Ossification of the Adductor Sesamoid and the Adolescent Growth Spurt

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INTRODUCTION

It is evident that in the adolescent child there is an acceleration of growth in the face and jaws which closely follows the same maturation scale as general skeletal growth, as represented by body height.[1-3,14,16-18]

Adequate consideration of the circumadolescent acceleration of growth in the facial skeleton is particularly warranted when planning orthodontic treatment for malocclusions associated with a discrepancy in the maxillo-mandibular skeletal relationship. For it can be expected that, in approximately nine to twelve months[16] after the onset of the circumadolescent statural increase, an acceleration in growth of the facial skeleton occurs with the mandibular ramus exhibiting the largest of the skeletal changes. Consequently, if the onset of this growth spurt can be predicted or detected, orthodontic treatment of appropriate nature can be timed to take advantage of, or to best cope with, the facial skeletal changes which take place during this period of rapid development.

LITERATURE REVIEW

A significant study relative to the possibility of predicting the age at maximum adolescent growth in statural height has been reported by Björk and Helm.[4] Their purpose was to try to relate the "circumpuberal" growth spurt to other criteria of maturation: ossification of the sesamoid bones in the thumb as evidenced in hand-wrist radiographs, stages in dental development and, in girls, the menarche. It is noted that the sesamoids of the metacarpophalangeal joint of the thumb were included as they are the only consistent ossification centres in the hand that appear near puberty.

Björk and Helm found "there was a close association between the age at maximum growth in body height and the age when ossification of the ulnar metacarpophalangeal sesamoid of the thumb occurred, and also in girls the age at menarche." It was evident that the onset of ossification of the ulnar sesamoid either preceded or coincided with maximum adolescent growth. It did not take place after the circumadolescent growth spurt and usually occurred one year before. Menarche, on the other hand, did not occur before this age and it was recorded up to a few years later. Dental development was found to be of little value as a criterion of adolescence.

Deming's[6] longitudinal study indicated that menarche occurred "without exception, a number of months after the point of maximum rate of growth. . . ." And the finding of Boas[5] supports this conclusion.

More recently, Frisancho, Garn and Rohmann[7] found in all cases of 110 Ohio-born white girls ". . . the adductor sesamoid appeared on an average 22 months before menarche."

Substantial evidence exists that dental development has no merit for assessing physiological maturity at adolescence.[12,13,15,17]

Björk[4] points out that, since growth in body height is the dimension by

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which maximum "puberal" skeletal growth is most easily determined, measurement of the annual growth in body height is recommended as a routine procedure for orthodontic patients treated over a long period. Further, he advocates the use of radiographic examination to determine ossification of the sesamoid to provide a guide where longitudinal records are not available. He mentions that this is easily recorded on a dental film, with the reservation that in single cases ossification of the sesamoid may not occur.

Purpose

This study has been conducted to relate the ossification of the ulnar sesamoid bone and developmental status of the metacarpophalangeal joint of the thumb with the accelerated increase in statural height of adolescent males and females. The investigation consists of two surveys.

1. A short longitudinal study of the height increments and ulnar sesamoid ossification in adolescent boys and girls.

2. A cross-sectional survey conducted to supplement the main study by way of showing occurrence of the sesamoid ossification in children of the ages ten to sixteen years.

While the sesamoids of the fingers are not always present,[10] the two sesamoids at the metacarpophalangeal joint of the thumb are not prone to irregularity.[11]

Material and Methods

The subjects included were children who had passed their tenth birthday and were attending the Department of Public Health (New South Wales) School Dental Clinic at Naremburn for dental and/or orthodontic treatment. Apart from the likelihood of being available for the required periodic examination of thumb-joint x-ray and height measurement, there was no condition of selection.

From the mixed longitudinal survey conducted since May 1968, records of thirty-three boys and thirty-eight girls, ten to sixteen years of age, have been selected for reporting in a longitudinal way pertaining to their growth at adolescence (i.e., in respect to the two stages of physical development being examined). The remainder of the sample, whose participation in the study has been of shorter duration, provide data for the supplementary cross-sectional survey.

Additionally, twenty pupils at the Naremburn Boys High School and twenty pupils at the Willoughby Girls High School were volunteer subjects included in the 15- and 16-year age groups of the cross-sectional study.

Technique

All radiographs of the first metacarpophalangeal joint have been taken using the standard size dental intraoral film. It can be seen from the various illustrations in this report that the film is large enough to record the skeletal developmental status of the joint area.

Height measurements were carried out after the method of Meredith[15] with an anthropometric rule permanently fastened to a wall of the dental surgery used by the author. On the floor, vertically below the instrument, were permanent marks on which the subject stood in stockinged feet, heels approximately three cm apart at their most medial aspect. With the feet correctly positioned the child was requested to stand erect in the military position of "attention." The sliding horizontal arm was then brought down into firm contact with the vertex.

All measurements and x-rays were performed by the author.

Longitudinal Study

The two stages of physical maturation examined are:

1. Ossification of the ulnar sesamoid and developmental status of the metacarpophalangeal joint of the thumb;
2. The accelerated increase of statural height at adolescence.

The metacarpophalangeal joint of the right thumb of each subject was x-rayed, usually as frequently as every three months to detect the onset of ossification of the sesamoid and record the progress of its ossification. For accuracy in assessing rate of growth over these relatively short periods, the age at each examination was recorded to the nearest half-month.

At each of the examinations the subject's height was measured and recorded. The stature records for each child were used to plot the height measurement with time as the abscissa. On the curve was plotted the age of the subject at the examination when the ulnar sesamoid was first radiographically evident, indicating also the stage of ossification. The slope of the distance curve served as an indication of the rate of growth.

The subjects upon entering the study would obviously not be all of the same developmental status. They ranged from preadolescent through to those who had almost completed adolescence, with the large middle group of children being around the commencement of adolescence.

It was therefore necessary to designate stages in the progress of ossification of the ulnar sesamoid to orientate the time of onset of ossification with the circumadolescent statural acceleration. Although the mature ulnar sesamoid varies in size from one individual to another, the four stages indicated below are submitted as being generally applicable to the development of the bone as seen in radiographs.

Stages of Adductor Sesamoid Ossification

AS0: No radiographic evidence of ossification.

AS1: "Pinhead" size. The first definite indication radiographically of commencing ossification. Approximately 1 mm diameter.

AS2: Ossification progressed past stage 1 but of indefinite outline.

AS3: Distinct outline, usually seed-shaped, evident. In females of small stature it is about 3 mm x 2 mm while in tall males about 5 mm x 3 mm, at this time, when the sesamoid is about 70% of its mature size.

Stage AS1 has about three months duration. In a few subjects this stage was missed notwithstanding an interval of only three to four months between examinations. Stage AS2 pertains for approximately six months before the distinctive seed shape becomes apparent. The typical sesamoid may be evident for up to eighteen months or more before fusion of the proximal phalanx begins. Figure 1 shows x-rays from the longitudinal records of an adolescent girl and boy illustrating the stages of ulnar sesamoid ossification described. The subjects' age and height at the time of each radiograph are also shown. Two further stages in the skeletal maturation of the thumb joint are noted and referred to as follows:

AS3+: Beginning fusion of the epiphyseal-diaphyseal proximal phalanx. By now ossification of the flexor sesamoid may be discernible through the head of the first metacarpal. (Fig. 2, left)

E.F.: Epiphyseal fusion of the proximal phalanx is apparently complete. The fusion line may be evident for many months however. (Fig. 2, right)

Mention was made of the children being at different developmental levels upon their entering the study. For evaluation of data the individuals have been divided into three groups based on their adductor sesamoid development as seen in the serial x-rays.

Children (11 males and 5 females)

Fig. 1 Top, left to right, a female ten years ten months, 1394 mm (AS0); eleven years five months, 1446 mm (AS1); eleven years eight months, 1458 mm (AS2); twelve years one month, 1499 mm (AS3).

Below, left to right, a male twelve years nine months, 1648 mm (AS1); thirteen years five months, 1706 mm (AS2); fourteen years, 1770 mm (AS3).

Fig. 2 Left, male fifteen years eight months, 1790 mm, fully developed adductor sesamoid and commencing epiphyseal — diaphysial fusion of the proximal phalanx. Right, male, sixteen years seven month, 1805 mm, fusion of the phalanx is complete with little evidence of the fusion line.

who have participated in the study for at least eighteen months without, or before, showing radiographic evidence of commencing sesamoid ossification (Group A).

Individuals (18 males and 23 females) who showed an early stage in their sesamoid's ossification at, or soon after, the time they entered the study (Group B).

Group C, subjects whose adductor sesamoid bone was found to be already well developed in their initial thumb joint x-ray (4 males and 10 females).

Obviously group B is composed of the subjects with whom this study is primarily concerned. The majority of the boys and girls whose records provide the data come within this category.

Comparison of the typical growth rates of the three groups should supplement the findings relating to the individual growth rate variations (associated with the onset and progress of the sesamoids ossification) exhibited by the group B subjects.

Age yrs.	Sex	N	Adductor Sesamoid: Metacarpophalangeal Joint Status					
			AS0	AS1	AS2	AS3	AS3+	E.P.
10	F	10	7	1	1	1		
	M	10	10					
11	F	10	2	1	1	6		
	M	10	9		1			
12	F	10		2	1	4	3	
	M	10	7	1	1	1		
13	F	10				5	4	1
	M	10	2	1		7		
14	F	10				1	3	6
	M	10	1	1		6	2	
15	F	10						10
	M	10				3	4	3
16	F	10						10
	M	10				3	3	4

Table I Adductor sesamoid ossification and thumb joint development in 70 girls and 70 boys aged 10 to 16 years.

Findings

Cross-Sectional Study

As the information arising from the cross-sectional survey provides a background for assessing the findings of the longitudinal study, the results of the supplementary study are presented first.

The occurrence of adductor sesamoid ossification in the seventy boys and seventy girls examined cross-sectionally is recorded in Table I, which is set out in accordance with the progressive stages of the metacarpophalangeal joints' development identified in the longitudinal study.

Three of the 10-year-old girls showed evidence of the sesamoid's ossification. There was no sign of any such formation in the radiographs of the 10-year-old boys. And only one of the 11-year-old boys registered the sesamoid ossifying. The radiographs of the 12-year-old boys show about equal osseous developmental status to that seen in the x-rays of the 10-year-old girls.

All the 12-year-old girls show the sesamoid present, various stages of ossification being radiographically evident. This groups status is about equalled by the 15-year-old boys.

In the female subjects the first definite sign of fusion commencing is in three of the 12-year-old girls' x-rays. The first evidence of commencing fusion in the males is registered by two 14-year-old boys.

All ten 15-year-old girls' radiographs show completed fusion of the proximal phalanx. But of the 16-year-old boys only four evidence completed fusion, three others have fusion commencing and the remaining three 16-year-old boys show a comparatively calcium-free diaphyseal-epiphyseal junction. By comparison, more of the 14-year-old girls (six subjects) show completed fusion of the proximal phalanx than the 16-year boys. Only one 14-year girl's x-ray shows a comparatively calcium-free epiphyseal-diaphyseal junction of the proximal phalanx.

The evident adductor sesamoid ossification and degrees of epiphyseal fusion of the proximal phalanx in the males and females cross-sectionally examined is consistent with the acknowledged sex difference in general developmental progress.

While the girls are approximately two years ahead commencing ossification of the adductor sesamoid bone, their rate of progressive ossification is also found to be faster than the boys.

Similarly, fusion of the proximal phalanx commences about two years earlier in the female subjects than in the males. In the latter the rate of fusion is evidently also slower.

Longitudinal Study

Figure 3 shows the traced growth distance curve of five of the thirty-three boys longitudinally examined. These selected records are representative of the typical rates of growth recorded by male subjects at different stages of adductor sesamoid ossification and thumb-joint development. Similarly, Figure 4 illustrates five typical growth curves for female subjects.

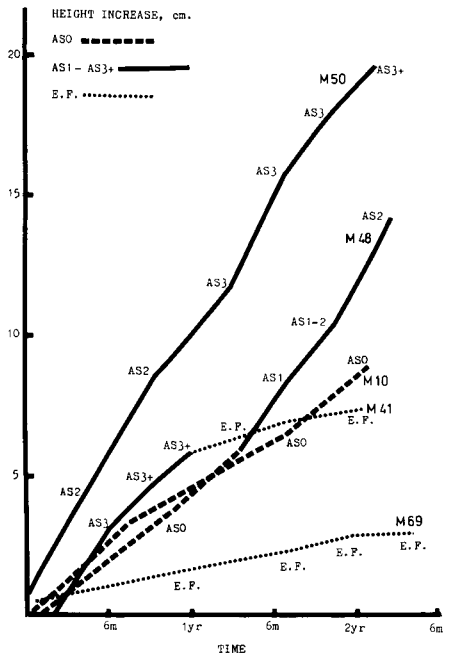

Fig. 3 Typical growth curves of male subjects at different stages of adductor sesamoid ossification / first metacarpophalangeal joint development.

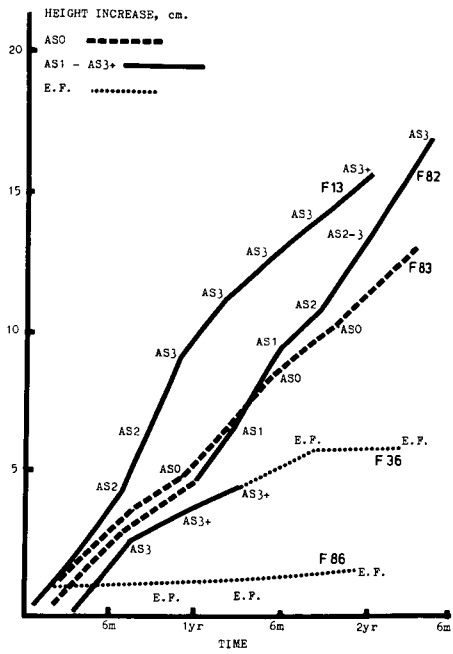

Fig. 4 Typical growth curves of females at different adductor sesamoid / first metacarpophalangeal joint maturational levels.

The broken lines record height growth prior to commencing ossification of the adductor sesamoid, unbroken lines represent height increase during progressive ossification of the sesamoid, and the dotted lines record height from the time of commencing epiphyseal-diaphyseal fusion of the proximal phalanx. Clearly, the slope of the unbroken lines is the steepest, that of the broken lines being the next steep, while the dotted lines have least inclination. The two composite graphs demonstrate the rate of height growth of the progressive-ossification status subjects being markedly faster than that of the pre-ossification subjects. Height increase for advanced ossification status is the minimum.

The rate of height increase for subjects of pre-ossification status is represented by the graphed records of M10 in Figure 3 (males) and F83 in Figure 4 (females).

The growth curves of M48 in Figure 3 and F82 (Fig. 4) typically illustrate the accelerated height increase of a boy and a girl at the time their thumb-joint radiographs showed beginning ossification of the adductor sesamoid bone (AS1).

The tracing of a boy's growth curve from the time his adductor sesamoid begins to ossify and throughout its progress of development is shown in Figure 3 (M50). Similarly, F13 (Fig. 4) illustrates the height increase recorded by a girl of progressive ossification status.

M41 in Figure 3 and F36 (Fig. 4) show the marked slowing of height growth coinciding with commencing epiphyseal-diaphyseal fusion of the proximal phalanx of a male and a female subject of advanced ossification status. M69 in Figure 3 and F86 (Fig. 4) demonstrate the minimal height increase of two subjects in whom there

was already epiphyseal fusion of the proximal phalanx.

For fifteen boys and fifteen girls the mean age of onset of the sesamoids ossification was found to be: 12y, 11m, ± 14m and 11y, 7m, ± 7.2m, respectively.

Progressive adductor sesamoid ossification of long duration is seen to occur simultaneously with a long spurt of height growth and, conversely, subjects with a brief spurt of height increase have a coinciding short duration of sesamoid development. Following the sesamoid's ossification, the proximal phalanx begins diaphyseoepiphyseal fusion. When this occurs, height increments are found to decrease and diminish rapidly as fusion is completed.

For every subject in whom beginning ossification of the sesamoid was detected there was a coinciding acceleration of height increase. The highest increment recorded by each of the subjects was always after the onset of ossification and during stage AS3 for most of the children concerned (Group B).

Table II relates the maximum height increment with the stage of adductor sesamoid ossification for ten males and twelve females whose serial x-rays record the progressive stages of development of their sesamoid.

Discussion

The accelerated growth in statural height found to coincide with the onset and progress of ossification of the adductor sesamoid bone is identified as the growth spurt of adolescence. The relative rates of growth recorded by the male and female subjects examined, the duration of the spurt, and the following deceleration to minimal increase or apparent cessation of growth in height are features consistent with what is known of this period of development.[17]

The cross-sectional findings suggest that adductor sesamoid ossification commences in females between eleven and twelve years of age and in males between thirteen and fourteen years. From the records of fifteen females and fifteen males longitudinally studied in this respect, the average age of onset is found to be 11 years, 7 months for the girls and 12 years, 11 months for the boys. The slightly earlier age of onset found longitudinally for the males (compared to the cross-sectional indication) is perhaps explained by the wide range of variability for age-at-appearance of this ossification centre. Garn and Rohmann[8] observed that it may appear in girls between the eighth and thirteenth year or it may appear in the radiographs of boys between the tenth and sixteenth year. The median age was 10.5 years for the ninety-two girls and 12.6 years for the eighty-seven boys examined by Garn and Rohmann.

Björk and Helm,[4] who studied twenty girls and thirty-two boys, arrived at the following figures for onset of the centre: girls (11y 6m ± 10.3m), boys (13y 3m ± 11.2m). While the 11y 7m average for the girls in the author's sample compares with the Danish girls (11y 6m), the 12y 11m average for the boys suggests a slight advancement of this particular male sample when compared with the 13y 3m average for the Danish boys.

Stage of Ossification and Maximum Growth

Björk and Helm found "in more than half of the sample, ossification of the ulnar sesamoid of the thumb occurred one year before maximum puberal growth (both sexes), it never occurred after this maximum." The above conclusion is in agreement with the indications of this study (Table II) that maximum growth takes place at the time the typical seed shape of the

MALES						FEMALES					
Add. Ses. Status			Max. Increment Recorded:		Months after onset of ossificn.	Add. Ses. Status			Max. Increment Recorded:		Months after onset of ossificn.
AS 1	AS 2	AS 3	mm.	per months		AS 1	AS 2	AS 3	mm.	per months	
CHAPMAN	M 75		57	6.5	6.5			F 22	24	3	14
		M 32	35	4	13.5		F 85		25	3	7
		M 28	37	3.5	12			F 16	24	3	13
		M 39	66	8	11			F 19	22	3	14
		M 27	30	3	13			F 13	22	2	6
		M 43	26	3	11			F 15	36	4.5	10
		M 36	29	2	8.5			F 73	32	3.5	7
		M 38	33	3	7		F 74		52	8	8
		M 40	28	3	16.5			F 25	30	2	9
		M 50	41	4	18			F 11	26	3.5	6
								F 17	21	2.5	11
								F 79	26	2	8
Average: 11.7 months after						Average: 9.4 months after					
Range: 6.5 - 18 months						Range: 6 - 14 months					
Standard Deviation: 3.6 months						Standard Deviation: 2.8 months					

Table II Maximum growth and stage of adductor sesamoid ossification

sesamoid is radiographically manifest (stage AS3).

In each subject exhibiting fusion of the epiphysis of the proximal phalanx a marked decrease in the height increments was found to coincide. Certainly, as pointed out by Garn, Rohmann and Silverman,[9] the developmental status of one bone or one joint does not perfectly meter the status of the over-all skeleton. But there are indications that fusion of the proximal phalanx at the first metacarpophalangeal joint signals completion of the adolescent spurt in height.

Björk and Helm observed one example of absent adductor sesamoid ossification in each sex of their series. Garn and Rohmann found that the sesamoid was present even in cases of gonadal agenesis. In both the cross-sectional and longitudinal studies reported herein there was no instance of the sesamoid being absent based on the developmental status of the metacarpophalangeal joint.

Summary

A radiographic method using a standard size dental film to assess the developmental status of the first metacarpophalangeal joint has been described.

Seventy males and seventy females, aged ten to sixteen years, were examined in a cross-sectional radiographic survey to determine occurrence of the adductor sesamoid bone.

Thirty-three males and thirty-eight females, whose ages on entering the study ranged from ten to sixteen years, were examined longitudinally to relate increments of height prior to, during, and after progressive ossification of the adductor sesamoid.

The following conclusions have been formed:

The adductor sesamoid bone is found to occur regularly in accordance with the development of the first metacarpophalangeal joint.

Onset of ossification of the sesamoid

takes place at the time the adolescent spurt in statural height begins. The duration of the latter is observed to coincide with the duration of the sesamoids' development.

In the group of subjects longitudinally examined, the maximum height increment was always recorded after the adductor sesamoid commenced ossifying and usually at the time the typical seed shape was radiographically manifest.

Commencing epiphyseal-diaphyseal fusion of the proximal phalanx at the thumb joint is found to mark the completion of the two maturational events which have been related.

It is submitted that the radiographic technique described is a convenient means to assess the developmental status of a patient in relation to the timing of the adolescent growth spurt.

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