used this method as a standard reference in their study. However, they found very good agreement between standard reference and visual assessment. Using a direct viewing technique for CVM assessment can simplify the process for interpretation leading to shortened time and decreased cost compared with the two tracing processes. The direct viewing technique seems to be more practical to detect growth status initially and rapidly in the clinic for orthodontic diagnosis and treatment planning.

Table 7. Cervical stages disagreement between methods

Methods	Disagreement	Examiner	
		1 (n)	2 (n)
Direct viewing and tracing only	1 stage apart	8	12
	2 stages apart	2	1
	3 stages apart	0	1
	Total n (%)	10 (10.4)	14 (14.6)
Direct viewing and tracing with digitized points	1 stage apart	15	20
	2 stages apart	2	1
	3 stages apart	2	2
	Total n (%)	19 (19.8)	23 (24.0)
Tracing only and tracing with digitized points	1 stage apart	14	8
	2 stages apart	1	0
	3 stages apart	1	1
	Total n (%)	16 (16.7)	9 (9.4)

n = number of subjects

There were some disagreements detected when the examiners interpreted a specific CVM stage of the same subject by the three methods. The number of stages apart in this study varied from one to three stages. However, the majority of disagreements were one stage apart. This infers clinical acceptability despite the disagreements. This result is consistent with the study of Perinetti et al[28] which reported that the most cervical stages disagreement between one method (direct visual) and another method (objective analysis) was one stage apart. In addition, this finding seemed to agree with the study by Gabriel et al[29] and Zhao et al[30], in which the most disagreement for the CVM determination of the same subjects were one stage apart.

Conclusion

From the present study, there was very good observer agreement with the three CVM assessment methods: direct viewing, tracing only, and tracing with digitized points method. Thus, it can be concluded that the use of the direct viewing is suitable and acceptable for CVM assessment without spending more time for tracing or digitized points. Nevertheless, the three methods could be used interchangeably.

What is already known on this topic ?

Growth assessment by using CVM method has been increasing used among clinicians. The clinicians trace the cervical vertebra morphology with a pencil to interpret CVM stage of a subject. However, some clinicians may directly inspect the cervical vertebra on a lateral cephalometric radiograph for CVM interpretation.

What this study adds ?

There is very good agreement on the tracing and direct viewing method for CVM assessment. Therefore, the direct viewing is suitable and acceptable for CVM assessment without spending more time on any procedure.

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Potential conflicts of interest

None.

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ความสอดคล้องกันของวิธีประเมินการเจริญเติบโตกระดูกสันหลังส่วนคอด้วยวิธีการเทรซซิงกับการมองด้วยตาโดยตรง

โอภาศ วิวัฒน์วรกุล, มนเทียร มโนสุดประสิทธิ์, พูนศักดิ์ ภิเศก, สุภาภรณ์ ฉัตรชัยวิวัฒนา, ทัศนีย์ วังศรีมงคล

วัตถุประสงค์: *เพื่อประเมินความสอดคล้องกันของวิธีประเมินการเจริญเติบโตกระดูกสันหลังส่วนคอสามวิธี ซึ่งประกอบด้วยการมองด้วยตาโดยตรง การเทรซซิงอย่างเดียวและการเทรซซิงร่วมกับการกำหนดจุด*

วัสดุและวิธีการ: *ผู้ทำการประเมินสองคนจะได้รับการฝึกฝนและทดสอบความน่าเชื่อถือในการประเมินการเจริญเติบโตกระดูกสันหลังส่วนคอ แต่ละวิธีก่อนประเมินผลความสอดคล้องกัน กลุ่มตัวอย่างคือภาพรังสีกะโหลกศีรษะด้านข้างเพศหญิงที่มีภาวะปากแหว่งเพดานโหว่จำนวน 96 ฟิล์ม (อายุตั้งแต่ 7-18 ปี อายุละ 8 ฟิล์ม) แต่ละฟิล์มจะถูกประเมินระดับการเจริญเติบโตด้วยวิธีการประเมินทั้งสามวิธี โดยที่การประเมินแต่ละวิธีมีระยะเวลาห่างกัน 4 สัปดาห์*

ผลการศึกษา: *ค่า weighted Kappa ของแต่ละคู่จากทั้งหมดสามวิธี มีค่าดังนี้ 0.96-0.98 สำหรับวิธีการมองด้วยตาโดยตรงและการเทรซซิงอย่างเดียว, 0.93-0.94 สำหรับวิธีการมองด้วยตาโดยตรงและการเทรซซิงร่วมกับการกำหนดจุดและ 0.96-0.97 สำหรับวิธีการเทรซซิงอย่างเดียวและการเทรซซิงร่วมกับการกำหนดจุดค่า ICC ของความสอดคล้องกันทั้งสามวิธีมีค่าเท่ากับ 0.95 ซึ่งผลทั้งหมดแสดงว่ามีความสอดคล้องกันในระดับดีมาก*

สรุป: *วิธีมองด้วยตาโดยตรงมีความเหมาะสมสำหรับประเมินการเจริญเติบโตกระดูกสันหลังส่วนคอโดยไม่จำเป็นต้องเทรซซิงหรือกำหนดจุด แต่อย่างไรก็ตามทั้งสามวิธีอาจใช้แทนกันได้*