Original Article

A Longitudinal Study of Condylar Growth and Mandibular Rotation in Untreated Subjects with Class II Malocclusion

Joohyung Kim, DDS[a]; Ib Leth Nielsen, DDS[b]

Abstract: Condylar growth intensity, mandibular growth rotation, and the association between growth intensity and rotation were evaluated in 32 untreated subjects with Class II malocclusions. Condylar growth was measured on serial lateral headfilms annually from ages 8 to 13. The analysis showed that the growth intensity of the condyles varied only slightly between girls and boys, with boys growing more. Fluctuations in growth intensity were observed in all subjects from year to year. None of the individuals maintained a consistent growth velocity over two or more consecutive years. The average condylar growth intensity was two to three mm per year throughout the period from age 8½ to 12½ for both sexes, with boys growing slightly faster than girls at some ages. The greatest growth velocity observed was eight mm in one year, which was seen in one boy. Three girls had as much as six mm of condylar growth in one year. Average mandibular rotation was −0.8 (±0.5 SD) per year in boys and −0.6 degrees (±0.6 SD) in girls, with great individual variation for both sexes. Ninety percent of the subjects showed some degree of anterior or forward rotation; only one subject demonstrated posterior rotation and three demonstrated almost no rotation. No clear relationship was found between amount of condylar growth and mandibular rotation. This study shows that condylar growth intensity varies considerably between subjects and from year to year in each subject, and suggests that clinicians need to be conservative when estimating treatment length for a patient with a Class II malocclusion. (*Angle Orthod* 2002;72:105–111.)

Key Words: Condylar growth; Mandibular rotation; Class II malocclusion, Cephalometrics; Orthodontics

INTRODUCTION

The pubertal growth spurt is generally considered to be the best time for orthodontic treatment in patients with Class II malocclusions.[1–4] Because of the increased intensity of condylar growth during the pubertal growth spurt, mandibular displacement during this period takes place with the greatest intensity. Although, to the clinician, the growth spurt may seem the most logical time for treatment in patients in whom a skeletal correction is needed, other considerations may indicate treatment before the spurt. In patients in whom the Class II malocclusion is more severe or there is an excessive overjet, postponing treatment may not be acceptable because of the risk of fracturing the incisors. A further problem is that the motivation of a patient near or in puberty often is low, so that delaying treatment until this stage may not be a good idea for psychological reasons.

Condylar growth studies in humans using metallic implants have shown that, during the prepubertal or juvenile growth period, mandibular growth takes place at variable and unpredictable rates. Björk[1] reported that condylar growth rate can vary from as little as 0.5 mm to as much as five mm per year during this period. While Björk demonstrated variation in growth intensity from year to year in untreated subjects, he did not specifically relate these variations to any type of occlusion.

PREVIOUS STUDIES

Facial growth in general

Nanda[5] investigated general facial growth in humans and reported that the time of onset and the peak rate of growth are different for the different dimensions of the face in a child and that not all dimensions grow at the same relative rate. The association between skeletal maturation and facial growth was investigated by Bambha and Van Nalta.[6] They reported that individuals who mature early, with advanced skeletal age, also have an early adolescent facial growth

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spurt whereas children with delayed skeletal maturation mature later. Bishara and colleagues[7,8] quantified the changes in facial dimensions and their relationship to the changes in body height. They found that the growth curve for body height was significantly different from that of the mandible and that it had little predictive value in determining the growth profile of the mandible.

Mandibular growth

The relationship between the magnitude and timing of pubertal spurts in the mandible, age at peak height velocity, menarche, and levels of skeletal maturity within individuals was analyzed by Lewis et al.[9] They reported that spurts in mandibular dimensions are common but not universal, and that the first pubertal spurt usually occurs before peak height velocity.

The increase in size of the mandible from 9 to 13 years of age is greater in girls than in boys, according to Maj and Luzi,[10] who also reported that mandibular condylar growth is not smooth from year to year but occurs in spurts. They also reported that condylar growth does not take place in a straight line but follows a curved path.

The correlation between changes in standing height and facial dimensions, including the mandible, in adolescent boys during the growth spurt was investigated by Bergersen.[11] He reported that there is a definite alteration in growth rate at the beginning of the adolescent growth spurt. That alteration continues for approximately two years and then taper off during the following two years. Mitani[12] analyzed the growth changes of the face associated with mandibular prognathism over a three-year period before puberty (from 7 to 10 years of age) and found growth to be similar to that of the normal group.

Condylar growth

The mandibular condyle is one of the major growth sites of the face and, in addition to the maxilla and the alveolar processes of the maxilla and mandible, has been studied extensively.[13] More specifically, condylar growth has been examined in both human and nonhuman subjects using various techniques including histology, histochemistry, metallic implants, and cephalometric analysis. Earlier studies of mandibular growth used simple methods for determining growth over time and measured increase in total length of the mandible on cephalometric headfilms in occlusion or on open-mouth headfilms.[14] Few studies have superimposed serial headfilms and measured the addition at the condyles. Also, in previous studies most investigators did not consider that the mandible undergoes surface modeling that makes conventional ‘‘best fit’’ superimposition inaccurate. There are few existing studies that provide reliable reference data for clinical evaluation of condylar growth.[1,15–17] Odegaard,[15–16] using metal implants, investigated condylar growth and reported that the direction of condylar growth varied with the gonial angle. Only a few studies have compared mandibular growth rates between patients with normal occlusion and untreated subjects with Class II malocclusion.[18–20] To our knowledge, no study has examined condylar growth longitudinally in untreated Class II subjects by measuring growth of the mandible directly at the condyle after structural superimposition.

The aim of this study is to evaluate condylar growth intensity, mandibular growth rotation, and the association between growth intensity and rotation in untreated subjects with Class II malocclusion during the juvenile and adolescent growth period.

MATERIALS AND METHODS

The material for this study consisted of lateral cephalometric headfilms of 32 (19 boys and 13 girls) untreated subjects with Class II malocclusion. The material originated from the Public Orthodontic Clinic in Malmö, Sweden. The subjects were seen annually between the ages of 8 and 13 years and annual headfilms were taken according to the Swedish regulations at the time. The age, sex distribution, and length of the observation periods are seen in Figure 1. The distribution of boys and girls according to age at the beginning and end of the observation period is seen in Tables 1 and 2.

The serial headfilms were traced on matte acetate and digitized using a Neumonics™ digitizer. The data was entered into a computer program TIOPS™ for analysis and tracing. Three sets of reference points were placed on the initial tracing of each headfilm in a series for superimposition on the cranial base, the maxilla, and the mandible. Using the computer tracings, a plot check was performed for each individual film to ensure correct data entry. Then the individual manual tracings for each subject were superimposed on the stable reference structures in the anterior and median cranial base according to Björk and Skieller.[4] The reference points were carried forward to subsequent films after superimposition on the stable structures as described by Björk and Skieller[4] and Nielsen.[21] The tracings and the transferred reference points were then digitized and checked for input error by superimposing the plots (Figure 2). Only the cranial base and mandibular superimpositions were used for this study. Mandibular condylar growth was measured to the nearest tenth of a millimeter on the superimposed plots of the mandibles of each patient's serial headfilms. The reference point articulare (ar) was used as a representation of the condyle. Mandibular rotation was measured as the change in the transferred nasion-sella line after superimposing on the stable structures in the mandible as described by Björk and Skieller.[4]

Statistical analysis

The mandibular growth rate was calculated longitudinally for each subject as the difference between two headfilms in the series for that subject. As the films were taken annually

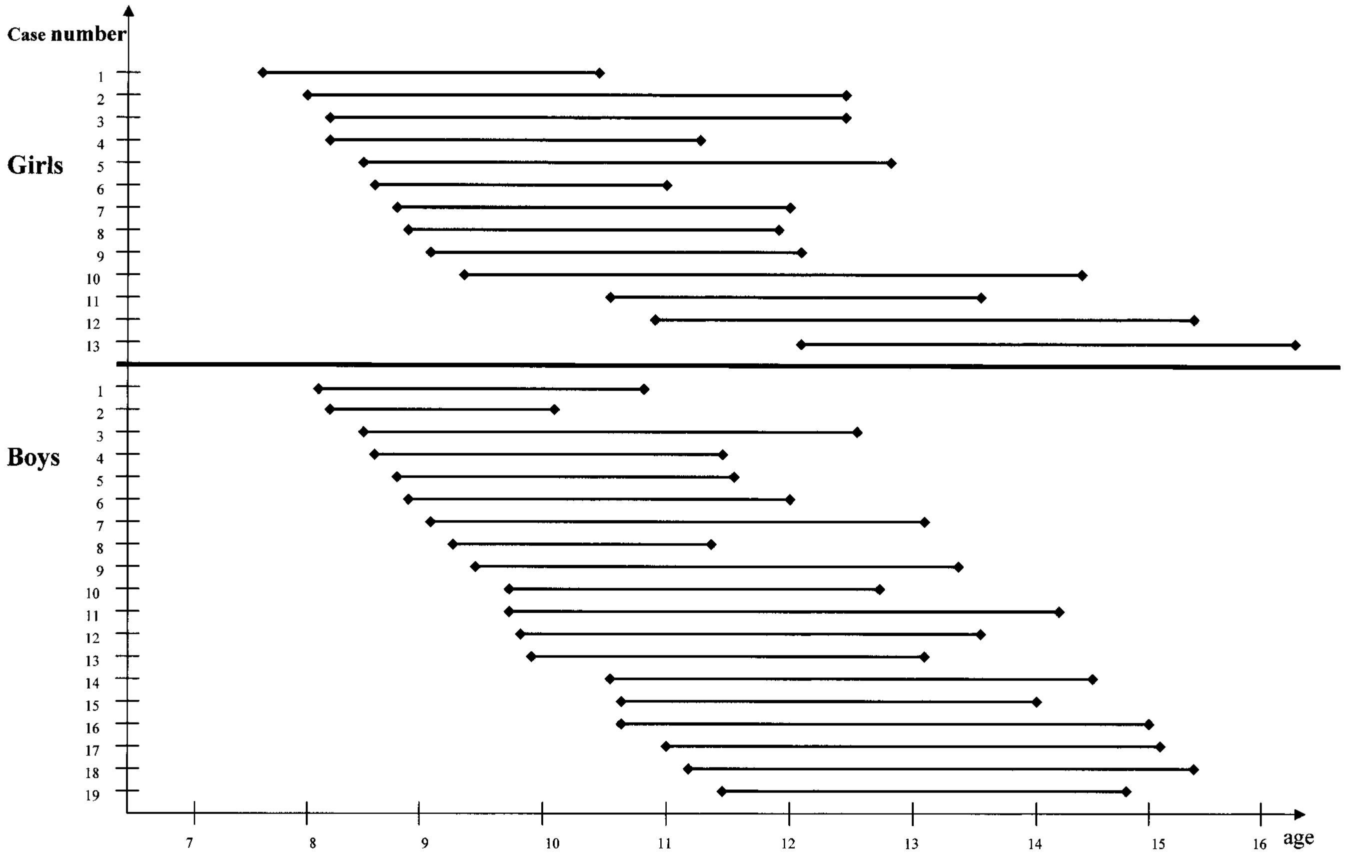

FIGURE 1. Age and sex distribution of 32 subjects with Class II malocclusion. The subjects are listed according to age at the beginning of the observation period. The bars indicate the length of the observation period.

TABLE 1. Condylar Growth Rates in Girls by Age (N = 13)[a]

	Age				
	8.5	9.5	10.5	11.5	12.5
MEAN	2.12	3.31	2.58	2.71	3.75
SD	1.03	1.46	1.91	0.99	1.71
Min	0.50	1.00	0.50	0.43	2.00
Max	3.82	6.00	6.00	3.50	6.00
COUNT	7	8	10	9	4

[a]N indicates number of girls; SD, standard deviation; Min, minimum; and Max, maximum.

TABLE 2. Condylar Growth Rates in Boys by Age (N = 19)[a]

	Age					
	8.5	9.5	10.5	11.5	12.5	13.5
MEAN	3.18	2.25	2.94	2.78	3.06	3.75
SD	1.57	0.94	1.39	1.54	2.10	1.80
Min	0.92	0.50	0.40	0.40	0.60	1.60
Max	5.00	3.69	5.08	5.50	7.38	6.50
COUNT	6	12	15	13	11	5

[a]N indicates number of boys; SD, standard deviation; Min, minimum; and Max, maximum.

in most subjects, the midpoint of each time period was used in the statistical analysis. Where the time difference between two headfilms was greater than 12 months, the annual growth rate was calculated and plotted at the midinterval.

Statistical analysis included computation of the means, standard deviations (± 2 SD), and range for condylar growth and for the associated condylar growth rotation in degrees. For each group, girls and boys, the variations in condylar growth rate are illustrated in Figure 3 and Figure 4. The combined condylar growth rates for girls and boys by age are illustrated in Figure 5. Because of the limited number of subjects in each age group, no statistical comparisons were made between girls and boys.

RESULTS

Our data analysis of 32 subjects (13 girls and 19 boys) showed that the growth intensity of the mandibular condyle varied considerably between the girls and boys and between individuals in each group over time. The subjects were studied longitudinally over a period of 2½ to 5 years. During the observation period, each subject demonstrated fluctuations in growth intensity from year to year. None of the

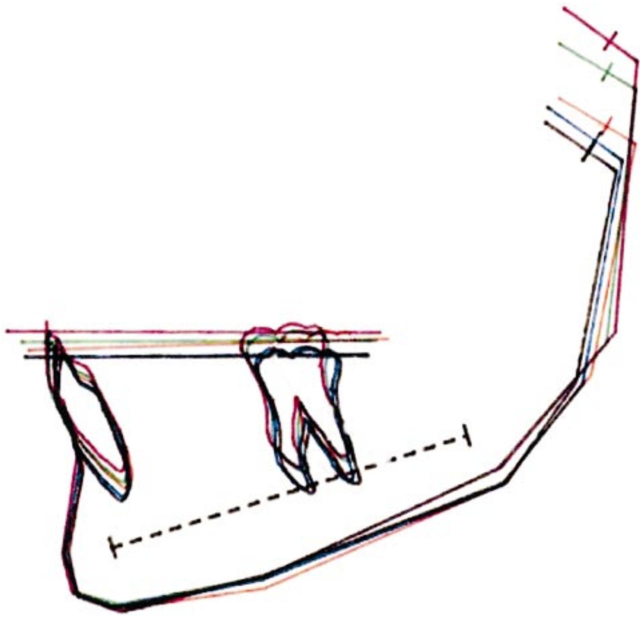

FIGURE 2. Superimposition of the mandibles in a subject over a period of five years. The superimposition is made on stable structures in the mandible according to Björk.[1]

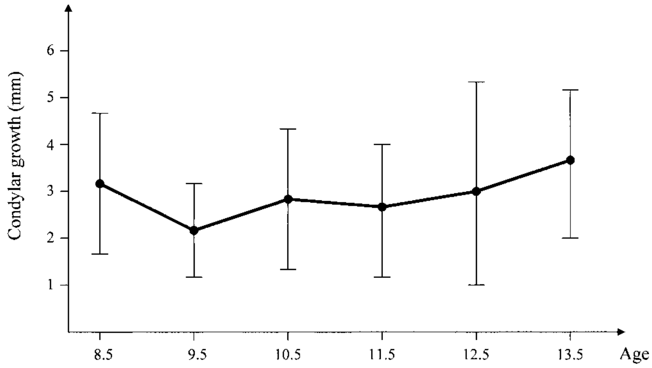

FIGURE 3. Means and ± 2 SD of mandibular condylar growth (mm/year) from age 8½ to 13½ in 19 boys.

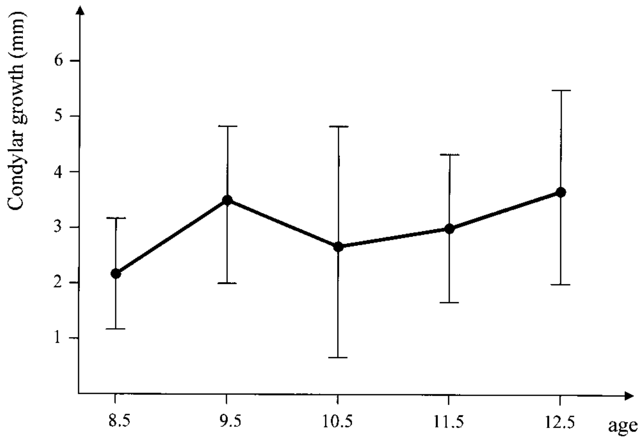

FIGURE 4. Means and ± 2 SD of mandibular condylar growth (mm/year) in 13 girls from age 8½ to 12½ years.

subjects maintained a consistent growth velocity over two or more consecutive years.

The mean growth intensity (±2 SD) for girls and boys during the juvenile period is illustrated in Figure 5. The average intensity for condylar growth was about two to three mm per year throughout the period from age 8½ to 12½ for both sexes, whereas boys seemed to grow slightly faster at age 8½ years and girls appeared to have a slight increase in growth intensity around age 9½ years. This was then followed by similar growth intensity between girls and boys until puberty. The standard deviations (±2 SD) were quite large at all ages.

The six boys and seven girls with the lowest growth intensity had less than one mm of condylar growth in a year. This very low growth intensity occurred between the ages of 8½ years and 12½ years in boys and 8½ and 11½ years in girls.

The highest growth velocity (five mm per year) was observed in five boys and was seen as early as age 8. One 13-year-old boy had as much as eight mm condylar growth in a year (Figure 6). The greatest growth intensity measured in girls was six mm per year, which was seen in three girls ages 9, 11, and 13 (Figure 7). We also noted that when an individual in the juvenile period had one or two years of good growth, it was frequently followed by a year with low growth intensity. After this reduction in intensity, a subsequent year usually had greater than average growth in many individuals (Figures 6 and 7).

Mandibular growth rotation was measured as the change in inclination of the nasion-sella line as previously described. Rotational changes were indicated with (−) for forward or anterior rotation and (+) for backwards or posterior rotation. Our measurements showed that the mandible rotated an average of −0.8 (±0.5 SD) degrees per year in boys and −0.6 degrees (± 0.6 SD) in girls, with great individual variation for both sexes (Table 3). The individual variations in growth rotation for boys and girls combined are seen in Figure 8. The graph shows that about 90% of the individuals showed some degree of anterior rotation; only one subject demonstrated posterior rotation and three demonstrated almost no rotation. When comparing mandibular rotation in boys and girls (Figure 9), we found that girls generally experienced less growth rotation than boys. Comparison of condylar growth intensity and the associated rotation of the mandible for each individual showed no clear relationship between amount of growth and rotation in either boys or girls (Figures 10–12).

DISCUSSION

The results of the present study show that condylar growth during the juvenile period varies considerably between individuals and within each individual from year to year. Periods of low growth intensity are often followed by periods with good growth intensity. In the individual patient, this variation seems to be unpredictable as previously

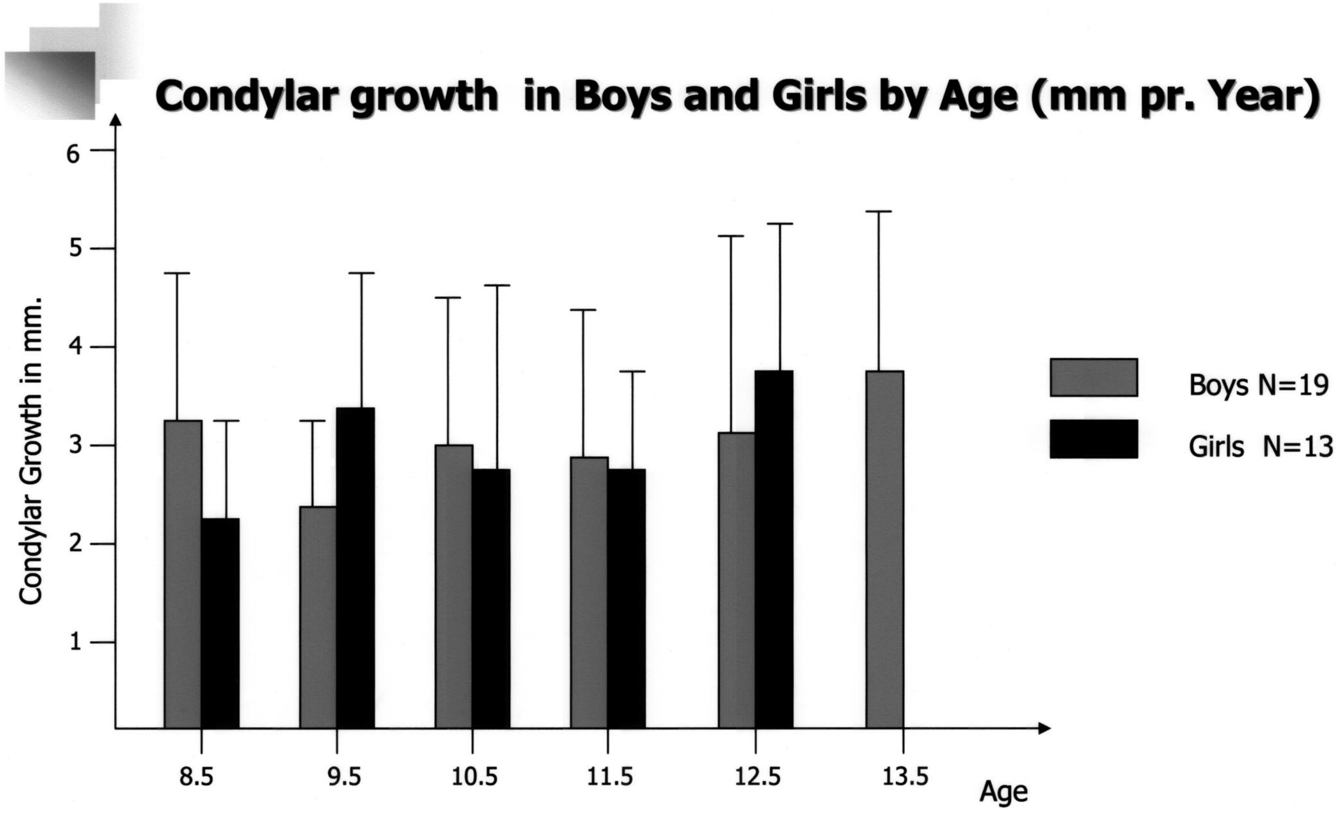

FIGURE 5. Mean condylar growth rates for boys (n=19) and girls (n=13) by age ± 2 SD.

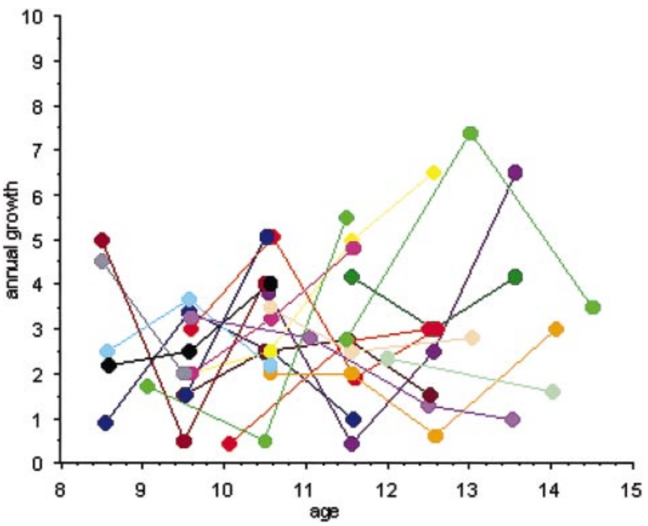

FIGURE 6. Individual condylar growth rates in 19 boys from age 8½ to age 14½. Note the annual fluctuations.

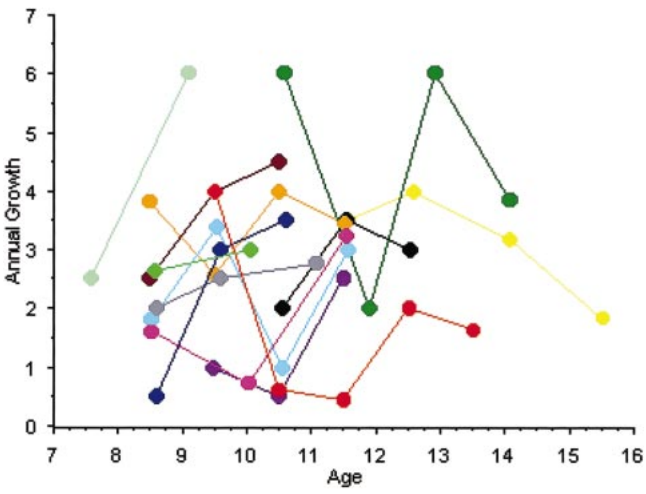

FIGURE 7. Individual condylar growth rates in 13 girls from age 7½ to age 15½. Note the annual fluctuations.

reported by Björk.[1] The idea of measuring growth intensity of the facial components is not new and several earlier studies have examined the changes in facial dimensions.[6,10,17] However, so far no other investigators have specifically studied growth at the condyle in subjects with Class II occlusion using ‘‘structural superimposition.’’

Nanda[5] showed that at a given age during the juvenile period the growth intensity of the mandibular condyles can vary from as little as 0.5 mm per year to as much as 6.5 mm. This finding is similar to what has been reported by Buschang et al[17] and to our findings. We specifically studied subjects with Class II malocclusions, whereas Nanda et al[5] and Buschang et al[18] used mixed samples including Class II malocclusions. Maj and Luzi[10] studied subjects with only Class I occlusions and reported that the increase in the size

TABLE 3. Condylar Growth and Mandibular Rotation in Boys (N = 19) and Girls (N = 13)[a]

	Mean	SD	Max	Min	Count
Boys					
Growth	2.80	0.70	4.00	1.80	19
Rotation	−0.80	0.52	−1.97	0.02	19
Girls					
Growth	2.70	0.88	4.10	1.30	13
Rotation	−0.60	0.57	−1.29	0.06	13

[a]N indicates number of patients; SD, standard deviation; Min, minimum; and Max, maximum.

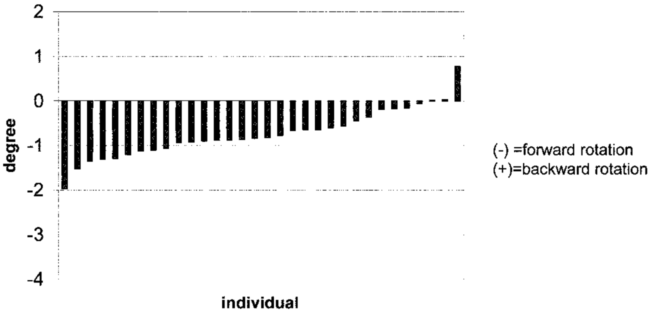

FIGURE 8. Mandibular growth rotation in 32 subjects listed according to amount and direction of the rotation, irrespective of age. Note that 95% of the subjects had some degree of forward or anterior rotation during the observation period.

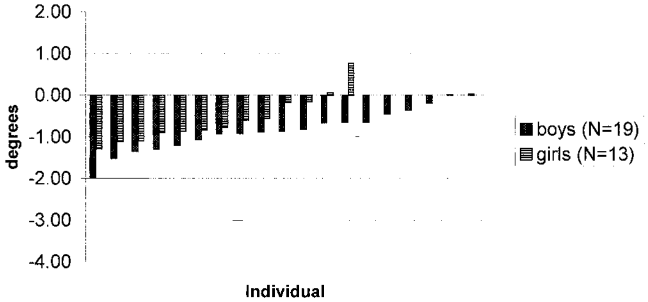

FIGURE 9. Mandibular growth rotation in boys (n=19) and girls (n=13) listed according to amount and direction of the rotation, irrespective of age. Note that 95% of the subjects had some degree of forward or anterior rotation during the observation period.

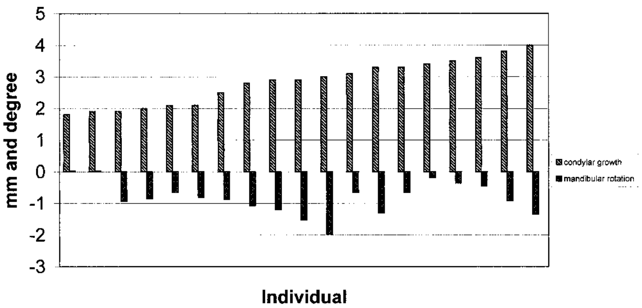

FIGURE 10. Condylar growth and mandibular rotation in boys (n=19). Note the lack of association between amount of condylar growth and rotation of the mandible.

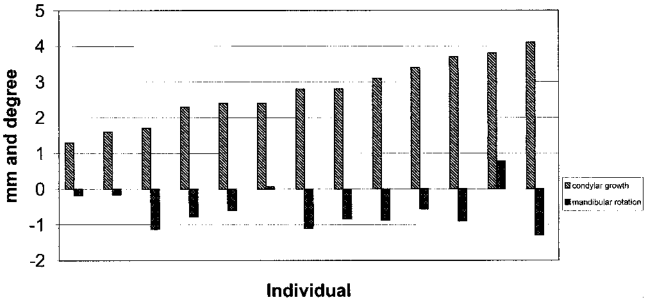

FIGURE 11. Condylar growth and mandibular rotation in girls (n=13). No association is seen between amount of condylar growth and rotation.

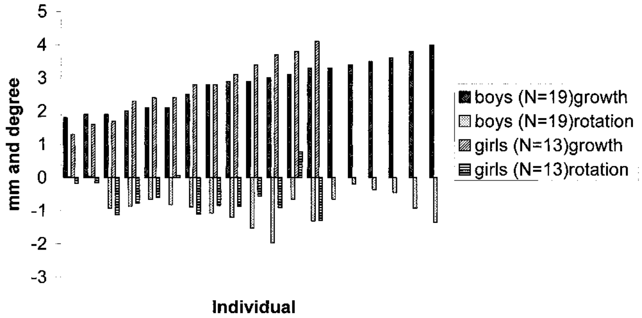

FIGURE 12. Individual condylar growth and mandibular rotation for 32 subjects.

of the mandible from ages 9 to 13 is greater in girls than in boys. Our study supports the idea that around age 9, girls appear to have slightly greater condylar growth velocity than boys (Figure 5). We also found that after age 9½, the average growth rate is similar in both sexes until puberty. It is possible that the observations of Maj and Luzi[10] are influenced by the fact that young children mature at an earlier age today than they did 40 years ago.

The annual fluctuations in growth intensity of the mandibular condyles present a clinical challenge especially in the correction of malocclusions of skeletal origin. Clinicians often tell the patient that a treatment period of 18 to 24 months is anticipated, but ignore the possibility that the individual child may be in a low growth phase. Some children in our study only grew one to two mm in the condyles in a year. In the treatment situation, this would necessitate at least 2½ to 3 years of orthodontic treatment in a patient with a skeletal Class II malocclusion. Granted, a few children may by chance have as much as four, five or even six mm of growth in a year, which would significantly reduce the treatment time. It is therefore important that the orthodontist does not underestimate the possible treatment time needed to correct a Class II malocclusion and not be too optimistic. Unfortunately, we still do not have a reliable method for predicting future growth potential, especially in the period prior to the pubertal growth spurt. Further research into this problem is clearly needed.

Some studies have reported that hand-wrist radiographs are good predictors of skeletal body growth, but lack clinically useful correlation to the timing of change in standing height, skeletal maturation, and changes in the various dentofacial parameters that clinicians are interested in predicting.[22,23] Therefore, it has been recommended that treatment of Class II skeletal malocclusion should be initiated when the orthodontist feels treatment is indicated irrespective of the age of the patient. According to Jamison and Bishara,[22] waiting for the pubertal spurt is not indicated as the presence, magnitude, and timing of such events in any one patient are highly unpredictable—at least to the degree that they are clinically useful to the orthodontist. Our data suggest that in some individuals, early treatment prior to the growth spurt could be successful as a reasonable amount of condylar growth was present. However, in other subjects delaying treatment may be a better choice. Unfortunately, the data also demonstrated the unpredictability of condylar growth in a given subject prior to puberty. In our study, we did not include hand-wrist radiographs to determine the stage of skeletal maturation. The majority of our subjects were observed during the juvenile growth period, prior to the pubertal growth spurt, where it has been demonstrated that hand wrist radiographs have no predictive value.[1]

We measured mandibular growth rotation over time in all subjects and found no direct association between amount of growth and rotation. This suggests that condylar growth is not the only factor that determines amount and direction of mandibular growth rotation. The direction of growth rotation in almost all subjects (95%) was in a forward or anterior direction that improves the anteroposterior mandibular position over time. This observation supports the findings of Björk and Skieller[2–3] who reported that the majority of untreated subjects show forward or anterior growth rotation over time.

CONCLUSIONS

Our data show that the growth intensity of the mandibular condyles in untreated subjects with Class II malocclusion varies considerably between subjects and within each subject from year to year. Some subjects could have as little as one mm condylar growth in a year; others could have as much as eight mm, irrespective of the subject's age. Girls on average grow less than boys. Mandibular growth rotation was in a forward direction in 95% of the subjects and there was great individual variation. No association was found between condylar growth intensity and growth rotation of the mandible.

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