Comparative Study between the Hand-Wrist Method and Cervical Vertebral Maturation Method for Evaluation Skeletal Maturity in Cleft Patients

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Objective: *To test the measure of agreement between use of the Skeletal Maturation Index (SMI) method of Fishman using hand-wrist radiographs and the Cervical Vertebral Maturation Index (CVMI) method for assessing skeletal maturity of the cleft patients.*

Material and Method: *Hand-wrist and lateral cephalometric radiographs of 60 cleft subjects (35 females and 25 males, age range: 7-16 years) were used. Skeletal age was assessed using an adjustment to the SMI method of Fishman to compare with the CVMI method of Hassel and Farman. Agreement between skeletal age assessed by both methods and the intra- and inter-examiner reliability of both methods were tested by weighted kappa analysis.*

Results: *There was good agreement between the two methods with a kappa value of 0.80 (95% CI = 0.66-0.88, p-value <0.001). Reliability of intra- and inter-examiner of both methods was very good with kappa value ranging from 0.91 to 0.99.*

Conclusion: *The CVMI method can be used as an alternative to the SMI method in skeletal age assessment in cleft patients with the benefit of no need of an additional radiograph and avoiding extra-radiation exposure. Comparing the two methods, the present study found better agreement from peak of adolescence onwards.*

Keywords: *Hand-wrist method, Cervical vertebral maturation (CVMI), Skeletal maturity, Cleft patients*

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Cleft lip and palate patients often develop Class III malocclusion[1-3] which is mostly from midface growth deficiency[1] as a result of surgical repair of palatal clefts[3]. Knowing the growth status of the patients will help determine whether adolescent growth modification has potential to correct the individual's malocclusion, or if other options, such as orthognathic surgery or dental camouflage, are indicated. Therefore, the estimation of a patient's growth status is important. There are many indicators for growth evaluation but skeletal age is the most commonly used for this purpose[4-6]. Traditionally, orthodontists have used hand-wrist radiographs (HWR) to establish a patient's skeletal age. However, recently, the use of a cervical vertebral maturation index (CVMI) as a side benefit of lateral cephalometric films for skeletal age assessment has been proposed[4,7,8]. The advantage of this cervical vertebral maturation (CVMI) method is that there is no need of the additional HWR which can reduce extra radiation exposure and expense to the patient[4].

Compared to non-cleft patients, cleft patients are likely to be exposed to more radiation because they are treated over a longer period and usually require special radiographic techniques such as occlusal films to evaluate their cleft sites before and after alveolar bone grafting and postero-anterior film to evaluate their skeletal discrepancies in transverse dimension. So that it would be good to have an alternative way of assessing skeletal growth to help decrease radiation exposure other than by use of HWRs.

Therefore, the aim of present study was to compare the skeletal maturation assessed by Hassel and Farman's CVMI method with the Fishman's hand-wrist SMI method for young cleft patients to test whether it can be used interchangeably with HWR.

Material and Method

Material

The material comprised hand-wrist and lateral cephalometric radiographs of 60 non-syndromic cleft lip and/or palate patients, 25 males and 35 females aged

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from 7 to 16 years, from the Department of Orthodontics, Khon Kaen University, Thailand. This sample size was calculated by using the data from Gandini and co-workers[9] which studied in non-cleft patients. All hand-wrist and lateral cephalometric films were required to have good quality and high contrast and the interval period between the hand-wrist and lateral cephalometric films not exceeding one month. Furthermore, the hand-wrist films should be of the left hand. Patients who had craniofacial deformity, systemic disease, history of trauma or other factors that affect general development and craniofacial growth and development were excluded.

Methods

Skeletal maturation assessment

The hand-wrist and lateral cephalometric radiographs were inspected on a light box in a darkened room separately by two examiners who were orthodontic postgraduate students without knowing chronological ages.

Hand-wrist films were assessed according to Fishman's skeletal maturation index (SMI) method[5]. This SMI method using a hand-wrist radiograph identifies 11 stages of bone maturation at sites located on the thumb, third finger, fifth finger and radius. The guide for assessing stages of SMI is listed in chronological order of change in Table 1.

Lateral cephalometric films were used to determine the cervical vertebral maturation stage according to the CVMI method of Hassel and Farman[4]. This method assesses maturational changes of the second, third, and fourth cervical vertebrae (C2, C3, and C4, respectively). Six distinct stages of CVMI were defined by Hassel and Farman[4] as in Table 2.

After all hand-wrist and lateral cephalometric films were assessed, the eleven SMI stages of each subject were re-categorized in six growth intervals from A to F as shown in Table 3 to enable matching with the six CVMI stages. Then 6 stages of the CVMI method were compared with adjusted six Fishman's intervals of growth (ASMI) to find the levels of agreement between these two methods as shown in Table 4.

Statistical analysis

Agreement between skeletal age assessed from Fishman hand-wrist method and Hassel and Farman CVM method was tested by weighted kappa analysis using STATA version 10 (STATA Corp, LP. College Station, TX).

Reliability test

All hand-wrist and lateral cephalometric films were scored by the two examiners and each film was scored twice with a 2-week interval to minimize the effect of memory bias on the results. The reliability of intra- and inter-examiner was calculated using weighted kappa statistic.

The interpretation of kappa value was based on data according to Altman in 1991[10].

The present study was approved by the Khon Kaen University Ethic Committee (number HE552105).

Results

Intra- and inter-examiner reliability using both methods

The results in Table 5 show that the intra-examiner reliability in assessing with Fishman's hand-wrist method was very good for both examiners A and B with the kappa value of 0.99. The kappa value of

Table 1. Assessment using Fishman's SMI method[5]

SMI	Ossification events
1	Proximal phalanx of the third finger, epiphysis is as wide as its diaphysis
2	Middle phalanx of the third finger, epiphysis is as wide as its diaphysis
3	Middle phalanx of the fifth finger, epiphysis is as wide as its diaphysis
4	Ossification of adductor sesamoid of the first finger
5	Distal phalanx of the third finger, epiphysis caps its diaphysis
6	Middle phalanx of the third finger, epiphysis caps its diaphysis
7	Middle phalanx of the fifth finger, epiphysis caps its diaphysis
8	Distal phalanx of the third finger, fusion of the growth plate
9	Proximal phalanx of the third finger, fusion of the growth plate
10	Middle phalanx of the fifth finger, fusion of the growth plate
11	Radius, fusion of the growth plate

Table 2. Assessment of cervical vertebrae maturation index (CVMI) using Hassel and Farman's method[4]

Phase	Criteria
CVMI-1: initiation	Very significant amount of adolescent growth expected. C2, C3, and C4 inferior vertebral body borders are flat. Superior vertebral borders are tapered posterior to anterior.
CVMI-2: acceleration	Significant amount of adolescent growth expected. Concavities developing in lower borders of C2 and C3. Lower border of C4 vertebral body is flat. C3 and C4 are more rectangular in shape.
CVMI-3: transition	Moderate amount of adolescent growth expected. Distinct concavities in lower borders of C2 and C3. C4 developing concavity in the lower border. C3 and C4 are rectangular in shape.
CVMI-4: deceleration	Small amount of adolescent growth expected. Distinct concavities in the lower borders of C2, C3 and C4. C3 and C4 are nearly square in shape.
CVMI-5: maturation	Insignificant amount of adolescent growth expected. Accentuated concavities of inferior vertebral body borders of C2, C3 and C4. C3 and C4 are square in shape.
CVMI-6: completion	Adolescent growth is completed. Deep concavities are present for inferior vertebral body borders of C2, C3 and C4. C3 and C4 heights are greater than widths.

Table 3. Re-categorizing SMIs in six growth intervals (Adjusted SMI: ASMI)

ASMIs	Interval
1 and 2	A
3 and 4	B
5 and 6	C
7 and 8	D
9 and 10	E
11	F

Table 4. Comparing CVMI with Fishman's 6 intervals of growth

CVMI	Fishman's 6 interval of growth (Adjusted SMI: ASMI)
1	A
2	B
3	C
4	D
5	E
6	F

intra-examiner reliability of using Hassel and Farman's CVM method was 0.91 for examiner A and 0.93 for examiner B.

Inter-examiner reliability of Fishman's hand-wrist method was very good between the two observers with kappa value of 0.99 for the first and second assessments (Table 5). In addition, the kappa values of the first and second assessments of using Hassel and Farman's CVMI method (Table 5) were 0.94 for the first assessment and 0.95 for the second assessment, which indicated there was very good inter-examiner reliability with each method.

Agreement between the Hassel and Farman's CVMI method and the Fishman's ASMI method

The overall agreement between the Hassel and Farman's CVMI method and the Fishman's hand-wrist method was good with a kappa value of 0.80 (95% CI = 0.66-0.88, p-value <0.001). This indicated a good relationship between the Hassel and Farman's CVMI method and the Fishman ASMI hand-wrist method (Table 6).

The results presented in Table 6 show that there was total agreement between CVMI-1 and interval ASMI-A. On the other hand, agreement between CVMI-2 with interval ASMI-B and agreement between CVMI-3 with interval ASMI-C were low with more than half of the samples rated as CVMI-2 and CVMI-3 being categorized in the earlier intervals of growth. Interestingly, the subjects rated as CVMI-4, most of them (15 of 19), were categorized in the interval ASMI-D, and this indicated high agreement between these two methods when used to assess skeletal age of CVMI-4. In addition, the agreement between the two methods was less when subjects were assessed skeletal age as CVMI-5 and CVMI-6.

Regarding gender, the agreement between these two methods was moderate in males with kappa value of 0.51, whereas in females, the agreement was very good with the kappa value of 0.87.

Discussion

This is the first study to evaluate the agreement between Hassel and Farman's CVMI method and Fishman SMI method in cleft patients.

Table 5. Intra- and inter-examiner reliabilities of Hassel and Farman's CVMI method and Fishman's SMI method

	Intra-examiner reliability		Inter-examiner reliability	
	A	B	1st assessment	2nd assessment
SMI	0.99	0.99	0.99	0.99
CVMI	0.91	0.93	0.94	0.95

Table 6. Agreement of the Hassel and Farman's CVMI method and the Fishman's adjusted SMI method

CVMI of Hassel & Farman (CVMI)	Adjusted SMI (ASMI)					
	A	B	C	D	E	F
1	6	0	0	0	0	0
2	8	4	0	0	0	0
3	6	2	3	0	0	0
4	0	4	0	15	0	0
5	0	0	0	2	5	2
6	0	0	0	1	0	2

Disadvantages of using HWRs for skeletal age assessment such as the extra-radiation exposure and expense to patient have been proposed[4]. Therefore, the CVMI assessment on a lateral cephalometric film was introduced to overcome these drawbacks. The present study found good agreement between CVMI method and SMI, indicating that the CVM method used in the present study is a good alternative to Fishman's SMI method for evaluating skeletal maturation in cleft patients. This finding is in accordance with previous studies of normal (non-cleft) subjects by Kucukkeles et al[11], Kamal et al[12], and Joshi et al[13] who reported that the Hassel and Farman's CVMI method was as reliable as the Fishman's hand-wrist method. This agrees with a study in Brazilian cleft lip/palate patients which reported that the analysis of CVMI in a lateral cephalometric film can be used interchangeably with a HWR analysis method for skeletal age assessment[14]. Furthermore, Sun and Li from China[15,16] also support the use of the CVMI for assessing skeletal maturation in patients with cleft lip and palate.

Although there was overall agreement between the CVMI and ASMI, looking at the data in Table 6, the agreement was more closely associated with changes after the peak of adolescent growth onwards (from CVMI-3 or interval ASMI-C onwards)[4,5].

According to gender, the results of the present study are in agreement with those of Ball et al[17] who reported less satisfactory results in males. However, they are in contrast to two studies from India[12,13] which reported that the agreement between both methods was higher in males.

The kappa values for ASMI in the present study showed very good intra- and inter-examiner agreement. Since this hand-wrist method provided high reproducibility both within and between the interpreters, indicating that Fishman's hand-wrist method provides good reliability. Similarly, the kappa values of the intra- and inter-examiner agreement using Hassel and Farman's CVMI method indicated that there was very good agreement within and between the interpreters. The very good agreement of these reliability tests are concordant with those of Hassel and Farman[4] and Uysal et al[18]. The results from Kucukkeles et al[11] showed good to moderate intra- and inter-examiner agreement using this CVMI method.

However, recently Gabriel et al[19] and Nestman et al[20] reported poor reproducibility of CVMI in both intra- and inter-observer agreement. But, it should be noted that the results of both of these studies[19,20] were based on the CVMI method of Baccetti and co-workers[21] which was developed related to mandibular growth, not to general growth as is the CVMI method used in the present study. In addition, the results from those authors' study indicated that CVMI method of Hassel and Farman is a good reliable method of measurement.

Since the sample size of the present study was small (60 subjects), the recruitment of the sample sizes such as multi-center study would provide more precise results.

Conclusion

Hassel and Farman's CVMI method had overall good agreement with Fishman's hand-wrist method, although this may have been mainly associated with late adolescent growth changes. This indicated that this CVMI method can be used interchangeably with Fishman's SMI method using hand-wrist radiographs for determining skeletal age in cleft patients with the benefit of no need of a hand-wrist radiograph and avoiding extra-radiation exposure.

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Potential conflicts of interest

None.

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การศึกษาเปรียบเทียบอายุกระดูกระหว่างกระดูกสันหลังส่วนคอกับกระดูกข้อมือในผู้ป่วยปากแหว่งเพดานโหว่

มนเทียร มโนสุดประสิทธิ์, ทัศนีย์ วังศรีมงคล, พูนศักดิ์ ภิเศก, เมลิสสา จันทรมังกร

วัตถุประสงค์: *เพื่อทดสอบความสอดคล้องระหว่างวิธีภาพถ่ายรังสีกระดูกข้อมือของฟิชแมน และวิธีภาพถ่ายรังสีกระดูกสันหลังส่วนคอในการประเมินอายุกระดูกในผู้ป่วยปากแหว่งเพดานโหว่*

วัสดุและวิธีการ: *ทำการประเมินอายุกระดูกจากภาพถ่ายรังสีกระดูกข้อมือและภาพถ่ายรังสีกระโหลกศีรษะด้านข้าง ของผู้ป่วยปากแหว่งเพดานโหว่ จำนวน 60 ราย (เพศหญิง 35 ราย, เพศชาย 25 ราย อายุระหว่าง 7-16 ปี) โดยอายุกระดูกจะถูกประเมินโดยการใช้วิธีภาพรังสีกระดูกข้อมือของฟิชแมน จากนั้นนำค่าอายุกระดูกที่ได้ไปปรับและนำไปเปรียบเทียบกับอายุกระดูกที่อ่านได้จากวิธีภาพรังสีกระดูกสันหลังส่วนคอของ ฮาสเซลแอนด์ฟาร์แมน ค่าความสอดคล้องระหว่างอายุกระดูกที่อ่านได้จากทั้งสองวิธี ค่าความน่าเชื่อถือภายในตัวผู้ประเมินและระหว่างผู้ประเมินของแบบวัดทั้งสอง ถูกทดสอบโดยใช้สถิติสัมประสิทธ์แคปปา*

ผลการศึกษา: *พบว่าวิธีทั้งสองมีความสอดคล้องกันในระดับดีด้วยค่าแคปปา 0.80 (ค่าช่วงเชื่อมั่น ร้อยละ 95 = 0.66-0.88, p-value <0.001) และค่าความน่าเชื่อถือภายในตัวผู้ประเมินและระหว่างผู้ประเมินของแบบวัดทั้งสองอยู่ในระดับดีมากด้วยค่าแคปปาในช่วง 0.91 ถึง 0.99*

สรุป: *วิธีภาพถ่ายรังสีกระดูกสันหลังส่วนคอสามารถใช้เป็นทางเลือกในการประเมินอายุกระดูกในผู้ป่วยปากแหว่งเพดานโหว่แทนวิธีภาพถ่ายรังสีกระดูกข้อมือได้ ซึ่งประโยชน์ของวิธีทางเลือกใหม่นี้คือไม่ต้องมีการถ่ายภาพรังสีกระดูกข้อมือเพิ่มจึงสามารถช่วยให้ผู้ป่วยเลี่ยงจากการได้รับรังสีเพิ่มเติมได้ด้วย การศึกษานี้พบว่าทั้งสองวิธีนี้มีความสอดคล้องกันดีขึ้นตั้งแต่ช่วงที่ร่างกายมีการเจริญสูงสุดเป็นต้นไป*