Timing of adolescent growth spurt among children with different skeletal classes

Waqar Jeelani, Mubassar Fida, Attiya Shaikh

Abstract

Introduction: Treatment with growth modification appliances is only successful if commenced at the right stage of the adolescent growth spurt. The aim of this study was to determine and compare the mean age of the adolescent growth spurt among children with three skeletal malocclusions.

Material and Methods: A retrospective cross-sectional study was conducted on the lateral cephalograms of 440 children (203 boys and 237 girls) aged 9-17 years. Subjects were categorized into three skeletal classes (Class I=187, Class II=169, Class III=84) according to the sagittal jaw relationship. The cervical vertebral maturation (CVM) stage of each subject was recorded using Baccetti’s method. The mean age at each CVM stage was compared between males and females using Mann-Whitney U test and among the three malocclusion groups using Kruskal-Wallis test.

Results: Pubertal growth peak occurred on average 1.5 years earlier in girls than boys. The mean difference in the time of adolescent growth spurt between Class I and Class II girls was of 7.5 months ($p = 0.026$) and between Class I and Class III boys was of 10.5 months ($p = 0.022$). All boys >16.5 years and girls >16.0 years were found to be in cervical stage 6.

Conclusions: Girls experience adolescent growth spurts on average 1.5 years earlier than boys. Adolescent growth spurt in Class II girls occurs earlier than Class I girls, while Class III boys mature later than Class I boys. However, timing of completion of adolescent growth spurt was comparable among the three skeletal classes.

Keywords: Cervical vertebral maturation; cervical stage; orthognathic surgery; dentofacial orthopedics

Introduction

The orthodontists of the current era are more inclined towards treating the underlying skeletal malocclusion instead of camouflaging it with the dentoalveolar compensations. Functional jaw orthopedics remain a popular method of treating different skeletal malocclusions in growing children. Similarly, an increase in the number of the patients undergoing orthognathic surgery for the treatment of skeletal malocclusions has been reported. Treatment of the skeletal malocclusions is desirable not only to achieve a greater improvement in the overall facial esthetics but also to have a more stable treatment outcome as compared to the bare dental compensations made during a typical camouflage treatment.

Different periods of growth acceleration and deceleration are the key components of the human development. Various forms of dentofacial orthopedics are routinely utilized for the growth inhibition or promotion at certain growth sites in the craniofacial skeleton. The adolescent growth spurt, a period of rapid growth offers a wider range of therapeutic modifiability and thus is of particular interest to the orthodontists. In this context, recommendations have been made about the appropriate timing for the use of different functional appliances. Similarly, orthognathic surgery is generally warranted in patients in which the adolescent growth spurt is essentially over as continued growth remains an important factor resulting in

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relapse in these cases.\textsuperscript{14,15} Since the success or failure of functional jaw orthopedics and orthognathic surgery is closely related to the maturational status of the patient, the diagnosis of the developmental stage of the patient has critical importance in orthodontic treatment planning.

Common methods to identify different stages of adolescent growth spurt involve increase in body weight and height, skeletal maturation of the hand and wrist, dental development, sexual changes, and cervical vertebral maturation (CVM).\textsuperscript{16-23} Different studies\textsuperscript{24-26} and a systematic review\textsuperscript{27} have shown that CVM method is reliable and has a moderate to high level of reproducibility. The validity of this method has also been affirmed in the Pakistani subjects.\textsuperscript{28} In addition, the use of lateral cephalograms in the CVM method eliminates the need of an additional radiation exposure to the patient for the assessment of the skeletal maturity.\textsuperscript{26}

Wide variations in the timing of onset and duration of the adolescent growth spurt have been reported in the literature.\textsuperscript{26,30} These variations are primarily related to the genetic background, ethnicity, nutritional status and the overall health of a child.\textsuperscript{31,32} In this situation, distinguishing children of the same chronological age but with different degrees of skeletal maturation becomes more critical. Orthodontic treatment strategies are generally based on the type of malocclusion, thus identification of skeletal malocclusion related variations in the timing of pubertal growth spurt is likely to be of greater practical significance to the orthodontists. Hence, this study was conducted with an aim to assess the timing of the adolescent growth spurt in children with different skeletal malocclusions.

**Material and Methods**

A retrospective cross-sectional study was conducted using the pretreatment lateral cephalograms of growing children presenting at the dental clinics, Aga Khan University Hospital, Karachi. The sample size for three skeletal classes was calculated using the findings of Garcia-Drago and Arriola-Guillen.\textsuperscript{33} Alpha was set as 0.05 and power was kept at 80\% for sample size calculation which showed that a sample size of 43 in each group was sufficient in order to detect a clinically significant difference of $0.43 \pm 0.63$ year in the mean age at Cervical Stage (CS) 4 between Class I and Class III subjects. Cephalometric data of maximum number of available subjects were included to enhance the power of the study. Thus a total sample of 440 subjects was achieved.

The following inclusion criteria was used: children of Pakistani origin, age 7 to 18 years, and normal vertical facial pattern (anterior cranial base to the mandibular plane (SNMP) angle = 32° ± 5°).\textsuperscript{34} Lateral cephalograms of children with the history of any type of orthodontic treatment, trauma or surgery of facial structures, any syndrome or developmental anomaly, or any chronic systemic disorder were excluded.

Patient's age was recorded to the nearest month and was converted into decimal expression for further use in the statistical analyses. The skeletal class of each subject was determined from the ANB angle and the vertical facial pattern was assessed by the anterior cranial base to the mandibular plane angle (SNMP angle) (Figure 1).\textsuperscript{35} Subjects were divided into three groups according to the following criteria:

- **Skeletal Class I** - subjects with ANB angle $> 1^\circ$ and $\leq 4^\circ$ (187 subjects)
- **Skeletal Class II** - subjects with ANB angle $> 5^\circ$ (169 subjects)
- **Skeletal Class III** - subjects with ANB angle $< 0^\circ$ (84 subjects)
Cervical vertebral maturation stages were assessed on the lateral cephalograms by Baccetti's method. The Kolmogorov-Smirnov test was used to assess the normality of the measurements. The Mann-Whitney U test was used for comparison of mean ages of CVM between boys and girls. Comparison of age of CVM and SNMP angle among the three skeletal classes was made using the Kruskal-Wallis test. For paired comparisons between different skeletal classes the sample of children in CS1 and CS6 was discarded and post-hoc Dunnett’s T3 and Scheffe’s tests were used. A $p$-value of $< 0.05$ was taken as statistically significant. However, Bonferroni corrections were employed for $p$-value where necessary.

To check the intra and inter-examiner reliability in assessing the CVM status, the lateral cephalograms of 30 subjects were assessed by the principal investigator and a second observer at two intervals. The Kappa value for intra and inter-examiner reproducibility in assessing cervical stages were found to be 0.90 and 0.81, respectively.

**Results**

The study sample comprised of 203 boys and 237 girls. The total sample ($N = 440$) was distributed according to different cervical stages: CS1 ($n = 46$), CS2 ($n = 79$), CS3 ($n = 77$), CS4 ($n = 92$), CS5 ($n = 82$) and C6 ($n = 64$). The mean SNMP angle of the total sample was $31.30^\circ \pm 3.09^\circ$. The SNMP angle was compared among three skeletal classes that showed no significant difference ($p = 0.155$). The mean age at different cervical stages was compared between boys and girls that showed significant differences ($p < 0.05$) at CS2 to CS5 (Table I). Based on these sex-based differences further analyses were carried out separately for boys and girls. The results of the Kruskal Wallis test showed significant variations in the timing of CVM among the three Classes at CS2, 3 and 4 across both genders (Table II).

Post-hoc analysis of children in CS 2 to CS5 showed that Class II girls undergo the adolescent growth spurt on average 0.63 year ($p = 0.025$) earlier than the Class I girls while Class II boys mature 0.23 years ($p = 0.664$) earlier than Class I boys. The Class III boys...
enter adolescent growth spurt on average 0.88 years later than the Class I boys \((p = 0.022)\) while the same difference was found to be 0.58 years \((p = 0.200)\) in girls (Table III). The mean age at CS5 was 14.65 ± 0.80 years for boys and 13.71 ± 1.49 years for girls. The age of completion of adolescent growth spurt was assessed with respect to the maximum age at CS5 which was 16.5 years for boys and 16 years for girls after which all the subjects were found to be in CS6.

### Table II: Mean age of CVM among three skeletal Classes

<table>
<thead>
<tr>
<th>Gender</th>
<th>Cervical Stage</th>
<th>Mean Age (years ± SD)</th>
<th>(p)</th>
<th>Post hoc Dunnett’s T3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Class I</td>
<td>Class II</td>
<td>Class III</td>
</tr>
<tr>
<td>Boys</td>
<td>CS 1</td>
<td>9.76 ± 1.65</td>
<td>9.65 ± 0.91</td>
<td>10.33 ± 0.50</td>
</tr>
<tr>
<td></td>
<td>CS 2</td>
<td>11.05 ± 1.06</td>
<td>10.89 ± 0.91</td>
<td>12.37 ± 0.55</td>
</tr>
<tr>
<td></td>
<td>CS 3</td>
<td>12.51 ± 0.88</td>
<td>12.02 ± 0.99</td>
<td>13.47 ± 0.62</td>
</tr>
<tr>
<td></td>
<td>CS 4</td>
<td>13.86 ± 0.42</td>
<td>12.95 ± 0.91</td>
<td>13.95 ± 0.70</td>
</tr>
<tr>
<td></td>
<td>CS 5</td>
<td>14.58 ± 0.99</td>
<td>14.72 ± 0.94</td>
<td>14.79 ± 0.82</td>
</tr>
<tr>
<td></td>
<td>CS 6</td>
<td>15.86 ± 0.73</td>
<td>15.33 ± 0.44</td>
<td>16.46 ± 0.87</td>
</tr>
<tr>
<td>Girls</td>
<td>CS 1</td>
<td>9.95 ± 0.98</td>
<td>10.28 ± 1.46</td>
<td>9.20 ± 0.93</td>
</tr>
<tr>
<td></td>
<td>CS 2</td>
<td>11.19 ± 0.90</td>
<td>10.19 ± 0.76</td>
<td>11.46 ± 0.78</td>
</tr>
<tr>
<td></td>
<td>CS 3</td>
<td>11.87 ± 1.03</td>
<td>11.61 ± 0.74</td>
<td>12.90 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>CS 4</td>
<td>12.93 ± 1.03</td>
<td>12.57 ± 0.69</td>
<td>13.59 ± 0.55</td>
</tr>
<tr>
<td></td>
<td>CS 5</td>
<td>13.75 ± 1.21</td>
<td>13.37 ± 1.93</td>
<td>14.40 ± 1.10</td>
</tr>
<tr>
<td></td>
<td>CS 6</td>
<td>15.83 ± 0.95</td>
<td>15.30 ± 1.17</td>
<td>16.17 ± 0.67</td>
</tr>
</tbody>
</table>

N = 203; SD - Standard Deviation; Kruskal-Wallis test with Bonferroni correction
After applying Bonferroni correction for multiple testing a \(p\)-value of <0.025 was taken as statistically significant.

\*\(p < 0.025\); **\(p < 0.001\)

**Discussion**

In orthodontic practice, a significant degree of speculation is involved in determining the growth status of a patient.\(^{36}\) Inaccurate diagnosis of skeletal maturity of a patient may result in failure to achieve significant skeletal improvement through dentofacial orthopedics and compromised stability of the corrective jaw surgery. The use of functional appliances in the preadolescent years is
associated with a high risk of relapse with original malocclusion returning in the forthcoming years. On the other hand, a great deal of unwanted dentoalveolar changes are the usual outcome of long functional appliance therapy carried out in the terminal stages of the adolescent growth spurt.

The variations in the onset and duration of the adolescent growth spurt may also play a role in determining the final facial form of an individual. Different craniofacial structures respond differently to the altered hormonal state during the adolescent growth spurt with studies showing mandibular growth being accelerated to a greater extent than the maxilla.

Table I. Comparison of mean age of CVM between males and females

<table>
<thead>
<tr>
<th>Cervical Stage</th>
<th>Boys (n=203) (years ± SD)</th>
<th>Girls (n=237) (years ± SD)</th>
<th>Mean Difference (years)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 1</td>
<td>9.81 ± 1.40</td>
<td>9.84 ± 1.24</td>
<td>0.03</td>
<td>0.941</td>
</tr>
<tr>
<td>CS 2</td>
<td>11.95 ± 1.03</td>
<td>10.69 ± 0.97</td>
<td>1.25</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>CS 3</td>
<td>12.61 ± 1.03</td>
<td>11.20 ± 0.92</td>
<td>1.41</td>
<td>0.002*</td>
</tr>
<tr>
<td>CS 4</td>
<td>13.69 ± 0.85</td>
<td>12.19 ± 0.91</td>
<td>1.50</td>
<td>0.003*</td>
</tr>
<tr>
<td>CS 5</td>
<td>14.68 ± 0.81</td>
<td>13.22 ± 1.50</td>
<td>1.45</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>CS 6</td>
<td>15.80 ± 0.76</td>
<td>15.21 ± 1.02</td>
<td>0.58</td>
<td>0.200</td>
</tr>
</tbody>
</table>

N = 440; SD - Standard Deviation; Mann Whitney U t-test
*p < 0.05; ** p < 0.001

During the adolescent growth spurt the growth potential of the patient is rapidly utilized. This depletes the population of progenitor cells and gives a more stable adult form to different body structures. A late start of the adolescent growth spurt invokes rapid growth of jaw bones when they have already achieved a larger size; while an early start of the adolescent growth spurt is likely to result in a small final size of different body structures. These theories are endorsed by the results of current study showing that the adolescent growth spurt occurs earlier in children with Class II malocclusion and later in those with Class III malocclusion. Same concept has been used by various authors trying to relate and early onset of puberty to a small sized mandible in girls as compared to the boys.

Table III. Mean differences in the timing of adolescent growth spurt among three skeletal classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>I vs II</td>
<td>0.23 (~ 2½ months)</td>
<td>0.63 (~ 7½ months)</td>
</tr>
<tr>
<td>Std. Error Difference</td>
<td>0.26</td>
<td>0.23</td>
</tr>
<tr>
<td>p</td>
<td>0.664</td>
<td>0.025*</td>
</tr>
<tr>
<td>I vs III</td>
<td>-0.88 (~ 10½ months)</td>
<td>-0.58 (~ 6½ months)</td>
</tr>
<tr>
<td>Std. Error Difference</td>
<td>0.31</td>
<td>0.32</td>
</tr>
<tr>
<td>p</td>
<td>0.022*</td>
<td>0.200</td>
</tr>
<tr>
<td>II vs III</td>
<td>1.12 (~ 13½ months)</td>
<td>1.21 (~ 14½ months)</td>
</tr>
<tr>
<td>Std. Error Difference</td>
<td>0.30</td>
<td>0.32</td>
</tr>
<tr>
<td>p</td>
<td>0.002*</td>
<td>&lt;0.001**</td>
</tr>
</tbody>
</table>

N = 440; Post Hoc Scheffe test, After applying Bonferroni correction for multiple testing a p-value of <0.025 was taken as statistically significant.*p < 0.025; ** p <0.001

Sexual maturity has been used as a reliable indicator of different stages of adolescent growth spurt. Literature shows the girls reach the skeletal maturity on average 2 years earlier than the boys. As judged from the timing of CVM, we found this difference to be...
of about 1.5 years in our sample. There is evidence that the secular trend in the age at menarche has reached a plateau, however, newer studies continue to highlight secular trends in the age of sexual maturation in boys. Concurrently, the ethnic variations in the timing of adolescent growth spurt are also reported in the literature. These factors, along with familial trends, nutritional status and systemic diseases necessitate for the orthodontist to have a keen look at the probable time of the adolescent growth spurt in a specific patient.

Assessing the time of pubertal growth spurt in the different skeletal malocclusions may represent a reverse prediction model since a specific skeletal jaw relationship may result from the variations in the timing and duration of pubertal growth spurt. Armond et al. has shown that the children with Class II malocclusion have a tendency to mature earlier than those with Class I jaw relationship. Similar results were given by Salazar-Lazo et al. who showed a difference of about 6 months in the timing of pubertal growth peak between Class I and Class II children. On the other hand, studies show that the duration of pubertal growth peak in Class III children is on average 5 months longer as compared to the Class I children. However, the increment in the jaw size during the pubertal growth spurt has been found to be comparable among the three skeletal classes. Similarly, there is strong evidence that in the cases of mandibular prognathism the mandible generally continues to show significant growth even after the pubertal growth spurt is over. Thus the variations in the timing of the adolescent growth spurt is less likely to significantly affect the final size of the mandible.

A controversy remains about the best method of assessing the developmental status of a child as some practitioners continue to give equal importance to dental and chronological age as compared to the skeletal age. Santioago et al. showed a moderate to high level of reproducibility of CVM method in assessing the skeletal maturity of an individual using the Kappa statistics. Same method was used in the present study which showed a high level of reproducibility in assessing CVM stages. Altered patterns in the skeletal and dental maturation have been reported among various vertical facial patterns. In this context, subjects with only normal vertical facial pattern were included in this study. The assessment of the craniofacial growth asks for a longitudinal study design as an essential method for reliable results. The longitudinal studies require repeated exposure to x-ray radiations that has certain ethical limitations.

**Conclusions**

From the results of the current study following conclusions are derived:

- Girls enter the adolescent growth spurt around 1.5 years earlier than boys.
- The Class II girls enter the adolescent growth spurt 7.5 months earlier than the Class I girls.
- The Class III boys enter the adolescent growth spurt 10.5 months later than the Class I boys.
- Girls enter the final stage of the adolescent growth spurt (CS6) on average 1.3 years earlier than boys.
- No significant differences in the timing of completion of the adolescent growth spurt were present among children with different skeletal classes.

Orthodontists should consider these variations in the timing of the adolescent growth spurt while assessing the developmental status, so that an effective and efficient treatment plan may be formulated for each patient.

**References**

2. Proffit WR, Jackson TH, Turvey TA. Changes in the pattern of patients receiving surgical-orthodontic
32. Parent AS, Teilmann G, Juul A, Skakkebaek NE, Toppari J, Bourguignon JP. The timing of normal puberty and the age limits of sexual precocity:
variations around the world, secular trends, and changes after migration. Endocr Rev 2003;24:668-93.