RESUMEN
El objetivo de la investigación fue determinar la duración del pico de crecimiento puberal a través del análisis de maduración de vértebras cervicales en adolescentes con maloclusión de Clase I y II.

La muestra de estudio estuvo constituida por 154 cefalogramas laterales de niños y adolescentes de 9-15 años de edad (84 mujeres y 70 hombres). Se realizó la evaluación de la etapa de maduración de las vértebras cervicales mediante el análisis morfológico visual (CS3 y CS4). La sagital esquelética relation was evaluated according to Steiner analysis. Descriptive statistics were used to summarize chronological age in each malocclusion group and for each CS3 and CS4 skeletal maturation stage. Due to a lack of normal distribution, comparisons of CS3 and CS4 age intervals on class I and II subjects were compared using the Mann-Whitney U test for independent samples. The results show that the mean duration of the adolescent peak growth spurt was 10 months between CS3 and CS4 stages in class I malocclusion subjects, whereas in class II malocclusion patiente the duration was 6 months. This difference of 4 months was statistically significant (p<0.001).

Los resultados muestran que el promedio de duración del pico de crecimiento puberal fue 10 meses entre CS3 y CS4 etapas en el grupo de maloclusión de Clase I, mientras que en el grupo de maloclusión Clase II la duración fue de 6 meses. Esta diferencia de 4 meses fue estadísticamente significativa (p<0.001).

Finalmente se identificó una diferencia clínicamente significativa de 4 meses en la duración del período del pico de crecimiento puberal entre los adolescentes con maloclusión de Clase I y II.

DURACIÓN DEL PICO DE CRECIMIENTO DE LA ADOLESCENCIA EN SUJETOS CON MALOCLUSIÓN DE CLASE I Y II UTILIZANDO EL MÉTODO DE MADURACIÓN DE VÉRTEBRAS CERVICALES

INTRODUCCIÓN
Determinación de la maduración esquelética durante la preadolescencia y la adolescencia es importante para planificar la ortodoncia. Uno de los métodos disponibles para realizar este seguimiento es el análisis morfológico visual de las vértebras cervicales durante la maduración esquelética. El análisis morfológico visual se realiza mediante el análisis del crecimiento de las vértebras cervicales durante la maduración esquelética. En este estudio se utilizó el método de Steiner para evaluar la relación sagital esquelética de acuerdo a cada etapa de maduración esquelética CS3 y CS4. Se calculó la duración de la etapa de maduración esquelética CS3 y CS4 para cada maloclusión de Clase I y II.

DURACIÓN DEL PICO DE CRECIMIENTO DE LA ADOLESCENCIA EN SUJETOS CON MALOCLUSIÓN DE CLASE I Y II UTILIZANDO EL MÉTODO DE MADURACIÓN DE VÉRTEBRAS CERVICALES

DURATION OF THE PEAK OF ADOLESCENT GROWTH SPURT IN CLASS I AND II MALOCCLUSION SUBJECTS USING A CERVICAL VERTEBRAE MATURATION ANALYSIS

ABSTRACT
The aim of the present work was to determine the duration of the adolescent peak growth spur using cervical vertebral maturation analysis in class I and II malocclusion subjects.

The study was conducted on a sample which consisted of 154 lateral cephalograms of children and adolescents aged 9-15 years (84 females and 70 males). The evaluation of skeletal maturation stage was performed using a visual morphological analysis of CS3 and CS4 cervical vertebrae. The sagittal skeletal relation was evaluated according to Steiner analysis. Descriptive statistics were used to summarize chronological age in each malocclusion group and for each CS3 and CS4 skeletal maturation stage. Due to a lack of normal distribution, comparisons of CS3 and CS4 age intervals on class I and II subjects were compared using the Mann-Whitney U test for independent samples. The results show that the mean duration of the adolescent peak growth spurt was 10 months between CS3 and CS4 stages in class I malocclusion subjects, whereas in class II malocclusion subjects the duration was 6 months. This difference of 4 months was statistically significant (p<0.001).

Finally, a clinically significant difference of 4 months in the duration of the adolescent peak growth spurt for class I and II malocclusion subjects was identified.

Key words: cervical vertebrae; cephalometry; malocclusion

INTRODUCTION
Determination of craniofacial skeletal maturation and concomitant evaluation of its growth potential during preadolescence or adolescence is important for orthodontic treatment planning. One of the available diagnostic tools currently used is the evaluation of the morphological changes in the cervical vertebrae during skeletal maturation. Growth potential and skeletal maturity can be determined using anatomical changes of the cervical vertebrae observed on lateral cephalometric radiographs. In 1972, Lamparski created the first standards for cervical vertebrae maturation as related to chronological age and to skeletal maturation through hand-wrist radiographs. Baccetti et al. presented an improved version of the cervical vertebrae maturation (CVM) and its validity for the appraisal of mandibular skeletal

Rodrigo Salazar-Lazo1, Luis E.Arriola-Guillén2, Carlos Flores-Mir3
1 School of Dentistry, University of Applied Sciences, Lima, Peru.
2 School of Dentistry, Científica del Sur University and University of San Marcos, Lima, Peru.
3 Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada.
maturity. They related the vertical growth of the mandibular ramus (expressed cephalometrically by the measure Co-Go) to the morphology of the bodies of the second (C2 –odontoid process), third (C3), and fourth (C4) cervical vertebrae. Chen et al.8 reinforced the possibility of evaluating mandibular growth with the use of cervical vertebral measurements based on the mandibular bone location next to the cervical vertebrae: the time of mandibular bone formation is closer to that of the cervical vertebral bone than of the hand-wrist bone. Subsequently, a few authors have warned that CVM has only a moderate level of correlation with the individual’s skeletal maturation13, so calibration and training are prerequisites for correct diagnosis in research.

The Steiner cephalometric analysis is one of the tools that identify maxillary sagittal skeletal relations (anteroposterior discrepancy of the jaws). According to Steiner9, the relationship of the maxilla and mandible is defined by angle ANB. Class I occurs with an ANB angle of 0° to 4°; class II, with an ANB angle greater than 4°, and class III with an ANB angle below 0°. Although Steiner’s ANB remains a reference for the sagittal skeletal relation diagnosis16-17, not all authors agree with it13,14, but in typical cases of Class II with great overjet, the diagnosis is more exact.

It has been reported that in subjects with Class III malocclusion, the greatest “increase” in mandibular length (coincident with the pubertal peak), occurred on average one year later in both sexes with Class III skeletal relationships than it did in those with Class I relationships15-16. The literature provides indications about the duration of the pubertal peak in subjects with Class I occlusions, and there is very little information for Class III15, but information about the duration of the growth peak in persons with Class II malocclusion is lacking and there is no comparative study comparing the length of the adolescent peak growth spurt between class I and II malocclusions. Significant differences have been found between class I and III malocclusions. Kuc-Michalska & Baccetti15 reported greater increases in mandibular length during the pubertal peak for class III malocclusion subjects. They related this to a longer duration of the adolescent pubertal peak spurt than in subjects with normal sagittal skeletal relationship. Thus, the purpose of the study was to determine the duration of the adolescent peak growth spurt according to Baccetti’s cervical vertebral maturation analysis of skeletal Class I and II malocclusion subjects.

### MATERIALS AND METHODS

This study was approved by a local ethics committee. The pre-treatment lateral cephalograms of 154 subjects were analysed. The sample consisted of 84 males and 70 females, whose ages ranged from 9 to 15 years. They were divided into four groups according to their cervical vertebral maturation stages and skeletal facial growth pattern (CS3-Class I = 41, CS3-Class II = 43, CS4-Class I = 34, CS4-Class II = 36). Sample size was calculated considering the comparison of two means for sample size estimation with a one-sided significance level of 0.05, a standard deviation of 5 months, a precision of 6 months and a power of 90%. The expected variance was obtained from a pilot study based on the duration of the adolescent peak growth spurt in Class II between stages CS3 and CS4. Based on these parameters, a minimum of 18 patients per group was required, but the final number of patients per group was higher (Table 1).

The following inclusion criteria were considered:

- Lateral cephalograms of good quality.
- Skeletal Class I malocclusions (control group) included subjects with ANB 2° ± 2° according to Steiner9, bilateral Class I angle malocclusion, bilateral Class I molar relations, overjet 2 to 4 mm, and Frankfort to mandibular plane angle (FMA) within the range of 25°± 3°.
- Skeletal Class II malocclusions based on the ANB>5°, Class II-1 angle malocclusion, bilateral Class I molar relations, overjet greater than 5 mm, and Frankfort to mandibular plane (FMA) angle greater than 29°.

| Table 1: Sample distribution according to sex, skeletal relation and cervical vertebral stage. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Skeletal relation | Cervical vertebral stage | Sex | Female | Male | Total |
| Class I | CS3 | 21 | 20 | 41 |
| Class I | CS4 | 20 | 14 | 34 |
| Class II | CS3 | 23 | 20 | 43 |
| Class II | CS4 | 20 | 16 | 36 |
| Total | | 84 | 70 | 154 |

Skeletal stages CS3 or CS4 based on the CVM method. CS3 corresponds to the initial stage of the accelerative portion of the pubertal growth peak, and CS4 corresponds to the final stage of the accelerative portion of the pubertal growth peak in adolescents. (Figs. 1 - 5)

General exclusion criteria were patients with previous orthodontic treatment, with congenitally missing or extracted teeth or systematic diseases.

Imaging was performed with digital cephalometric panoramic equipment (ProMax®, Planmeca, Finland). Device settings were set at 16mA, 72 kV and 9.9 seconds. Cephalometric analyses were performed with Planmeca Romexis® software. ANB angle was determined and analysed for each patient. Patients were classified into 2 groups according to skeletal pattern: skeletal Class I (0° ≤ANB <4°) or Class II (ANB>5°).

Cephalometric tracings were performed by a previously calibrated orthodontist, with 10 years’ experience in drawing cephalograms. The intra- and inter-observer agreement was assessed with the kappa coefficient, which was 0.90 for osseous maturation and skeletal relation. All the cephalometric tracings were drawn twice, with a one-week interval between drawings.

Anatomical changes were observed in the concavity of the lower border of C3 and the bodies of C3 and C4.
C4 should be rectangular in stage CS3. For CS4, the concavity of the lower border of C3 and C4 was also observed and both were rectangular shaped.

Statistical Analysis
The collected data were statistically analyzed using SPSS ver.20 for Windows (IBM SPSS, Chicago, Illinois, USA). Descriptive statistics were used to summarize class I and class II malocclusion chronological age in each group and for each CS3 and CS4 skeletal maturation stages. Due to a lack of normal distribution, comparisons of CS3 and CS4 age intervals in class I and II malocclusion subjects were analyzed using the Mann–Whitney U test for independent samples.

RESULTS
Reliability results showed a kappa of more than 0.90 for both the osseous maturation and skeletal relation determination.

Descriptive statistics were used to summarize the sample characteristics according to sex and CS skeletal maturation stages (Tables 1 and 2).

Table 2: Characteristics of the sample by of cervical vertebral stages and skeletal relation.

<table>
<thead>
<tr>
<th>Group</th>
<th>Measurement</th>
<th>n</th>
<th>X</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I – CS3</td>
<td>ANB angle</td>
<td>41</td>
<td>2.70</td>
<td>1.05</td>
<td>0.50</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>FMA angle</td>
<td>41</td>
<td>26.46</td>
<td>1.70</td>
<td>23.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Class I – CS4</td>
<td>ANB angle</td>
<td>34</td>
<td>2.65</td>
<td>1.11</td>
<td>0.50</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>FMA angle</td>
<td>34</td>
<td>25.95</td>
<td>1.77</td>
<td>23.00</td>
<td>27.00</td>
</tr>
<tr>
<td>Class II – CS3</td>
<td>ANB angle</td>
<td>43</td>
<td>6.12</td>
<td>1.29</td>
<td>5.50</td>
<td>9.00</td>
</tr>
<tr>
<td></td>
<td>FMA angle</td>
<td>43</td>
<td>31.7</td>
<td>1.05</td>
<td>30.00</td>
<td>33.00</td>
</tr>
<tr>
<td>Class II – CS4</td>
<td>ANB angle</td>
<td>36</td>
<td>6.24</td>
<td>1.86</td>
<td>5.50</td>
<td>9.50</td>
</tr>
<tr>
<td></td>
<td>FMA angle</td>
<td>36</td>
<td>32.00</td>
<td>1.85</td>
<td>30.00</td>
<td>34.00</td>
</tr>
</tbody>
</table>

Table 3: Age of onset of cervical vertebral stages by skeletal relation.

<table>
<thead>
<tr>
<th>Skeletal relation</th>
<th>Cervical vertebral stage</th>
<th>Age</th>
<th>n</th>
<th>X</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I CS3</td>
<td>11y 9m 11y 11m 9y 10m</td>
<td>41</td>
<td>11y 9m</td>
<td>11y 11m</td>
<td>9y 10m</td>
<td>13y 9m</td>
<td>0.936*</td>
</tr>
<tr>
<td>Class I CS4</td>
<td>12y 7m 12y 5m 10y 2m</td>
<td>43</td>
<td>12y 7m</td>
<td>12y 5m</td>
<td>10y 2m</td>
<td>14y 1m</td>
<td>14y 5m</td>
</tr>
</tbody>
</table>

* Mann–Whitney U test for independent samples

Table 4: Mean interval duration of the peak puberal interval on Class I and II subjects.

<table>
<thead>
<tr>
<th>Skeletal relation</th>
<th>Cervical stage</th>
<th>CS3-CS4</th>
<th>CI inferior limit</th>
<th>CI superior limit</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>11 y 9 m</td>
<td>12 y 7m</td>
<td>10 m</td>
<td>3 m</td>
<td>18m</td>
</tr>
<tr>
<td>Class II</td>
<td>11 y 11 m</td>
<td>12 y 5m</td>
<td>6 m</td>
<td>3 m</td>
<td>12m</td>
</tr>
</tbody>
</table>

* Mann–Whitney U test for independent samples
DISCUSSION
The results of this study blend nicely with the results from a previous study by Kuc-Michalska & Baccetti
[15], who determined that the adolescent peak growth spurt is longer in class III than in class I malocclusions. The current result adds more information by determining that the adolescent peak growth spurt is longer in class I than in class II malocclusions. So, in essence, it is now known that progressively, class III malocclusions have a longer adolescent peak growth spurt than class I malocclusions, which indeed have a longer adolescent peak growth spurt than class II malocclusions. The difference in length is 5-6 months between malocclusion types. This information is useful and has significant clinical implications, as a shorter length of the adolescent peak growth spurt in class II malocclusions means a shorter treatment time to maximize potential mandibular growth. It also has to be considered that this means that the chances of missing the adolescent peak growth spurt are increased when craniofacial growth of a patient is not monitored closely.

The cervical vertebral maturation diagnostic system uses morphological changes in the cervical vertebrae observed on lateral cephalometric radiographs to determine craniofacial skeletal maturity. It is a widely used approach because lateral cephalograms are routinely taken as orthodontic diagnostic radiographs. So instead of the hand-wrist x-rays that were used in the past, the orthodontist can now theoretically determine the craniofacial skeletal maturity status from a tool that is normally used.

CVM method has been proposed as an effective diagnostic tool to assess the adolescent peak growth spurt both in body height and mandibular size [5,19]. This method has also been suggested as extremely useful for orthodontic decision making or for the long-term evaluation of treatment outcomes. Nonetheless, the method has a few detractors, who have warned that CVM has only a moderate level of correlation with the individual’s skeletal maturation [3], so calibration and training are prerequisites for correct diagnosis in a study, as was done in this research, since the information was collected by a qualified, trained orthodontist. The appearance of a visible concavity at the lower border of the third cervical vertebra is the anatomic characteristic that primarily accounts for the identification of the stage immediately preceding the peak in mandibular growth [3,17]. This was also seen on CS3 and CS4 for class I and II subjects in our study. Baccetti et al. [3] found that the peak in mandibular growth occurs between CS3 and CS4. Furthermore, Hassel & Farman [4] report that by looking briefly at the cervical vertebrae on a lateral cephalometric radiograph, the orthodontist can now evaluate the patient’s skeletal maturity and have a reasonable idea of how much growth should be factored into anticipated treatment. In the present study, a statistically significant difference of four months was found for the peak growth duration in class I and II subjects. This difference may be a key factor in mandibular growth. Similarly, Kuc-Michalska & Baccetti [15] found a five month difference between class I and class III subjects. The mean age of study subjects was similar to that in previously reported studies [4,18,19]. Zaror & Paniagua [20] reported that CS3 stage is the ideal phase to start functional apparatus therapies for correcting mandibular deficiencies, as peak mandibular growth will occur during the current year to this observation. In addition, the mean time of the onset peak of growth for class I subjects was 11 years and 9 months. A similar time was found for class II subjects (11 years and 11 months). Kuc-Michalska & Baccetti [15] found a mean time of puberal peak of 11 years and 5 months in class I and II subjects. A systematic review by Santiago et al. [21] reported a low level of validity and reliability in cross-sectional studies, suggesting that CVM methods should be used with extreme caution. In growth and development studies, longitudinal studies are an essential method for evaluating craniofacial growth. Gu & McNamara [22] performed a longitudinal study on 20 subjects where the cervical vertebral maturation was evaluated in six consecutive phases and the adolescent peak growth spurt was observed during stages CS3 and CS4. According to Soegiharto et al. [23] there are difficulties in obtaining a large enough sample size because of the associated increase in the number of radiographic exposures, which tends to make this methodology difficult. This is why a cross-sectional design was applied in this study. Subjects were matched for skeletal class, sex and mandibular plane divergence. The reproducibility of the cervical vertebral method has been studied by several authors [3,5]. Gabriel et al. [2] reported moderate inter- and intra-observer agreement. Nestman et al. [3] found an inter-observer agreement below 50% and an intra-observer agreement of 62%. Santiago et al. [1] obtained moderate to high reproducibility using the same method (Kappa coefficient). It was therefore concluded that it is difficult to reliably classify vertebral body shapes, which by default explains the reported variation of the CVM method.
method reproducibility. In our study, inter- and intra-observer reproducibility was greater than 0.9, which implies adequate reproducibility. Having said so, accuracy cannot be ensured, as no gold standard was available for this sample. This should be considered when using the results of this study clinically. In summary, it was concluded that in class I malocclusion subjects, the interval between CS3 and CS4 (duration of the adolescent peak growth spurt) was 10 months, whereas a duration of 6 months was found in class II malocclusion subjects. A difference of 4 months was therefore found between class I and class II malocclusion subjects. This difference should be clinically useful, as a shorter length of the adolescent peak growth spurt in class II malocclusions could mean a shorter treatment time to efficiently maximize potential mandibular growth. This could also mean that the chances of missing the adolescent peak growth spurt are increased due to the relatively small opportunity window in relation to our usual facial growth monitoring time frames.

CONCLUSION
The mean time of onset for the adolescent peak growth spurt was similar in class I and II malocclusion subjects. A significant difference of 4 months (10 vs. 6 months respectively) was found in adolescent peak growth spurt duration between class I and II malocclusion subjects.

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REFERENCES