Evaluation of skeletal maturation in individuals with cleft lip and palate

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Objectives: The assessment of hand-wrist films to identify skeletal maturation stage is a commonly used method for the determination of the status of a growing patient. However, there is limited information available regarding skeletal growth evaluation in subjects with a unilateral cleft lip and palate (UCLP). Therefore, the current study aimed to examine skeletal and chronological ages in subjects with a UCLP for comparison with those of a non-cleft control group to derive clinical guidelines.

Methods: Hand-wrist films of 45 UCLP subjects (24 male, 21 female) and 45 Angle Class I orthodontic patients (17 male, 28 female) were evaluated. Skeletal age was assessed by comparing ossification events with standard radiographs illustrated in the Greulich-Pyle atlas and recording based on the best match of maturity criteria.

Results: A high correlation coefficient was observed between skeletal and chronological ages in the overall study sample ($p < 0.01$) ($N = 90$). Skeletal age (11.4 years) was delayed in the UCLP group when compared with chronological age (12.3 years), although the difference between the two was statistically insignificant. Skeletal age (13.6 years) was similar to chronological age in the control group (13.1 years).

Conclusions: The discrepancy between chronological and skeletal age was greater in UCLP subjects compared with controls. Given that the skeletal age of male and female UCLP subjects was delayed in comparison with their chronological ages, it is of particular importance that hand-wrist films should be used instead of chronological age to assess the growth status of UCLP subjects.

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Introduction
The determination of growth status and the percentage of remaining facial growth is an essential part of the orthodontic treatment planning process. The knowledge of a patient’s skeletal age provides an indication of the expected growth of a subject following the completion of active treatment and is therefore useful in predicting ultimate craniofacial patterns and post-treatment relapse.1

Several characteristics can be used to help identify a skeletal growth stage, including chronological age; peak growth velocity in standing height; pubertal markers such as appearance of pubic and axillary hair, voice changes in males and menarche and breast development in females; bone maturation (determined radiographically); and dental development.2 However, dental eruption time is not an exact indicator of a patient’s skeletal age,3,4 nor is chronological age, due to wide variations between subjects in the onset of the pubertal growth spurt.5,6 Hägg and Taranger reported not only a two-year difference in the beginning, peak and end of the pubertal growth period for males and females, but individual variations of approximately six years for each growth event.7

A radiographic analysis is a widely used method for determining the skeletal maturation stage of an individual. Although the use of the cervical spine has been reported,8,9 skeletal maturation is generally determined by examining the ossification sequence of the hand-wrist bones.6,10,11 Hand-wrist films have traditionally been used to assess somatic maturity
According to Jensen et al., skeletal maturity in those with a combined cleft lip and palate (CLP) is delayed, when compared with normal children. The report of 48 males with CLP suggested that early feeding problems and recurrent upper airway infection, combined with the surgical procedures, played a significant role in the delay in skeletal development. However, a review of the literature provided very little information about skeletal development in UCLP subjects. Therefore, the present study aimed to evaluate the relationship between skeletal and chronological age in individuals with a UCLP for comparison with an Angle Class I control group.

Materials and methods
The study sample included 45 subjects with a UCLP (24 male, 21 female) and 45 Angle Class I orthodontic patients (17 male, 28 female) who served as a control group. Chronological age ranges were 6–17 years (mean age: 12.3 years) for the UCLP group and 8–16 years (mean age: 13.1 years) for the control group. Left hand-wrist films (Figure 1) of all subjects taken as part of routine orthodontic assessment were retrieved from the archives of the Department of Orthodontics. The hand-wrist radiographs were viewed in a darkened room to facilitate bone identification, and skeletal age was assessed by comparing ossification events in the subjects with standard radiographs found in the Greulich-Pyle atlas and by recording the best match of maturity criteria. All radiographs were evaluated by the same experienced examiner. Descriptive statistics and Pearson correlation coefficients were used to assess differences between the groups. Statistical analysis was performed using the Statistical Package for the Social Sciences (Version 13.0, SPSS Inc, IL, USA) software program.

Results
Descriptive analysis and correlation coefficients for chronological and skeletal ages for each group are provided in Tables I and II. The mean chronological ages for the UCLP and control groups were 12.3 years and 13.1 years, and the mean skeletal ages were 11.4 years and 13.6 years, respectively. Discrepancies in mean skeletal and chronological ages for the two groups are shown in Figure 2. Correlation coefficients revealed a statistically significant relationship between chronological and skeletal age in males and females in both groups as well as in the overall study sample (p < 0.01). However, skeletal age lagged behind chronological age in the UCLP group, but the opposite was noted in the control group. Skeletal age was markedly behind chronological age for UCLP males in particular (11.8 ± 3.0 versus 10.7 ± 3.3). The

![Figure 1. A hand-wrist film of a subject with a UCLP.](image-url)
discrepancy between skeletal and chronological age was greater in the UCLP group compared with the control group (Figure 3).

Although skeletal age was delayed (11.4 years) when compared with chronological age (12.3 years) in UCLP patients, the difference between the two was statistically insignificant. Skeletal age (13.6 years) for the control group was similar to chronological age (13.1 years). Overall, skeletal age was greater in females than in males. Whereas skeletal age lagged behind chronological age in males (11.7 years versus 12.2 years), the two were similar in females (13.2 years compared with 13.1). Skeletal age in UCLP males (10.8 years) and females (12.2 years) was delayed in comparison with male (13.2 years) and female (13.9 years) controls.

Discussion
Aberrant development of the nose, upper lip and jaw in infants as a result of a facial cleft requires treatment for functional and aesthetic reasons. Although psychological and/or functional concerns may mandate the need for reparative and orthognathic surgery on growing cleft patients, the surgeon must be aware of the possibility of adverse post-surgical growth and the need for future additional surgery. More predictable outcomes may be achieved if maxillary osteotomies are performed on cleft patients after facial growth is complete. Therefore, it is important to accurately assess the growth status of a cleft individual.

Previous studies have reported a significant association between skeletal maturity and facial growth, however, others have shown little association between skeletal maturity indicators and specific components of craniofacial growth. Research has determined an association between facial peak growth velocity and peak velocity of statural growth during puberty. In addition, individuals demonstrating delayed or increased maturational timetables exhibit comparable delays or acceleration in skeletal maturation and facial growth. Further studies, however, suggest that facial growth does not occur until after the peak statural growth velocity. Given this contradiction, Verma et al. suggested the use of hand-wrist

Table II. Correlation coefficients for the chronological and skeletal ages in UCLP and control groups.

<table>
<thead>
<tr>
<th></th>
<th>Chronological age (mean ± sd)</th>
<th>Skeletal age (mean ± sd)</th>
<th>Correlation coefficient</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control, males (N = 17)</td>
<td>12.7 ± 2.2</td>
<td>13.2 ± 2.2</td>
<td>0.872</td>
<td>**</td>
</tr>
<tr>
<td>Control, females (N = 28)</td>
<td>13.3 ± 2.0</td>
<td>13.9 ± 2.3</td>
<td>0.859</td>
<td>**</td>
</tr>
<tr>
<td>UCLP, males (N = 24)</td>
<td>11.8 ± 3.0</td>
<td>10.7 ± 3.3</td>
<td>0.937</td>
<td>**</td>
</tr>
<tr>
<td>UCLP, females (N = 21)</td>
<td>12.9 ± 3.9</td>
<td>12.2 ± 3.7</td>
<td>0.907</td>
<td>**</td>
</tr>
</tbody>
</table>
** p < 0.01
radiographs to assess individual growth stages in order to facilitate treatment planning.

Several methods may be used to assess hand-wrist radiographs to determine skeletal age. The Greulich and Pyle method compares each bone of the subject’s hand-wrist with the corresponding bones in an atlas and an age in months is assigned. Clinicians select the plate that best matches that of a specific subject. An alternative method focuses on individual maturation rather than on mean values, in which hand-wrist radiographs are assessed for specific indicators that connect skeletal maturation to the pubertal growth curve. The literature has described a number of these indicators, such as calcification of the sesamoid bone, the hook of the hamate and stages of the middle phalan- ges of the third finger. However, it should be noted that there is still no agreement on the reliability of quantitative craniofacial growth prediction based on hand-wrist radiographs. Specifically, it should be noted that all patients have their own individual growth patterns, and different craniofacial structures possess different growth potential.

Manosudprasit et al. tested the level of agreement between the skeletal maturation index method (SMI) using hand-wrist radiographs and the cervical vertebral maturation index method (CVMI) for assessing skeletal maturity in cleft patients. It was concluded that the CVMI method might be used as an alternative to the SMI method in skeletal age assessment of cleft patients with the safety benefit of avoiding additional radiograph and radiation exposure.

In the current study, the assessment of hand-wrist radiographs showed that the skeletal age of both male and female UCLP subjects was delayed when compared with their chronological ages (Table I). In an earlier study, Menius et al. reported differences in skeletal and chronological age to be below standard deviation limits in 27 of 48 cleft palate subjects, with 83% of males and 33% of females suffering more severe clefts displaying skeletal ages below normal limits. Jensen et al. reported that the pubertal growth spurt in CLP boys was less marked than in controls and that maximum pubertal growth occurred an average of six months later in CLP males when compared with controls. It was also stated that the total growth period was prolonged, thus enabling CLP subjects to ‘catch up’ with the growth of controls, and suggested that growth delay might be related to early feeding problems and recurrent upper airway infections combined with surgical procedures in the CLP group.

Ravi and Ravikala assessed the skeletal maturity of children with unilateral cleft lip and palate for comparison with non-cleft children. It was found that children with UCLP exhibit a delay in attaining skeletal maturation when compared with non-cleft children. The result of the study showed that there was a delay in skeletal maturation at a younger age but not in an older-age group of children with UCLP. However, Menius et al. reported that a disproportionate number of cleft palate subjects, particularly males, exhibited skeletal ages lower than established norms. It was also suggested that socio-economic level may influence growth and development, and recommended that a more extensive, longitudinal study be considered. Montagnoli et al. reported that reduced height and weight was more severe in cleft lip and palate and isolated cleft palate children when compared with isolated cleft lip children and attributed the difference to feeding difficulties.

In summary, the current study showed that the discrepancy between skeletal and chronological age is greater in UCLP subjects compared with non-cleft control subjects. The highlighted delay in growth of UCLP subjects needs to be considered by health care professionals who offer treatment.

Conclusions

- The discrepancy between skeletal and chronological age is greater in UCLP subjects compared with a control group.
- The skeletal age of male and female UCLP subjects is delayed when compared with their chronological ages; therefore, rather than the use of chronological age, a hand-wrist film evaluation should be obtained when deciding on treatment timing.

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