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Correlation of Chronological Age and Skeletal Maturity in Chinese Patients: A Cross-Sectional Study

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The assessment of growth in the facial skeleton is very important for diagnosis and treatment planning in orthodontics treatment. With correct timing, the growth of the jaw of patients with favourable skeletal pattern could be altered. This study aims to examine the relationship between skeletal maturity and chronological age among Chinese patients attending USIM Polyclinic using the cervical vertebra method (CVM). The timing of peak pubertal growth was also determined. All cephalometric radiographs of Chinese patients aged 7-19 years from 2010 to 2016 were assessed. Thirty-two radiographs met the criteria. The cervical vertebrae on the radiograph were traced and classified according to Baccetti's newly modified version of cervical vertebrae maturation (CVM) stages (2005). Chronological age was found correlated (r_s = 0.622) with the CVM stages ($p < 0.001$). In conclusion, skeletal maturity and chronological age correlated among Chinese patients attending USIM polyclinic. The peak pubertal growth for male and female Chinese patients was also determined. The peak pubertal growth spurt, which occurred after CVM 3 and has occurred within 1 to 2 years before CVM 4, is after 12.0 and within one or two years before 14.0 ± 1.1 years for male and within one or two years before 15.45 ± 1.63 years for female.

Keywords: chronological age; CVM; peak growth; skeletal age; vertebral maturation

I. INTRODUCTION

The assessment of growth is indispensable in orthodontics treatment planning. Orthodontics patients usually come with complaint of unaligned teeth, teeth or chin too forward, or difficulty to eat properly because something is off with their bite. These can be treated by aligning the teeth or correcting the position of the jaw. In cases where the upper and lower jaws are not in harmony, the choice of treatment would either be the orthognathic surgery for adult patients or the functional appliance for growing patients. Using certain orthopaedics devices or known as the functional appliance, the growth of the jaw can be modified to a certain extent to improve the appearance and the relationships between the upper and lower jaw (Proffit *et al.*, 2007). However, the optimum result can only be achieved at a certain stage of growth (Hagg & Pancherz, 1998; Baccetti *et al.*, 2000). Although the retrognathic lower jaw in Class II skeletal cases is principally managed when the mandibular growth is at its peak, the prognathic mandible in Class III skeletal pattern is best handled before this phase (Bacetti *et al.*, 2005). In contrast, the surgical case requires growth to come to a halt (Proffit *et al.*, 2007).

Growth of the jaw is found to follow the somatic growth pattern. Patients' standing height records (Proffit *et. al.*, 2007; Graber, 1972) and sexual maturation phases (Hagg & Taranger, 1980a) are several indicators used to assess the somatic growth pattern and predict the peak pubertal growth of the patients. More precise methods using radiographs have been described in previous studies, such as the hand-wrist maturity (HWM) (Hagg & Taranger, 1980b; Perinetti & Contardo, 2017) and the cervical vertebral maturation (CVM) stage (Bacetti *et. al.*, 2002; Perinetti & Contardo, 2017). Despite the sensitive methods available, estimating the stage of patients' growth through their chronological age (Hagg & Taranger, 1982) is a simpler procedure that is still being used in students' clinic to avoid unnecessary radiograph. The prediction that is

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used, however, is based on the Caucasian sample (Mitchell, 2001).

On the other hand, most routine orthodontics examinations involve taking the lateral cephalometric radiograph. The spine or the cervical vertebral is usually included in this routine radiograph up to the fourth or fifth vertebrae. Therefore, despite taking extra radiograph as in HWM method, this radiograph is a useful predictor. CVM is also shown to have a high correlation with the chronological age (Wong *et al.*, 2009).

The general objective of this study is to obtain an overview of the relationship between chronological age and skeletal maturation among patients attending the USIM dental clinic. Since growth is significantly influenced by ethnic background (Proffit *et. al.*, 2007; Wingerd *et al.*, 2009), the study was conducted on a single ethnicity, the Malaysian Chinese. Using the CVM stage as the skeletal growth predictor, the relationship between chronological age and skeletal maturity among Chinese patients was investigated. Peak pubertal growth was also examined as it is crucial in some part of orthodontic treatment.

II. MATERIALS AND METHOD

A cross-sectional design was employed in this descriptive research. A total of 32 subjects comprising of cephalometric radiographs Chinese patients attending the undergraduates and specialist clinic of Faculty of Dentistry, USIM, was evaluated.

The inclusion criteria for this study were as follows: 1) patients aged 6 to 19 years with complete initial records, 2) normal development and growth, no history of chronic illness, no prior injury or trauma to the face area, no congenital or acquired malformation of the cervical vertebrae, and no developmental modification caused by hormone disorders or medical syndrome, 3) the radiograph was of high clarity, good contrast, and the first four vertebrae's inferior border were clear.

The date of the radiograph taken was recorded, while the chronological age of the patients was documented in accordance to the date of birth. All lateral cephalometric radiograph were taken on the same machine using both identical source subject and subject-film distances. All evaluations were conducted in a dark room with a light box to assure contrast enhancement of the bone images. The films' tracing was performed using a 0.003-inch matte acetate tracing paper and a 0.35H lead pencil. Three parts of the cervical vertebrae were traced, encompassing the body of the third cervical vertebrae C3, the body of the fourth cervical vertebrae C4, and the dens odontoid process C2.

The cervical vertebra was evaluated for skeletal maturation based on the newly modified Cervical Vertebral Maturation (CVM) method by Baccetti *et al.* (2005). This method is dependent on the morphology of three cervical vertebrae (C2, C3, and C4). They were assessed according to two sets of variables:

a) the absence or presence of a concavity at the inferior border of C2 (odontoid process), C3, and C4;
b) the shape of the bodies of C2, C3, and C4.

Trapezoid, rectangular horizontal, square, and rectangular vertical were examined as shown in Table 1.

Both variables are further segregated into six sequential stages (CS1 to CS6) in cervical maturation as shown in Figure 1. Bacetti *et al.* (2005) underline that the peak in mandibular growth will occur in the year after CS3 and within 1 or 2 years before cervical stage 4 (CS4).

The stages of cervical maturation were classified without learning the chronological ages.

Table 1. Definition of the CVM stage and the stage of growth represented

CVM stage (CS)	Definition	The peak of mandibular growth
CS 1	Lower borders of all three vertebras are flat.	Will occur on average 2 years after this stage.
	The bodies of both C3 and C4 are trapezoid in shape.	Prepubertal stage.
CS 2	Concavity is present at the lower border of C2.	Will occur on average 1 year after this stage.
	The bodies of both C3 and C4 are still trapezoid or rectangular in shape.	Prepubertal stage ('get ready' stage).
CS 3	Concavities at the lower borders of	Will occur during the year after this stage.

	both C2 and C3 are present.	Circumpubertal stage.
	The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape.	
CS 4	Concavities at the lower borders of C2, C3 and C4 are present.	Has occurred within 1 or 2 years before this stage.
	The bodies of C3 and C4 are rectangular horizontal in shape.	Circumpubertal stage.
CS 5	Concavities at the lower borders of C2, C3, and C4 are present.	Has ended at least 1 year before this stage.
	At least one of the bodies of C3 and C4 is square in shape.	Postpubertal stage.
	If not square, the body of other cervical vertebrae still is rectangular horizontal.	
CS 6	Concavities at the lower borders of C2, C3 and C4 are still evident.	Has ended at least 2 years before this stage.
	At least one of the bodies of C3 and C4 is rectangular vertical in shape.	Postpubertal stage.
	If not rectangular vertical, the body of other cervical vertebra is square.	

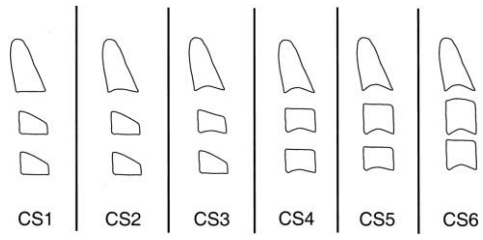

Figure 1. Schematic representation of the stages of cervical vertebrae maturation (CVM) according to the CVM method

Statistical analysis was conducted using the Spearman's rank correlation to analyse the correlation between the CVM stage and the chronological age. The mean was used to categorise the chronological age into each CVM stages. A reliability test was also carried out by the examiner to evaluate the agreement in determining the shape and the presence of concavity of the vertebrae and analysed using the Kappa score from SPSS.

III. RESULTS AND DISCUSSION

This study identified 44 folders from Chinese patients attending the orthodontic clinic. A total of 36 lateral cephalograms were obtained. However, only 32 samples met the inclusion criteria. From the 32 samples, 22 patients were females while 10 were males. The largest age group in this study was teenagers aged 17 (10 patients). The second-largest group, which consisted of 6 teenagers were 14 years old, whereas the 5 patients aged 16 made up the third-largest group. The rest of the samples were aged 18 (3 patients), aged 15 (4 patients), and aged 13 (3 patients). Only one sample was 12 years old. The distribution of patients by gender is shown in Figure 2, while the distribution of patients according to age is depicted in Figure 3.

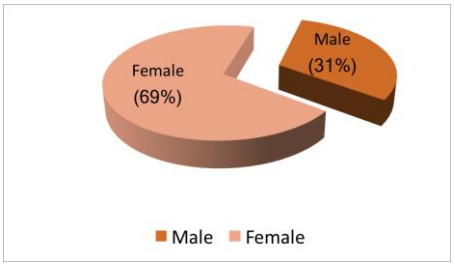

Figure 2. Sample distribution by gender

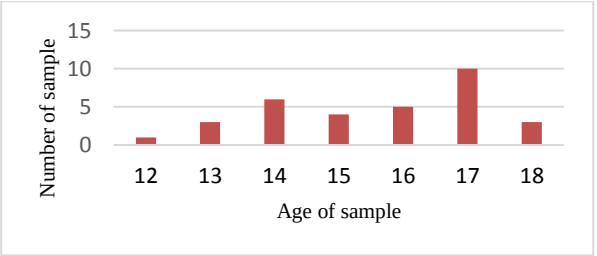

Figure 3. Sample distribution by age

As shown in Table 2 and Figure 4, the cervical vertebral maturation (CVM) stage is proven to be strongly correlated

to the chronological age with a value of $r_s = 0.622$ and $p < 0.001$, which is highly significant.

Table 2. The result of the Spearman's rank correlation analysis between the chronological age and the skeletal maturity (CVM) stage

Correlations

			Age when taking radiograph	CVM stage
Spearman's rho	Age when taking radiograph	Correlation Coefficient	1.000	.622**
		Sig. (2-tailed)	.	.000
		N	32	32
	CVM stage	Correlation Coefficient	.622**	1.000
		Sig. (2-tailed)	.000	.
		N	32	32

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4. Correlation between the chronological age and the skeletal maturity (CVM) stage

None of the study's samples was in CS 1 and CS 2. Only one patient could be categorised into CS 3 while most of the patients were in CS 4. The only patient that was categorised as CS 3 was a male patient aged 12. Patients that were in CS 4 were 6 males and 11 females, and had a mean age of 14.0 ± 1.1 and 15.45 ±1.63, respectively. The mean age for both genders in this stage was 14.94 ± 1.6. They made the largest group by being 17 out of 32 samples. From a total of 7 samples, only one 16-year-old male patient was in CS 5. Another 6 patients were female with a mean age of 16.0 ±0.89. Overall, the mean age for this stage is 16.14 ±0.9 years old. For CS 6, 2 males were categorised into this group with a mean age of 17.5 ±0.7, while 5 females in this group were in the mean age of 17.0 ± 0.7 years old. The mean chronological age for both genders in this group of 7 is 17.14 ± 0.69. It was also identified that the age of female patients is greater than the male patients in CS 4. This is also true in CS 5, but the difference is very small. In CS 6, the males were older than the females. The gender dimorphism could not be compared in CS 3 due to the unavailability of female patients. The mean chronological age for each CVM stage is shown in Table 3.

Table 3. Mean chronological age of Chinese patients attending USIM polyclinic for each CVM stage

CVM stage	**CS 3**	**CS 4**	**CS 5**	**CS 6**	
Chronological age for both genders (Years)	12.00	14.94 ± 1.60	16.14 ± 0.90	17.14 ± 0.69	Total number of male
Number of male (n)	1	6	1	2	10
Chronological age for male (Years)	12.00	14.00 ± 1.10	16.00	17.50 ± 0.70	Total number of female
Number of female (n)	0	11	6	5	22
Chronological age for female (Years)	-	15.45 ± 1.63	16.00 ± 0.89	17.00 ± 0.70	TOTAL
Total number of sample	1	17	7	7	32

The peak in mandibular growth will occur in the year after CS 3 and has occurred within 1 or 2 years before cervical stage 4 (CS 4). As shown in Table 3, this stage is from after 12.0 year old to within 1 or 2 years before 14.0 ± 1.1 years for males, and within a year or two before 15.45 ± 1.63 years for females.

A. Sample

The relatively small sample is a limitation of this study. Not many growing Chinese patients were indicated to take the lateral cephalometric radiographs when attending USIM polyclinic. Only one sample aged 12 was available. The unequal distribution between age may have also affected the comparison between gender. Nevertheless, the age of male and female patients was still analysed separately to observe the trend. The available data showed that pubertal growth spurt would have occurred 2 years earlier in females (Soegiharto *et. al.*, 2008; Mitchell, 2001).

B. Method

The skeletal age maturation among Chinese orthodontic patients can be carried out through cervical vertebrae maturation (CVM) assessment as indicated in the results. The skeletal maturation and the chronological age are proven to be strongly correlated in these patients. The CVM

method itself has received several criticisms, especially on its reproducibility (Nestman *et. al.*, 2011; Kucukkeles *et al.*, 1999). A study by Engel *et al.* in 2015 did not support the hypothesis that CVM can predict the peak craniofacial growth. Despite the negative response, the method demonstrates validity in various research. Its availability in a routine orthodontic record has attracted researchers to conduct extensive studies regarding the use of CVM as skeletal growth predictor and develop a proper method. It was originally described in 1972 by Lamparski, which was later proposed by Hassel and Farman in 1995. The improvisation was later done in a few stages through several studies (Bacetti *et. al.*, 2002; Bacetti *et. al.*, 2005; McNamara & Franchi, 2018). For the present study, a reliability test was conducted prior to the study in two weeks apart, showing a Kappa score of 1.00. The staging was also done according to a detail user's guide in 2018, which was based on nearly 20 years of experience in staging the CVM (McNamara & Franchi, 2018).

C. Peak Pubertal Growth

The jaw should still be in the stage of actively growing to be able to undergo an optimum growth modification. There is a period where a very rapid growth occurs, followed by further slower growth. This rapid growth phase is known as the circumpubertal growth period or the peak pubertal growth (Mitchell, 2001). According to Bacetti *et al.* (2005), the peak in mandibular growth will occur during the year after CS 3 and has occurred within 1 or 2 years before cervical stage 4.

Growth is not only significantly affected by racial background, but also by gender dimorphism (Proffit *et. al.*, 2007; Wingerd *et al.*, 2009). It is well-known that females attain maturity earlier than males in skeletal maturation (Taranger & Hagg, 1980). In this study, the samples comprised of 10 males and 22 females. This unequal sample distribution between genders could have affected the results in determining skeletal maturity stage among the samples. Chinese males were found to have a more advanced skeletal maturation in CVM stage 4 with a 1.5 years difference in mean, whereas females are more advanced in CVM stage 6 with a mean difference of 0.5 years. The peak pubertal growth for Chinese males is from after CVM 3 to within 1 to 2 years before CVM 4, which is from after 12.0 years to within a year or two before 14.0 ± 1.1 years old, while Chinese females were shown to be within a year or two before CVM 4, which is 15.45 ± 1.63 years old. The findings contradict a majority of other findings in previous studies. A record of a pubertal growth spurt of a Caucasian group showed that the male attained spurt later at 14 ± 2 years old lasting for 3 ½ years, while the female attained it at 12 ± 2 years old lasting for 2 years (Tanner *et al.,* 1975). The results derived from this study also showed a striking difference from the findings of a previous study on another Caucasian group. The Caucasian growth spurt was predicted to occur between 12.1 years and 17.1 years old in males and 10.0 years to 14.8 years old in females (Taranger & Hagg, 1980). Compared to Asian, Caucasian may attain skeletal maturation earlier. It was shown that white children attain 0.5 to 1 year earlier than their Indonesian peers (Soegiharto *et al.*, 2008). The trend, however, remains similar where males are found to attain spurt at a later age.

A previous similar study was done on Malay patients attending USIM polyclinic (Zahid *et al.*, 2017). This study has not studied the peak pubertal age separately according to gender. The previous study found that CS 3 occurs slightly later at the age of 13.20 ± 1.44 years, compared to the 13-year-old single Chinese sample in this study. While CS 4 occurs at 14.90 ± 2.35 years for Malays, Chinese was also shown to attain it at a similar age of 14.94 ± 1.6 years old. Overall, the peak pubertal growth was almost similar in both groups when gender is not considered. As for racial comparison, a study done on deutro-Malay in Indonesia shows that CS 3 and CS 4 could have occurred between 12 and 13 years old (Oscandar *et al.*, 2018) while pubertal growth spurt in Iranian girls was expected to occur at a mean age of 11.48 years (Safavi *et al.*, 2015).

A national survey done in Chinese ethnicity in the Republic of China showed that despite inheriting the same racial descendant, a significant difference in the timing of menarche was found between the rural and urban Chinese Han, where the urban Chinese girls attained menarche at an earlier age (Sun *et al.*, 2011). This could be used to explain our findings. Despite the difference in racial background, several readings in the current study were closely similar to the Malays from the previous study conducted in USIM. This could attributed to the environmental background, whereby the patients could have come from similar places nearby USIM.

D. Clinical Significance

As previously mentioned, the functional appliance is efficient in inducing the mandibular growth in Class II skeletal pattern, if performed during the pubertal growth spurt (Hagg & Pancherz, 1998). The peak pubertal growth for Chinese males is from after CVM 3 to 1 to 2 years before CVM 4, which is from after 12.0 years to within 1 to 2 years before 14.0 ± 1.1 years old, while for Chinese females is within a year before CVM 4, which is within 1 to 2 years before 15.45 ± 1.63 years old. The mean pubertal growth spurt for both genders is from after 12.0 to within 1 to 2 years before 14.94 ± 1.6 years old. Thus, the functional appliance should be instituted during or slightly after the age mentioned to gain the maximal effect. This is slightly different compared to the usual practice where the appliance is introduced to patients from aged 14 in males and aged 12 in females when the Caucasian group data were used as a reference (Mitchell, 2001).

A Class III skeletal pattern is where the lower jaw is protruded or the upper jaw is retruded. Thus, this condition demands the appliance be instituted before the peak growth spurt occurs. Bacetti *et al.* (2005) corroborated the findings that face mask and the rapid maxillary expander as best to be carried out during CS 1. However, as reflected in the result, no data were obtained from this study for CS 1 and CS 2.

For a stable result, orthognathic surgery was often recommended to be carried out after the pubertal growth spurt has ended (Proffit, 2007). The mandibular growth spurt should have ended at least two years after CS 6, thus, it can be said that the surgery should not be affected by growth, 2 years after age 17.14 ± 0.69 for Chinese patients. In Malay patients, the age is slightly higher at 17.58 ± 1.21 years old (Zahid *et al.*, 2017). Regardless of the findings, currently, only patients aged 19 years and above are considered for orthognathic surgery.

IV. CONCLUSION

The cervical vertebral maturation was used in this study to predict the stage of skeletal growth of Chinese patients. This can be employed to estimate the correct timing to treat patients using the orthopaedic device, other than using the available data of the Caucasian group. This data could also provide the estimated time that is suitable for surgical intervention. Although the sample is limited, the present study could serve as a sequence to the previous pilot study done in Malay patients, thus, becoming an addition to the available data.

This study concludes that there is a correlation between chronological age and skeletal maturity among Chinese patients attending USIM polyclinic. The timing of peak pubertal growth of male Chinese patients attending USIM polyclinic is from after 12.0 years to within 1 to 2 years before 14.0 ± 1.1 years old, while for female Chinese patients is within 1 to 2 years before 15.45 ± 1.63 years old. The mean peak pubertal growth for both genders is from after the age of 12 to within 1 to 2 years before 14.94 ± 1.60.

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