

ORIGINAL ARTICLE

Relationship Between Age at Menarche and Skeletal Maturation Stages in Taiwanese Female Orthodontic Patients

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Background/Purpose: The age at menarche reflects a pubertal girl's physiologic maturity. The aims of this study were to evaluate the relationship between the age at menarche and skeletal maturation in female orthodontic patients.

Methods: Hand-wrist radiographs and lateral cephalometric radiographs from 304 adolescent female subjects (age, 8–18.9 years) were selected from the files of the Department of Orthodontics, National Taiwan University Hospital (NTUH). Hand-wrist bone maturation stages were assessed using the NTUH Skeletal Maturation Index (NTUH-SMI). Cervical vertebral maturation stages (CVMS) were determined using the latest CVMS Index. Menarcheal ages were self-reported by the patients and verified by the patients' mothers. The relationships between the NTUH-SMI or CVM stages and menarcheal status were investigated.

Results: More than 90% of the 148 subjects who had already attained menstruation had skeletal maturation beyond the NTUH-SMI stage four or CVMS III. However, the subjects who had never experienced menarche mostly had skeletal maturation before NTUH-SMI stage five or CVMS IV. During the period of orthodontic treatment, 19 females experienced their menarche. The mean age at menarche for the 167 female patients in total was 11.97 years. In average, menarche occurred between NTUH-SMI stages four and five or between CVM stages III and IV. The percentage of girls with menses increased from 1.2% at age 9 to 6.6% at age 10, 39.5% at age 11, 81.4% at age 12, 97% at age 13, and 100% at age 14. Compared with the results obtained 20 years previously, we found a downward shift of 0.47 years per decade for the mean age at menarche in female orthodontic patients.

Conclusion: The majority of female orthodontic patients have passed the pubertal growth spurt when they experience their menarche. Menarche usually follows the pubertal growth spurt by about 1 year and occurs after NTUH-SMI stage four or CVMS III. [*J Formos Med Assoc* 2008;107(7):527–532]

Key Words: cervical vertebrae, hand bones, menarche, musculoskeletal development, wrist

In orthodontics, a clinician often has to evaluate the patient's physiologic and skeletal maturation before conducting the treatment. The most favorable orthodontic and dentofacial orthopedic treatment outcomes occur when the treatment begins at a patient's optimal maturation stage. Because there are considerable variations in development among individuals of the same chronological age, it has been advised the chronological age is not reliable for evaluating the skeletal maturation of an individual. Several biologic indicators have been proposed to assess individual physiologic

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Received: January 17, 2008

Revised: February 20, 2008

Accepted: March 4, 2008

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maturity. These include the increase in body height, pubertal markers (such as voice changes in males, menarche in females, breast development, and the appearance of pubic or axillary hair),¹ dental development and tooth eruption,² skeletal maturation of the hand and wrist,³ and skeletal maturation of the cervical vertebrae.⁴ Among these biologic indicators, serial recording of body height may not be practical. Evaluation of dental development has gained in popularity, and intraoral or panoramic radiography is needed. Assessing the skeletal maturation by reading hand-wrist and cervical vertebrae radiographs has been the most popular and accurate means used by the orthodontists. However, additional radiation exposure is required for this.

The age at menarche, an easily recallable event, is an important biologic indicator in assessing the physiologic maturity in girls. The relationship between the growth spurt in body height and onset of menarche has been investigated.⁵⁻⁸ The peak and end of the pubertal growth spurt could be assessed by means of menarche and hand-wrist skeletal maturation.⁷ It was reported that the growth velocity of body height stopped increasing within 1 year after menarche.⁸ A previous study has shown a strong correlation between peak height velocity and the peak velocity of facial growth during puberty.⁹ If the relationship between menarcheal age and skeletal maturation stages is determined, the onset of menarche may serve as an indicator for immediate clinical judgment of the facial growth in female orthodontic patients without resorting to radiographs. The age at menarche is known to be influenced by genetics, ethnic origins, socioeconomic status, general living conditions, and environmental factors.^{10,11} Downward shifts in the mean menarcheal age have also been observed worldwide during the past few decades.¹²⁻¹⁴ These could be assumed to be the consequences of improved sanitary, nutritional, and socioeconomic conditions. Economic gains in the mid-1980s in Taiwan¹⁵ might have acted in conjunction with the rapid rise in the estimated consumption of fat and protein, to result in a secular change in pubertal maturation.

The aim of this study was to evaluate the relationship between the age at menarche and skeletal maturation in Taiwanese female orthodontic patients.

Methods

Hand-wrist radiographs and lateral cephalometric radiographs from 304 adolescent female subjects (age, 8–18.9 years) were selected from the files of the Orthodontic Department of the National Taiwan University Hospital (NTUH). Each subject had to fulfill the following criteria: Chinese ancestry; no general developmental anomaly; no abnormal cervical vertebrae; menarcheal information provided; and possession of a good-quality hand-wrist radiograph (right hand) and lateral cephalogram (projected from the right side) taken on the same date. Each hand-wrist radiograph was evaluated and assigned to one of the nine skeletal maturation stages according to the NTUH-Skeletal Maturation Index (NTUH-SMI),¹⁶ which was developed for the Taiwanese population to evaluate physiologic maturity by determining ossification stages found at five anatomical sites located on the thumb, index finger, middle finger, and the radius. Each lateral cephalometric radiograph was assessed and assigned to one of the six cervical vertebral maturation stages (CVMS) according to Baccetti et al's latest definition¹⁷ by evaluating the outline and morphologic changes of the cervical vertebrae (C2, C3, C4). Our pilot study showed that Spearman's rank correlation of interobserver reliability ranged from 0.997 to 0.999 for the NTUH-SMI system and from 0.963 to 0.981 for CVMS. The correlation for intraobserver reliability was 1.000 for both NTUH-SMI and CVMS.

Menarcheal information was documented at the time when hand-wrist and lateral cephalometric radiographs were taken. The age at the onset of the first menstrual period was recorded to the nearest whole year. The mothers of the patients had been asked to confirm the exact menarcheal status reported by the patients themselves. Descriptive

statistics were used to calculate the means and standard deviations of the chronological age of the subjects in each of the nine NTUH-SMI stages and six CVM stages. The number of female subjects who already had attained menstruation at each year from age 9 to age 14 was calculated and described as a cumulative percentage. The sequence of the specified skeletal maturation indicators and the onset of menarche were tabulated for comparison of these growth events.

Results

A total of 304 adolescent female subjects fulfilled the inclusion criteria. The mean chronologic age and number of the subjects in each of the NTUH-SMI stages are shown in Table 1 and those in the CVM stages are shown in Table 2. There was a significant difference in the mean chronological age of subjects in nine different NTUH-SMI stages and in six different CVM stages (one-way ANOVA, $p < 0.001$).

All 304 female subjects were born between 1984 and 1997. Skeletal maturation of 148 female subjects who had already attained menstruation (post-menarche group) and of 156 female subjects who had never experienced menarche (pre-menarche group) according to the NTUH-SMI and CVMS is shown in Table 3. All 148 female patients in the post-menarche group had skeletal maturation beyond NTUH stage three or CVMS II. In addition, all 156 female patients in the pre-menarche group had skeletal maturation before NTUH stage nine or CVMS VI.

An additional 19 female patients attained their menarche during the period of orthodontic treatment. Accordingly, the number of subjects with menstruation increased from 148 to 167. The mean age at menarche for these 167 female subjects was 11.97 years. The distribution and cumulative percentage of these subjects according to the age at menarche is shown in Table 4. The percentage of girls with menses increased from 1.2% at age 9 to 6.6% at age 10, 39.5% at age 11, 81.4% at age 12, 97% at age 13, and 100% at age 14.

Table 1. Mean chronologic age and number of subjects in each of the National Taiwan University Hospital-Skeletal Maturation Index (NTUH-SMI) stages

NTUH-SMI stage	Subjects, <i>n</i>	Chronologic age (yr), mean \pm SD (range)
1	23	8.49 \pm 0.41 (8.00–9.58)
2	56	9.50 \pm 0.99 (8.17–2.08)
3	30	10.34 \pm 1.01 (8.50–12.67)
4	42	11.09 \pm 1.21 (8.25–14.42)
5	24	12.22 \pm 0.99 (10.50–14.00)
6	17	13.02 \pm 1.17 (11.25–15.33)
7	22	13.59 \pm 1.28 (11.42–15.58)
8	43	14.96 \pm 1.48 (10.67–18.83)
9	47	17.01 \pm 1.09 (14.08–18.92)

Table 2. Mean chronologic age and number of subjects in each of the cervical vertebral maturation stages (CVMS)

CVMS	Subjects, <i>n</i>	Chronologic age (yr), mean \pm SD (range)
I	68	9.14 \pm 0.88 (8.00–11.08)
II	40	10.18 \pm 1.12 (8.25–12.67)
III	35	10.71 \pm 1.04 (8.17–12.25)
IV	41	12.51 \pm 1.21 (9.67–16.42)
V	72	14.92 \pm 2.02 (10.67–18.92)
VI	48	16.02 \pm 1.57 (12.17–18.92)

The sequences of the specified skeletal maturation indicators and onset of menarche according to the mean ages are tabulated in Table 5. On average, menarche occurred between NTUH-SMI stages four and five (0.85 years after stage four and 0.38 years before stage five) or between CVM stages III and IV (1.17 years after stage III and 0.63 years before stage IV).

Discussion

Although the self-reported menarcheal age may cause bias, it has been documented that the recall method is reliable and valid enough for epidemiologic research.¹⁸ Previous studies on the recall age at menarche reported high correlation

Table 3. Assessment of skeletal maturation of 156 subjects in pre-menarche group and 148 subjects in post-menarche group using National Taiwan University Hospital-Skeletal Maturation Index (NTUH-SMI) and cervical vertebral maturation stage (CVMS)

CVMS	NTUH-SMI									Total
	1	2	3	4	5	6	7	8	9	
Pre-menarche										
I	21	44	2	1	0	0	0	0	0	68
II	2	10	25	3	0	0	0	0	0	40
III	0	2	2	26	2	0	0	0	0	32
IV	0	0	1	3	7	1	0	0	0	12
V	0	0	0	0	0	2	1	1	0	4
VI	0	0	0	0	0	0	0	0	0	0
Total	23	56	30	33	9	3	1	1	0	156
Post-menarche										
I	0	0	0	0	0	0	0	0	0	0
II	0	0	0	0	0	0	0	0	0	0
III	0	0	0	2	1	0	0	0	0	3
IV	0	0	0	7	12	6	3	0	1	29
V	0	0	0	0	2	8	15	25	18	68
VI	0	0	0	0	0	0	3	17	28	48
Total	0	0	0	9	15	14	21	42	47	148

Table 4. Distribution and cumulative percentage of 167 female subjects according to age at menarche

Age (yr)	Subjects, <i>n</i>	Cumulative %
8-9	2	1.2
9-10	9	6.6
10-11	55	39.5
11-12	70	81.4
12-13	26	97.0
13-14	5	100

coefficients between actual age and recall age at menarche with mean errors being lower than 0.5 years. High reliability has been reported even 30 years after the event occurred.¹⁸ In this study, all the menarcheal ages self-reported by the patients were also verified by the mothers to reduce errors in menstrual information.

In orthodontics and dentofacial orthopedics, it is important to identify the growth stage of an individual patient, because orthopedic appliances work well only when growth persists. The results of this study (Table 3) revealed that all 148 subjects who had already attained menstruation had

Table 5. Sequences of specified skeletal maturation indicators and onset of menarche according to mean chronologic ages (given in years within brackets)

Age (yr)	NTUH-SMI	CVMS
8	1 (8.49)	
9	2 (9.58)	I (9.22)
10	3 (10.44)	II (10.27)
		III (10.80)
11	4 (11.12)	Onset of menarche (11.97)
12	5 (12.35)	IV (12.60)
13	6 (13.09)	
	7 (13.45)	
14	8 (14.84)	V (14.79)
15		VI (15.79)
16		
17	9 (17.07)	

NTUH-SMI = National Taiwan University Hospital-Skeletal Maturation Index; CVMS = cervical vertebral maturation stage.

skeletal maturation beyond the NTUH-SMI stage three and only nine (6.1%) subjects who had experienced menarche had the skeletal maturation at NTUH-SMI stage four. According to previous

research, the NTUH-SMI stage three represents the accelerating period of the growth spurt and the NTUH-SMI stage four is considered as the stage when peak height velocity occurs.¹⁶ This implies that only a small percentage of female orthodontic patients had experienced menarche before peak height velocity, which concurs with the findings of Hägg and Taranger in their longitudinal and prospective growth study.¹ Our results also revealed that all 156 female subjects who had never experienced menarche had skeletal maturation before NTUH-SMI stage nine (Table 3). Pubertal growth is considered to be completed at the NTUH-SMI stage nine. This implies that the majority of female orthodontic patients would experience menarche by the time adolescent growth decelerates dramatically and before the growth spurt is completed. Thus, a clinician must know that a large proportion of female orthodontic patients should have passed peak height velocity if she attains menstruation at the time of initial examination or during orthodontic treatment.

On average, menarche occurred 0.85 years after NTUH-SMI stage four and 0.38 years before NTUH-SMI stage five (Table 4). This corresponded well to the findings that the attainment of menarche is highly correlated with the hand-wrist bone maturation stage five with a correlation coefficient of 0.95,¹⁹ and that menarche usually follows peak height velocity by about 1 year.⁷

Menarcheal age is not only an important maturity indicator for assessing the developmental status of an individual, it also reflects the socioeconomic status of the population. Several studies from different countries have shown the secular shift towards a younger age at menarche.¹²⁻¹⁴ However, the results from some countries revealed stability in age at menarche^{20,21} and a few showed a rising trend.²² The mean age at menarche of female orthodontic patients in this study was 11.97 years, which was 0.9 years earlier than that in the study conducted 20 years ago by Lin and Lee²³ and 0.14 years earlier than that in Wu's study conducted in 2005.²⁴ This implies that the mean age at menarche in female orthodontic

patients has an estimated downward shift of 0.47 year per decade. This secular trend may be related to the very rapid economic gains and changes in lifestyle during recent decades following the 1981-1982 economic recessions.¹⁵

As with other cross-sectional studies, there were some limitations in interpreting the data in this study. The current analyses were based on adolescent females seeking orthodontic treatment at the Orthodontic Department of the NTUH. Because the cost of orthodontic treatment is high and not covered by insurance, these female orthodontic patients most likely come from well-off families and live in a stable and affluent environment. Therefore, they may not be representative of the general Taiwanese population. It should be realized that menarcheal ages could vary by socioeconomic status, general living conditions, and location as well as environmental factors.^{10,11} Thus, the downward secular trend in maturation observed in this study should be interpreted with caution.

In summary, the current study demonstrated the relationship between the age at menarche and skeletal maturation stages. Our results showed that the majority of female patients have passed the pubertal growth spurt when they experience their menarche at the time of initial examination or during orthodontic treatment. Menarche usually follows peak height velocity by about 1 year. Further studies are recommended to address the longitudinal relationships among skeletal maturation stages, the age at menarche, and the growth of craniofacial structures in the Taiwanese population. A larger scale survey on the general child and adolescent population would be helpful to further elucidate the menarcheal trend and its relation to socioeconomic status and environmental factors in Taiwan.

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