Relationship of the Ulnar Sesamoid Bone and Maximum Mandibular Growth Velocity

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INTRODUCTION

The timing of active treatment in orthodontics has long been of much concern. Clinicians have increasingly recognized the part played by growth in aiding or dissipating the effects of their therapy and try to plan their treatment accordingly. Unfortunately, specific indicators of periods of rapid facial change, such as occur during the prepubertal acceleration, are not precise. The orthodontist attempting to utilize this period of growth to assist his treatment uses those means readily available to him, e.g., onset of rapid increase in body height, early signs of physiological change and occasionally skeletal maturation from a carpal radiograph.

One of the indicators found to be of use in assessing the onset of adolescence is the presence or absence of the ulnar sesamoid bone of the hand. However, the area of particular interest to the orthodontist is facial and, especially, mandibular growth. It was decided therefore to investigate whether the presence or absence of the sesamoid bone could provide clinically useful information concerning the onset of peak velocity in mandibular growth at adolescence.

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REVIEW OF LITERATURE

Facial Growth

Cephalometric radiography has enabled research workers to relate growth of facial components to that of various other body structures, such as height. Nanda,[17] in a longitudinal study of several facial dimensions, formulated distance and velocity curves to illustrate the changes he observed. He found a general circumpubertal increase in growth velocity, though the timing of both the onset and the peak rate of growth were different for the various dimensions of the same child. Circumpubertal acceleration in facial growth occurred approximately nine months after that in body height.

Bambha's[3] findings in general support those of Nanda and in addition he suggested that it was possible to estimate the time of onset of the adolescent growth spurt in the face by observing the time of onset of the preceding similar acceleration in body height.

Hunter[12] challenged the findings of both Nanda and Bambha. He concluded that maximum facial growth was coincident with maximum height growth in the majority of subjects in his study. The anteroposterior length of the mandible, of all the facial dimensions studied, showed the most consistent relationship with growth in height.

The implication in these and other studies is that the factors responsible for general body growth and matura-

tion also control facial growth and maturation. However, there is another school of thought which treats each growth site in the facial complex as having its own pattern of maturation and its own growth rate, as argued by Burstone[7] and Roche.[18] Such an approach is best exemplified in the development of mandibular growth curves.

Mandibular growth curves

Several investigators have examined longitudinal mandibular growth, including Nanda, Bambha, Harris[9] and Harvold.[10] Summarizing their findings, mandibular growth has been shown to proceed in an irregular way with a preadolescent deceleration in velocity, then a definite acceleration associated with the onset of adolescence. Harvold, and Maj and Luzi[16] have commented on the difficulty of predicting mandibular dimensions at one age from those at an earlier age.

The accuracy of these studies is largely dependent on the method of measuring mandibular length. The mandibular condyle is frequently used as a reference point. This structure is very difficult to determine accurately on a lateral radiograph. In addition, all the investigators treated their longitudinal data in a cross-sectional manner thus disguising what is actually occurring in the individual.

In an attempt to overcome some of these inherent difficulties, an exhaustive study of mandibular growth is in progress at the University of Toronto under Dr. D. G. Woodside.[22] Longitudinal data have been utilized from the Burlington Orthodontic Research Centre and mandibular length has been measured from 45° oblique lateral skull radiographs of the head, with the symphyseal point being decided from the posteroanterior radiographs. Using this technique, a very accurate measure of mandibular length with minimum distortion can be obtained. The resultant mandibular growth curves are computer-smoothed from the raw data and from this information can be derived distance curves, velocity curves and relative growth rate curves. From these data it is hoped to be able to use the mandible as its own maturity indicator.

Skeletal Maturation and Mandibular Growth

Various methods of expressing stages of growth have been proposed as substitutes for chronological age. These include stages of development of body height, external genitalia, menarche, tooth eruption and skeletal age. Skeletal age, usually assessed by progressive maturation of the bones of the left wrist and hand, is the most widely used. Acheson[1] has discussed the merits of the various methods used in deciding skeletal age.

Several studies of the association between skeletal maturation and mandibular growth have been made. Rose,[19] in a cross-sectional study from nine to eighteen years, decided that skeletal age is an inefficient guide for prediction of linear mandibular growth. Bambha and Van Natta[3] found an association only with the two extremes. Early maturers, as assessed by skeletal age, had an early adolescent spurt in mandibular growth and late maturers had a late spurt of mandibular growth.

Johnston, Hufham, Moreschi and Terry,[13] using a mixed longitudinal female sample aged 7-16.5 years, found that use of skeletal maturation indicated a close relationship between mandibular growth and general growth patterns but this was not the case for other facial dimensions.

Roche[18] has stated that although maturity of the hand-wrist area is not correlated exactly with that of the mandible, it is not likely to deviate from it by more than five months of skeletal age.

It is apparent that, although some association between skeletal maturation and mandibular growth has been reported, there is disagreement as to the extent of this association. Most investigators have been handicapped by lack of numbers in the samples available and in most instances they have used longitudinal data in a cross-sectional manner.

Recent work completed at the University of Toronto has also examined the problem of mandibular growth and skeletal maturity. Luks,[15] using a longitudinal sample of 112 males from the Burlington Research Centre material, examined the relationship between somatotype and skeletal maturation as assessed by two different methods and growth of the mandible. He found no relationship between somatotype and chronological or skeletal age at maximum growth velocity of the mandible. He concluded from his findings that use of carpal assessments or somatotyping for estimation of mandibular growth accelerations could not be justified. Luks' findings are in contrast to the general view taken by other workers.

Ulnar Sesamoid Bone

The ulnar sesamoid bone is one of five sesamoid bones in the adult hand and lies at the metacarpophalangeal joint of the thumb. The function of sesamoid bones is not clearly understood although various theories such as pressure or protection of tendons have been suggested to account for their presence.

The frequency of occurrence of the ulnar sesamoid bone is well documented with most investigators reporting an incidence of almost 100%, as did Joseph,[14] and Björk and Helm.[4]

The ulnar sesamoid bone of the metacarpophalangeal joint of the thumb is the only consistent ossification centre in the hand that appears near puberty. A number of investigators have studied the timing of ossification of the bone including Buehl and Pyle,[5] Joseph, Garn and Rohmann,[8] and Björk and Helm. The consensus seems to be that ossification begins around 10 to 11.5 years for females and 12 to 14.5 years for males with a range of approximately three years for females and four and one-half years for males.

Use of the Sesamoid Bone as a Maturity Indicator

Due to its time of appearance, the ulnar sesamoid bone has been utilized as a possible indicator of puberty. Its relation to easily identifiable adolescent phenomena such as menarche or increased height acceleration is well established with the sesamoid appearance preceding menarche by two and one-half years on average and maximum height increase by about one year in girls and nine months in boys, according to Björk and Helm. These figures are supported by the findings of other workers if allowance is made for Björk and Helm's assumption that the start of calcification of the ulnar sesamoid bone precedes its appearance on a radiograph by six months.

It would seem from these studies that the appearance of the ulnar sesamoid bone can be used as a fairly reliable indicator of puberty. Its relation to growth of the face at adolesence has only been inferred indirectly by Björk and Helm and direct evidence is lacking as to the relationship of the ulnar sesamoid bone appearance and facial growth. Similarly, no attempt has been made to correlate appearance of the sesamoid bone to acceleration of mandibular growth at adolescence.

Experimental Procedures

Description of the Sample

The sample consists of 108 females and 91 males from the serial experimental group of the Burlington Orthodontic Research Centre.[6] Originally, 92 males were examined but one indi-

vidual failed to show appearance of the sesamoid bone by twenty years although his general development otherwise was normal. This gives an incidence of absence of 0.5% in the sample. This incidence is very similar to that previously reported. While the Burlington sample cannot be considered as being truly random, it is as close to a random sample as it is possible to achieve in a longitudinal study. The population is predominantly Caucasian and is considered to be representative of the Province of Ontario. Radiographs for each individual were taken annually along with physical and dental records. Subjects were seen as close to their birthday as possible.

Method of Determining Age of Peak Mandibular Growth Velocity

Data concerning mandibular growth from three to eighteen years were available for the individuals in the sample. These data had been prepared for Woodside's[22] investigation and were derived from serial 45° oblique lateral skull radiographs since the head of the condyle is distinct in this projection. Mandibular length was measured from the most distal and superior point in the condylar head to the symphysis (Fig. 1). The symphyseal point was taken as being the mid-point of the inferior border of the symphysis of the mandible. The posteroanterior cephalogram was used to assist in establishing the contour of the mandible.

Peak mandibular velocity in the majority of cases was obtained initially from the individual computer-smoothed velocity curves which were derived from the corresponding computer-smoothed distance curves. These curves gave the mandibular velocity at .01 year intervals. The validity of the smoothed peaks was confirmed by an analysis of the actual increments for both right and left sides of the mandible and by a comparison of the smoothed velocity

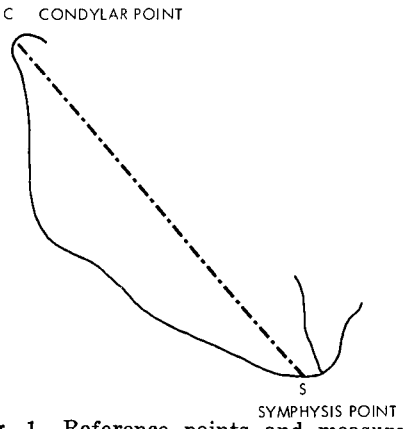

Fig. 1 Reference points and measurement lines for mandibular length.

curves with the velocity and distance curves as plotted from the raw data. In seventeen cases, (10 females, 7 males) computer-smoothed curves were not available due to a lack of sufficient information. The most recent radiographs of these cases were measured and provided sufficient information to enable estimation of the peak velocity from the raw data, as plotted on both the velocity and distance curves. Distribution of these estimated peak velocites was found to be normal and did not bias the sample. The decimal age was calculated after the manner of Tanner, Whitehouse and Takaishi[21] and was expressed to the nearest tenth of a year.

Method of Determining Age of Appearance of the Ulnar Sesamoid Bone

Annual carpal radiographs were examined carefully for the first signs of calcification in the area of the ulnar sesamoid bone of the thumb. When the first appearance was noted, the preceding and following carpal radiographs were reexamined to confirm the age of the initial appearance.

The date of the radiograph was recorded and a corresponding decimal age was calculated to the nearest tenth of a year to give the age of appearance of the bone.

TABLE I

	Number	Mean	S.D.	Minimum Value	Maximum Value
Age of Peak Mandibular Velocity					
Males	91	13.94	1.26	11.10	16.5
Females	108	11.97	1.02	8.70	14.5
Age of Sesamoid Bone Appearance					
Males	91	13.22	1.21	10.00	16.1
Females	108	10.88	1.04	7.89	13.1

It is recognized that the sesamoid bone is actually present approximately six months before it is observed on the carpal radiograph as pointed out by Björk and Helm but, to be clinically useful, the observer must rely on the age when he first sees the bone on a radiograph.

Method of Assessment of Relationships

Scatter diagrams were constructed and the correlation coefficients were calculated to determine the relationship between the age of appearance of the ulnar sesamoid bone and the age of peak mandibular velocity in males and females.

Observer Error

Each of the two observers undertook a reexamination of the data for twenty-five individuals to determine accuracy of observations. This was done one month after the first observations were made. Perfect repeatability was obtained. Similarly, interobserver examination of an identical group of twenty-five individuals' records gave complete agreement, both as to the age at appearance of the sesamoid bone and the age at peak mandibular velocity. Such unanimity between observers is not unexpected in view of the straightforward nature of the observations being made.

Results

The mean values with one standard deviation and ranges for both the age of peak mandibular velocity and for the appearance of the sesamoid bone on a radiograph are given in Table 1. The mean sesamoid bone appearance precedes mean peak mandibular velocity by 0.72 years in males and 1.09 years in females. The females are ahead of the males both for sesamoid bone appearance (by 2.34 years) and for peak mandibular velocity (by 1.97 years).

Coefficient correlations were calculated between the age at appearance of the sesamoid bone and the age at maximum mandibular acceleration. The correlation coefficient was 0.428 for the males and 0.364 for the females. These values are greater than the minimum value of 0.254 which is required for statistical significance at the 1% level of confidence but, as Hirschfeld and Moyers[11] point out, one must distinguish between statistical significance and clinical utility. The individuals for whom raw data on mandibular growth were used instead of the computer-smoothed data do not appear to affect the distribution of the sample.

Peak mandibular velocity occurred before appearance of the sesamoid bone in 25.3% of males and 19.5% of females (Table II). This was an unexpected finding since Björk and Helm found that the sesamoid bone never appeared after peak acceleration in body height.

The sample was broken down into one-year age groups according to the age at which the sesamoid bone was first observed (Table III). The mean values, standard deviations, minimum and maximum values were then estab-

TABLE II

Distribution of Sesamoid Bone Appearance Relative to Occurrence of Peak Mandibular Velocity.

	Percentage of Total Sample	Age Range
Sesamoid Appearance Before Peak Mandibular Velocity		
M	74.7	0.1 - 5.0 yrs.
F	78.7	0.1 - 3.4 yrs.
Sesamoid Appearance Coincident with Peak Mandibular Velocity		
M	—	—
F	1.8	—
Sesamoid Appearance after Peak Mandibular Velocity		
M	25.3	0.1 - 2.9 yrs.
F	19.5	0.1 - 2.4 yrs.

lished. There is a relatively smooth series of increases in the mean values for peak mandibular velocity except for the single male in the 9.5 to 10.4 year group and for the mean value of the male 12.5 to 13.4 year group. Inspection showed that this latter value for peak mandibular velocity was affected by two extremely low readings; when these were left out of the calculation, the mean was 13.8 years.

The mean value for age at appearance of the sesamoid bone was 13.22 years for the males and 10.88 years for the females. These values are approximately the same as those given by other workers,[5,14] but Björk and Helm's sample gave slightly older values. This could be due to a population difference.

Discussion

The results show that appearance of the sesamoid bone precedes peak mandibular velocity by 0.72 years in males and 1.09 years in females. However, there is a lack of sufficient correlation to enable any form of prediction to be made concerning peak mandibular velocity from the first appearance of the sesamoid bone. The most that may be stated is that absence of the sesamoid bone means that 74.7% of males and 78.7% of females still have peak mandibular velocity to come.

The mean age of appearance of the sesamoid in females precedes the mean age in males by 2.34 years and the mean

TABLE III

Variation in Occurrence of Peak Mandibular Velocity

Age Range of Sesamoid Bone Appearance in Years	Number	Mean Age of Occurrence	S.D.	Minimum Value	Maximum Value
MALES					
9.5 - 10.4	1	15.0			
10.5 - 11.4	6	12.9	1.05	11.6	14.2
11.5 - 12.4	18	13.6	1.08	11.6	15.4
12.5 - 13.4	29	*13.4	1.07	10.2	15.6
13.5 - 14.4	27	14.4	1.35	12.2	15.8
14.5 - 15.4	7	14.7	0.58	13.8	15.3
15.5 - 16.4	3	15.8	0.22	15.1	16.5
FEMALES					
7.5 - 8.4	2	11.25			
8.5 - 9.4	8	11.11	1.11	8.7	12.7
9.5 - 10.4	24	11.65	0.87	9.6	13.0
10.5 - 11.4	47	11.97	1.02	9.7	14.3
11.5 - 12.4	21	12.59	0.81	11.4	14.5
12.5 - 13.4	6	12.48	0.98	11.7	14.4

* Two extreme cases affecting mean.

age of peak mandibular velocity in females also precedes that in males by 1.97 years, but there is considerable overlapping of males and females in the 11.5 to 12.4 years age group. By 13.5 years, all the females had shown appearance of the sesamoid bone whereas it was 16.5 years before all the males had reached a similar point of development. These differences between the sexes are in keeping with those of other physiological phenomena during the prepubertal phase as described by Tanner.[20]

One aspect of the findings in this investigation requires further comment; 25.3% of males and 19.5% of females did not show sesamoid bone appearance until *after* peak mandibular velocity had been achieved. This finding may offer an explanation of the differences of opinion reported in the literature,[3,12,17] concerning the onset of peak mandibular velocity in relation to other events at the circumpubertal phase. Most attempts to establish the time of peak velocity of mandibular growth have related this to other general changes such as body height, skeletal maturation, etc. Appearance of the sesamoid bone is accepted as a useful indicator of pubertal change being imminent but, as has been shown in this investigation, peak mandibular velocity may well be completed before the sesamoid bone appears. If peak mandibular growth bears such a low correlation to a well-defined and easily documented event such as appearance of the sesamoid bone, it is likely to be even less well-correlated to those events known to follow the sesamoid appearance such as maximum body height increase.

The best hope of achieving accuracy in predicting the onset of peak mandibular velocity in growth may lie in using the mandible as its own maturity indicator. Mandibular growth acceleration during adolescence is a relatively brief event during a period of great change and it is possible that further investigations linking maximum mandibular growth with other adolescent changes such as height increase, skeletal maturation, appearance of certain sexual characteristics, etc., may not greatly improve the accurate prediction of mandibular growth, a point of view supported by Luks' findings.[15] Woodside's[22] data are available in the form of population distance curves for mandibular length with the periods of increased velocity defined. Using these data, it is hoped to achieve a clinically useful degree of prediction for mandibular length. The question of direction of mandibular growth is also being studied and this is perhaps a more critical problem in prediction of facial development.

Summary and Conclusions

1. The purpose of this study was to determine the relationship between the appearance of the ulnar sesamoid bone of the thumb and the maximum rate of mandibular growth at adolescence.
2. The sample consisted of 91 males and 108 females from the serial experimental group of the Burlington Orthodontic Research Centre. Longitudinal data were obtained from radiographs taken annually.
3. Peak mandibular velocity was determined from individual computer-smoothed velocity curves of mandibular growth. These in turn were derived from the distance curves.
4. The date of appearance of the ulnar sesamoid bone was determined by inspection of the annual carpal radiographs.
5. A correlation of 0.428 for the males and 0.364 for the females

was obtained with the mean appearance of the sesamoid bone preceding mean maximum mandibular velocity by 0.72 years in males and 1.09 years in females.

6. Although the correlations are statistically significant, they are too low for any possible clinical prediction of maximum mandibular velocity at adolescence.
7. It may be stated that for 74.7% of males and 78.7% of females in the sample, if the ulnar sesamoid bone is not visible on a radiograph, then maximum acceleration of mandibular growth is still to come.
8. 25.3% of males and 19.5% of females did not show appearance of the ulnar sesamoid bone until *after* maximum velocity of mandibular growth was completed.
9. It is suggested that the considerable variation in timing of maximum mandibular velocity in relation to the ulnar sesamoid bone may also apply in relation to other phenomena such as maximum acceleration in body height. This may explain the differences in findings reported by previous authors.

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