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CORRELATION OF CERVICAL VERTEBRA MATURATION WITH HAND-WRIST MATURATION IN CHILDREN

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The purpose of this study was to evaluate the reliability of cervical vertebra maturation as an indicator of skeletal age during the circumpubertal period. This was determined by correlating cervical vertebra maturation to hand-wrist maturation. The vertebral skeletal age was assessed using lateral cephalometric radiographs according to maturity indicators modified from Lamparski. The hand-wrist skeletal age was evaluated in radiographs with the system developed by Fishman. The sample consisted of 503 subjects (244 boys and 259 girls), aged 8 through 18 years. The Spearman rank correlation coefficients and Wilcoxon sign rank test showed that a statistically significant relationship existed between the two assessments. Both the intra- and inter-judge tests of reliability displayed no significant differences. The results of this study indicate that skeletal age assessment made from the maturational changes of cervical vertebrae were reliable, reproducible and valid.

Key words:maturation, skeletal age, cervical vertebrae, hand-wrist radiograph, lateral cephalometric radiograph

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The use of skeletal age is more reliable and precise than chronological age in assessing an individual's maturity [1-7]. With many orthodontic or pedodontic patients, pubertal growth needs to be considered in diagnosis and treatment planning [8-11]. Determination of maturation and subsequent evaluation of growth potential during the circumpubertal period is extremely important. Orthodontic treatment during periods of accelerated growth can contribute significantly to correction of dentofacial deviations and improvement of facial appearance [12-15].

Skeletal changes of the hand and wrist are most frequently used to assess a patient's progress toward maturity, but other bones have also been used. The technique for assessing skeletal age consists of visual inspection of the bones – their initial appearance and subsequent ossification changes. Various areas of the skeleton have been used: the foot, the ankle, the hip, the elbow, the hand-wrist and the cervical vertebrae. Lamparski [16] described a reasonable alternative to the hand-wrist radiograph that used a lateral cephalometric radiograph that orthodontists routinely have as part of their records. He developed maturity indicators based on changes seen in the cervical vertebrae.

The purpose of this study was to determine whether the ossification events in the cervical vertebrae could be used to assess skeletal age with a precision comparable to that of the hand-wrist. Correlations were made between these two methods. The basis for selecting this area for assessment is that it can be recorded on routine lateral cephalometric radiographs, thus, eliminating the need for an additional radiograph.

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MATERIALS AND METHODS

The study sample consisted of 244 boys and 259 girls aged 8 through 18 years. Information on the 503 subjects was taken from the patient files of the orthodontic clinics of Kaohsiung Medical University Hospital and National Taiwan University Hospital (Table 1). The radiographs used included the left hand-wrist and the lateral cephalogram. Records were selected randomly; the only segregation of subjects was on the basis of gender and age. None of these subjects had congenital or acquired malformations of the cervical vertebrae or hand-wrist, and they did not have any developmental alterations due to medical syndromes or hormonal disorders.

The hand-wrist radiographs were evaluated using the system developed by Fishman [10, 17, 18], which uses four stages of bone maturation found at six anatomical sites located on the thumb, third finger, fifth finger, and radius (Fig. 1). The sequence of four ossification stages includes epiphyseal widening on selected phalanges, ossification of the adductor sesamoid of the thumb, capping of selected epiphyses over their diaphyses, and fusion of selected epiphyses and diaphyses. Eleven adolescent skeletal maturation indicators (SMI) are found on these six sites.

Lateral cephalographs were traced on 0.003-inch matte acetate with a 0.03-mm diameter mechanical lead pencil. Three parts of the cervical vertebrae were traced: the dens (odontoid process), the body of the third cervical vertebra (C3) and the body of the fourth cervical vertebra (C4). The cervical vertebrae tracings were evaluated for the presence or absence of curvature in the inferior borders of the dens, C3, and C4, and general shapes and forms of the bodies of C3 and C4. Cervical vertebrae C2, C3 and C4 were observed and each subject was placed in a cervical vertebrae maturation indicators (CVMI) category using the criteria as described in Fig. 2. Cervical vertebral development was evaluated using a modification of Lamparski's criteria [16] based on changes seen in the second to fourth cervical vertebrae on which maturational changes were assessed (Fig. 2). These areas were selected and not all of cervical vertebrae as in Lamparski's criteria because the fifth and sixth cervical vertebrae sometimes could not be visualized when a thyroid collar was worn during radiation exposure.

The CVMI readings were then evaluated statistically against the previously determined SMI readings to see what correlations existed. The Spearman rank correlation coefficients (r_s) and Wilcoxon sign rank test (W) were evaluated for the two skeletal maturity indicators.

The double determinations of 25 hand-wrist and cervical vertebrae skeletal age assessments made by one investigator of this study were checked for intra-judge tests of reliability. The 25 hand-wrist and cervical vertebrae skeletal age assessments made by two investigators were checked for inter-judge tests of reliability.

RESULTS

The Wilcoxon sign rank tests showed probability (p) values of 0.067 for the boys and 0.069 for the girls between the cervical vertebra and hand-wrist assessments of skeletal maturation (Table 2). The Spearman rank correlation coefficients were 0.9730 for the boys and 0.9701 for the girls (Table 3).

The CVMI categories were determined from 25 lateral cephalometric radiographs. These same radiographs were reevaluated 2 weeks later by the

Table 1. Number of subjects in each age group of 503 samples

Age (yrs)	Boy	Girl
8	22	26
9	29	36
10	26	41
11	39	30
12	27	28
13	23	21
14	21	21
15	21	22
16	21	20
17	8	6
18	7	8
Total	244	259

Table 2. Relationship between cervical vertebra and hand-wrist maturation stages

	Wilcoxon sign rank test		
Gender	N	W	p-value
Boy	244	77.500	0.067
Girl	259	83.000	0.069

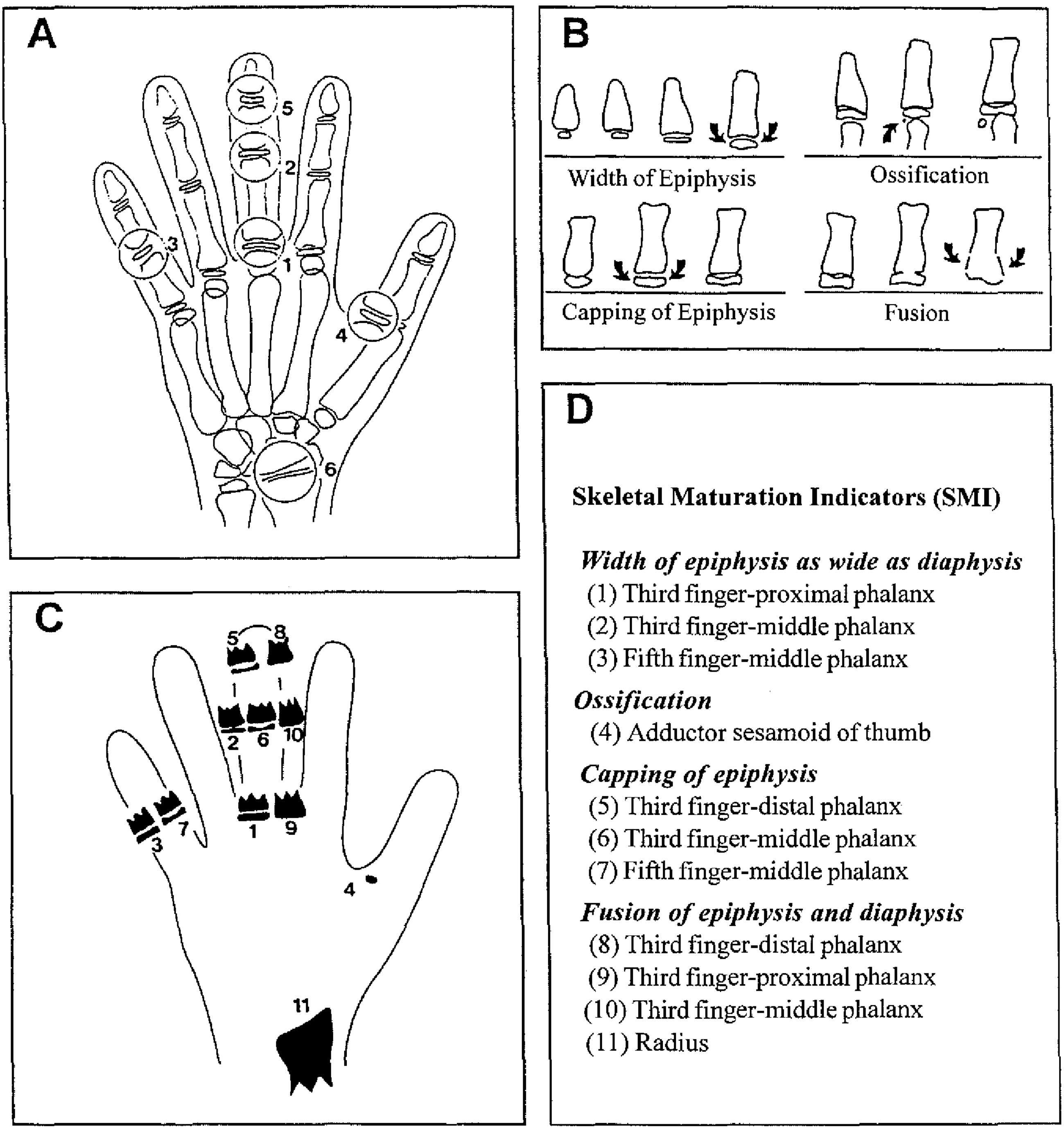

Fig. 1. Maturation stages of hand-wrist. A, sites of bone maturation; B, skeletal maturation indicators; C, stages of ossification; D, skeletal maturation indicators in chronological order (modified from Fishman).

same individual in the group of the authors. Twenty-three of 25 CVMI determinations were the same in the second evaluation as they were in the first (Wilcoxon sign rank test: W = 1.5000, df = 24, p = 0.5000) (Table 4).

The SMI categories from these same 25 subjects were also evaluated. The same hand-wrist radiographs were reevaluated 2 weeks later by the same person. Twenty-four of 25 SMI category determinations were the same as those determined 2 weeks previously (Wilcoxon sign rank test: W = 1.5000, df = 24, p = 0.5000) (Table 4).

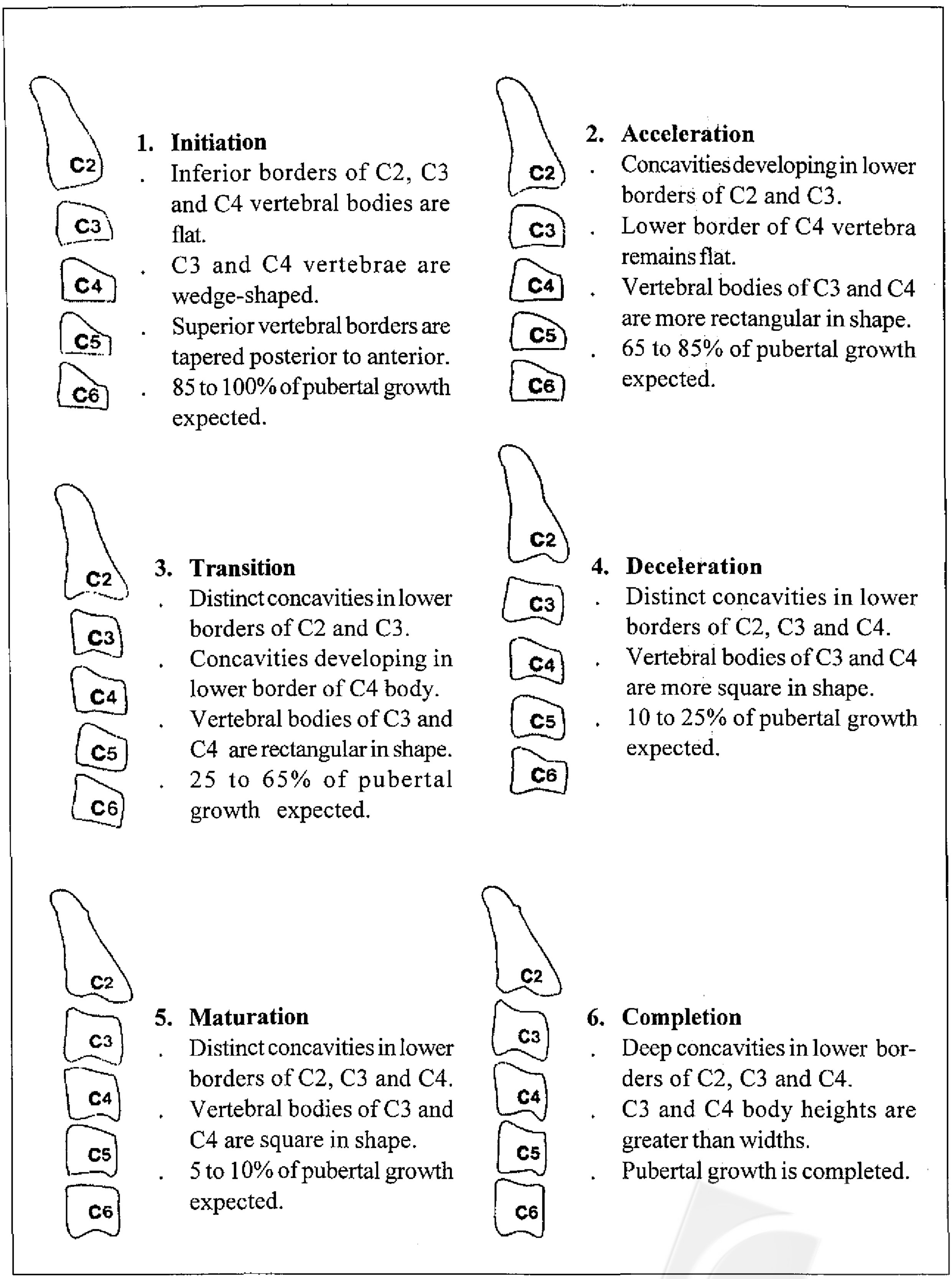

Fig. 2. Maturational stages of cervical vertebrae (modified from Lamparski).

The results of the double determinations of 25 hand-wrist and cervical vertebrae skeletal age assessments made by the two investigators are recorded in Table 5. Agreement of the SMI determination occurred in 24 of the 25 cases. The discrepancy was within one SMI category (Wilcoxon sign rank test: W = 0.500, df = 24, p = 1.000). The CVMI determination also agreed in 24 out of 25 times. A borderline case was interpreted with one category difference (Wilcoxon sign rank test: W = 0.500, df = 24, p = 1.000).

DISCUSSION

The shape and form changes of the C2, C3 and C4 vertebral bodies occur regularly and sequentially, and are summarized as follows:

1.The inferior borders of the vertebral bodies were flat when most immature, and concave when mature.

2.The curvatures of the inferior vertebral borders appeared sequentially from C2 to C3 to C4 as the skeleton matured.

3.The concavities became more distinct as the person matured.

4.The shapes of the C3 and C4 vertebral bodies changed from somewhat wedge shaped (tapering from posterior to anterior), to a rectangular shape, then to a square shape, and finally the vertical dimension became greater than the horizontal dimension, as skeletal maturity progressed.

The Wilcoxon sign rank tests indicated no significant differences between the cervical vertebra and hand-wrist assessments of skeletal maturation ($p > 0.05$). The Spearman rank correlation coefficients showed that very strong correlation existed between the two methods for both boys and girls ($p < 0.001$). The validity of hand-wrist assessments has been confirmed by many previous studies [1, 3, 5, 7, 11, 17, 18]. We showed that there are no significant differences between the cervical vertebra and hand-wrist assessments for determining stage of maturity. Thus, we conclude that cervical vertebra maturity assessment is a valid method to assess skeletal age.

Six distinct maturation stages in the cervical vertebrae are related to the hand-wrist maturation stages. The 11 SMI groupings in the hand-wrist were condensed into the six CVMI categories. The SMI groupings 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, and SMI 11 correlate to CVMI categories 1 through 6, respectively.

Both the intra- and inter-judge tests of reliability for cervical vertebral age displayed no significant difference between readings. The maturity indicators can be repeatedly assessed as the same and are, thus, reliable.

Finally, a significant difference existed between boys and girls in the mean ages of onset of skeletal maturation (data not shown). All skeletal stages were more advanced in girls than in boys.

The results of this cross-sectional study indicate that skeletal age assessments made from cervical vertebra maturational changes are reliable, reproducible and valid. Vertebral age is a valuable adjunct in clinical dentistry for assessment of the maturity status of an individual during the circumpubertal period. However, further longitudinal studies are required to determine the relationships between the vertebral age and increases in craniofacial growth and stature, and to refine and possibly quantify the changes seen in the cervical vertebrae.

Table 3. Correlation of cervical vertebra and hand-wrist maturation stages

Spearman rank correlation coefficient			
Gender	N	r_s	*p*-value
Boy	244	0.9730	< 0.001
Girl	259	0.9701	< 0.001

Table 4. Reliability tests for intrajudge errors of cervical vertebra and hand-wrist skeletal age assessments

	Wilcoxon sign rank test		
Skeletal age	W	*p*-value	df
Vertebra age	1.5000	0.5000	24
Hand-wrist age	1.5000	0.5000	24

Table 5. Reliability tests for interjudge errors of cervical vertebra and hand-wrist skeletal age assessments

	Wilcoxon sign rank test		
Skeletal age	W	*p*-value	df
Vertebra age	0.500	1.000	24
Hand-wrist age	0.500	1.000	24

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頸椎成熟度與手腕骨成熟度之相關性

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齒顎矯正患者的診斷與治療，發育成熟程度的判定及其後生長潛能的評估極爲重要。本研究之目的在於評估青春期前或青春期，使用頸椎骨成熟指數(Lamparski)來判定骨齡的的可靠性；使用頸椎骨齡的信度與效度，經由比對手腕骨齡(Fishman)的相關性。任意選取8歲至18歲，共11組研究對象，244位男性與259位女性，其手腕骨X光片與側顱X光片的描繪與判定，統計結果發現，包括司皮爾門等級相關係數(男性 $r_s = 0.9730$，　女性 $r_s = 0.9701$)以及威爾卡克森符號等級檢定(男性 W = 77.5 ，p值 = 0.067；女性 W = 83.0 ，　p值 = 0.069)，男性與女性都顯示這二種骨齡有顯著相關性。

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