A LONGITUDINAL CEPHALOMETRIC STUDY OF FEMALE MANDIBULAR GROWTH FROM AGE 15 TO 26 YEARS

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INTRODUCTION

Cephalometrics has been used in orthodontics since Broadbent's classic paper in 1931[1] as a means of describing growth and treatment changes. Whether orthodontic treatment is performed in the mixed dentition stage, during the pubertal growth "spurt," or both, posttreatment growth related changes are an important consideration in the prevention of relapse.[2]

Many investigations of facial growth describe changes from birth up to age 15 years,[3,4] but few provide significant information on facial growth after the age of 16 years.[5] One reason is because most research has been focused on possible growth changes during orthodontic treatment and also because projection, landmark identification and measurement errors involved in posttreatment research have been greater than growth increments.[6]

Since facial profile convexity nearly always decreases between seven and 17 years of age,[7] this owing to an increase in mandibular prognathism, it is assumed that if a significant change is to be found, it will be in the mandible and therefore the mandible was chosen for this study. Furthermore, the mandible is known to be one of the latest maturing bones dimensionwise in the skeleton.

The purpose of this research then is to examine late mandibular dimensional changes which may occur in posttreatment orthodontic patients. This is of concern because of the possible influence on the stability of the corrected malocclusion and the timing of any orthognathic surgery.

REVIEW OF THE LITERATURE

Broadbent's 1931 paper[1] describes a standardized radiographic technique, using lateral and antero-posterior headfilms, that has formed a basis for cephalometric studies for the past 50 years. He described tracing and superimposition method using consecutive films of the same child to illustrate growth and development changes. He also addressed the problem of a nonparallel beam of x-rays. An enlargement error formula was developed using known target-to-subject and subject-to-film distances so that actual growth changes could be documented.

Because cephalometrics involves the reduction of a three-dimensional object to a two-dimensional tracing, foreshortening occurs when measuring, for example, mandibular body length because the landmarks used are not both in the same sagittal plane.[8] This phenomenon is of little consequence in growth studies provided that all films are taken with the midsagital plane parallel to the film.

Since Broadbent's time, a number of growth studies have used an implant technique[9,10,11] for superimposition so that remodelling of landmarks does not influence any changes recorded. It is now becoming increasingly difficult to start new implant studies and, therefore, this investigation has used a comparison of serial tracing measurements based on cephalometric landmarks. Any remodelling of landmarks is believed to be minor due to the age of the patients and superimposition error was minimized.

Most mandibular growth studies concentrate on changes at the onset of puberty plus or minus two years.[12,13,14] The age of cessation of measurable mandibular growth is not usually indicated but can be assessed by close scrutiny of the data presented.

Some recent examples include a paper by Bjork[5] who examined variations in the growth pattern of the human mandible. A graph relating condylar growth to age for a sample of 45 Danish boys indicates an annual condylar growth rate of greater than 1 mm per year up to the age of 19. His measurement error, determined on the basis of repeated measurements, was within the limits of ± 0.5 mm.

Meredith[15] performed a serial study on a sample of 17 females and 14 males of the ages five to 17 years. Of his five subgroups one had a pogonion to postgonion dimensional increase of 2 mm from 16 to 17 years of age. Another two subgroups (six females and six males) had a mean increase of 1 mm for the same age range.

Both Bjork's and Meredith's articles indicate that variation of cessation of mandibular growth on an age basis is a common finding. Anderson, Thompson and Popovich[16] attempted to correlate the occurrence of late mandibular growth to other characteristics so that people exhibiting late mandibular growth might be easily identified. In a sample of 111 females from the Burlington Growth Centre, the late maturers caught up to the early maturers by age 16 years, in height and weight, but not in mandibular length. Growth in mandibular length continued on past the age at which growth in stature had ceased. Tanner,[17] in his book Growth at Adolescence, described a similar observation.

When examining the mandible for growth changes cephalometrically, Virginia Knott[18] discovered a significant (at P .01) increase in mandibular body length in males between the ages of 17 years and early adulthood (24 to 29 years). Less change was found in the same dimension in females; however, these females increased between 1 to 4 mm each. Between the ages of 15 and 17 years both males and females showed significant increases for the same measurement of mandibular depth.

When gonial angle was investigated by Thompson and Popovich,[19] they found that the gonial angle size had little practical significance in the determination of future mandibular growth. Gonial angle size decreased on average from age four to 14 years and then remained relatively stable. On an indivudal basis, gonial angle size tended to be inversely related and significantly correlated with mandibular body length. That is, a mandible with a more obtuse gonial angle had a shorter mandibular body length and a mandible with a more acute gonial angle had a longer mandibular body length.

Bjork[5,20] also found a decrease in gonial angle with age but not as great a change as anticipated from his analysis of the direction of condylar growth as related to the tangent to the posterior border of the ramus and to the tangent to the lower border of the mandible. The "less than expected" decrease in gonial angle was due to resorptive remodelling below the angle of the mandible and to periosteal growth on the inferior aspect of the symphysis. In specific cases where gonial angle decreased the most, the condylar growth direction was more vertical. When the gonial angle increased, condylar growth was in a more horizontal direction.

Sicher[21] and Enlow[3] have been major contributors to the understanding of mandibular growth processes although much of their work is not related to specific ages. It is of note that evolvement of the ramus is posterior, cranially and laterally directed to correlate with the expanding cranial base, while the mandibular body grows cranially to maintain its relation with the maxilla by extension of the alveolus and teeth. These vectors serve to relocate the lower jaw in a downward and foreward position in space. The two growth processes in the mandible responsible for the foregoing are condylar growth and an accompanying progressive remodelling. In later adolescent growth the remodelling processes involve a small variable degree of deposition or resorption at the chin as well as ramus remodelling to accommodate the third molars.

The amount and direction of late mandibular growth cannot be reliably predicted on an individual basis.[22] Lande[7] showed that the mandible generally grows at a greater rate than the maxilla, in an anterior direction, at later ages and that it continues to grow after growth in the maxilla has ceased. Therefore if orthognathic surgery were anticipated, it would be ideal to wait until growth of the mandible is complete before surgery is performed for optimal long-term results. Many of the early workers[23,24] in orthognathic surgery in conjunction with orthodontics did not address the problem of late mandibular growth directly. However, their case reports are all of patients over the age of 16 years, if female, or over the age of 17 years, if male.

Although most of the aspects of mandibular growth from early fetal stages to immediately post-pubertal changes are well documented, the specific questions of late mandibular growth and age of cessation of mandibular growth are not well addressed in the literature. Therefore, this paper is directed toward achieving a better understanding in these areas.

MATERIALS AND METHODS

The sample consisted of 26 females aged approximately 16 years and above (Fig. 1). They were chosen from the treatment records of the Oregon Health Sciences University, Department of Orthodontics.

The data was derived from consecutive lateral head radiographs taken with the same Broadbent-Bolton cephalometer. When available, more than two films of the one subject were used. Films were taken at intervals of one year apart or greater. Routine cephalometric acetate tracing techniques were utilized.

The definitions of the cephalometric landmarks Pogonion, Menton and Articulare are those recommended by the Second Research Workshop on Roentgenographic Cephalometrics.[25] Condylon was the point on the condylar head that was furthest from pogonion. Gonion was defined by connecting pogonion to articulare and then constructing the longest perpendicular to the angle of the mandible. Gonion was located where this perpendicular crossed the mandibular angle.[26] The posterior plane of the ramus was that plane connecting articulare to gonion. The mandibular plane was described by a line connecting menton to gonion (Fig. 2).

Where paired landmarks appeared due to the difference in the relationship between the central ray from the x-ray tube and paired structures, both images were traced and the landmark used was a point bisecting the two images.[27]

The measurements taken for investigation were:

1. Pogonion to Condylon, to represent total mandibular length.
2. Pogonion to Articulare, as a second and possibly more accurate representation of total mandibular length.[28]
3. Pogonion to Gonion, to illustrate mandibular body length.
4. Gonion to Condylon, a measurement of total posterior mandibular height.
5. Gonion to Articulare, posterior ramus height.
6. Gonial Angle, as defined by the intersection of the posterior plane of the ramus and the mandibular plane.

Linear measurements were all affected by a 6-8% enlargement. A correction factor was not included in data computations.

Twelve randomly chosen lateral headfilms were traced on two separate occasions and the replicate measurements were recorded to evaluate measurement error.[6]

A statistical analysis of the data was applied according to accepted standard procedure. The mean, standard deviation, and standard error of the mean were calculated for all measurements on the first film and the last film of each subject. A one tailed, independent student "t" test was used to test for significant growth changes between the first film and last film taken of the subjects.

FINDINGS

The findings and statistical results are presented in Table I and Figure 3.

The average age of the sample when the first film was taken was 17 years and seven months with a standard deviation of one year and six months. When the last film was taken, the average age was 21 years and 10 months with a standard deviation of two years and seven months.

The average total length of the mandible, measured from pogonion to condylon, on the first film of all subjects was found to be 117.6 mm with a standard deviation of 7.2 mm. This dimension increased by 1.4 mm to 119 mm on the final film with a standard deviation of 6.6 mm. This change was not found to be statistically significant. This measurement from pogonion to condylon had the highest standard error of the measure at 1 mm.

The distance from pogonion to articulare proved to be more accurately reproducible, having a standard error of the measure of 0.8 mm. However, it increased by only 0.9 mm from 108.6 mm to 109.5 mm. This was not a statistically significant change.

Mandibular body length increased slightly from 74.2 mm to 74.7 mm. However, this 0.5 mm change was less than the 0.7 mm measurement error.

The combined ramus and condylar height measured from gonion to condylon increased by 0.9 mm, from 61 mm to 61.9 mm, between the two films. This was not a statistically significant change at the 95% level of confidence.

The measurement of ramus height alone, from gonion to articulare increased the smaller amount of 0.6 mm.

Gonial angle diminished by an insignificant 0.3°. Measurement error was 0.5°.

DISCUSSION

The purpose of this study was to illustrate mandibular growth in females over the age of 16 years. Therefore, the dimensions selected for measurement were chosen because they had exhibited significant change at an earlier age in previous studies.

In dealing with late growth, it was expected that increments of change would be small and, therefore, emphasis on reduction of errors was important. Longitudinal data of implanted subjects was not available. However, every precaution was taken to reduce landmark identification error. The same individual performed all tracings and located all landmarks in a darkened room, under ideal conditions. All linear measurements were performed with the same accurately calibrated, dial reading, micrometer gauge. All cephalograms were taken by the same experienced radiographer. Even so, in two instances the standard error of the measure was greater than the mean change.

When examining the change in the dimension pogonion to condylon, it became clear that in the majority of cases there was no demonstrable difference in length of the mandible between the first film and the last film. However, in examining individual subjects, many increased by 2 to 3 mm, one even increased 7 mm. The latter subject only increased 5 mm in the distance pogonion to articulare. This could indicate that condylar growth was in a more horizontal than vertical direction.

Measurement error could also account for some of the difference between changes in the measurements pogonion to condylon and pogonion to articulare.

Late condylar growth could have been masked by resorption of pogonion[29] and, therefore, the overall effect of condylar growth on total mandibular length would have been diminished.

The mandibular body length mean increased by 0.5 mm. This dimension would be expected to increase by addition remodelling on the posterior border of the ramus, mostly in the inferior third. It could also decrease or increase due to remodelling of pognion.[29] In this study an increase of 0.5 mm cannot be given any significance since it is less than the standard error of either mean and the standard error of the measure. On an individual basis there were several increases of up to 5 mm and a few decreases of up to 3 mm. Similar changes over a greater age range were reported by Knott.[18]

The mean increases in gonion to condylon and gonion to articulare were similar, although the former was slightly larger by 0.3 mm. Here, according to Enlow, we are seeing the effects of the vertical component of condylar growth offset by resorption referred to as antigonial notching.[3]

Gonial angle stayed fairly constant with increasing age on the average. Even individual changes were slight in this age range, with almost an equal number increasing as decreasing.

SUMMARY AND CONCLUSIONS

Moorrees,[30] Björk,[31] Tanner,[17] Hixon[32] and many others, in their discussions on facial growth, have emphasized that each person should be appraised as an individual because growth changes do not conform to a set of rules. If this sample is taken and examined "on the average," no mandibular growth can be illustrated statistically after the age of 16 years. Alternatively, when all possible errors are taken into account, a number of the sample have exhibited measurable late mandibular growth.

These late mandibular growth changes may be of sufficient magnitude to become clinically evident in the form of relapse of corrected malocclusions or the appearance of new malocclusions after orthodontic treatment and/or orthognathic surgery in certain individuals. Although this study holds no clues on how to identify late growing individuals in everyday orthodontic practice, it has become evident that longitudinal radiographic evidence is a reliable method of establishing when late mandibular growth has ceased.

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TABLE I

Statistical Analysis of the First Film (FF), the Last Film (LF) and the Differences (D) Between Them

Dimension		N	Mean	S.D.	t	S.E.M.	S.E.Meas. N=12
Pogonion-Condylon (mm)	FF	26	117.6	7.2		1.4	0.96
	LF	26	119.0	6.6		1.3	
	D		+1.4		0.757		
Pogonion-Articulare (mm)	FF	26	108.6	6.5		1.3	0.79
	LF	26	109.5	6.7		1.3	
	D		+0.9		0.508		
Pogonion-Gonion (mm)	FF	26	74.2	5.7		1.1	0.75
	LF	26	74.7	5.9		1.1	
	D		+0.5		0.344		
Gonion-Condylon (mm)	FF	26	61.0	4.5		0.9	0.58
	LF	26	61.9	4.2		0.8	
	D		+0.9		0.750		
Gonion-Articulare (mm)	FF	26	48.7	3.2		0.6	0.54
	LF	26	49.3	3.3		0.6	
	D		+0.6		0.701		
Gonial Angle (degrees)	FF	26	130.6	6.1		1.2	0.5
	LF	26	130.3	6.1		1.2	
	D		-0.3		0.159		

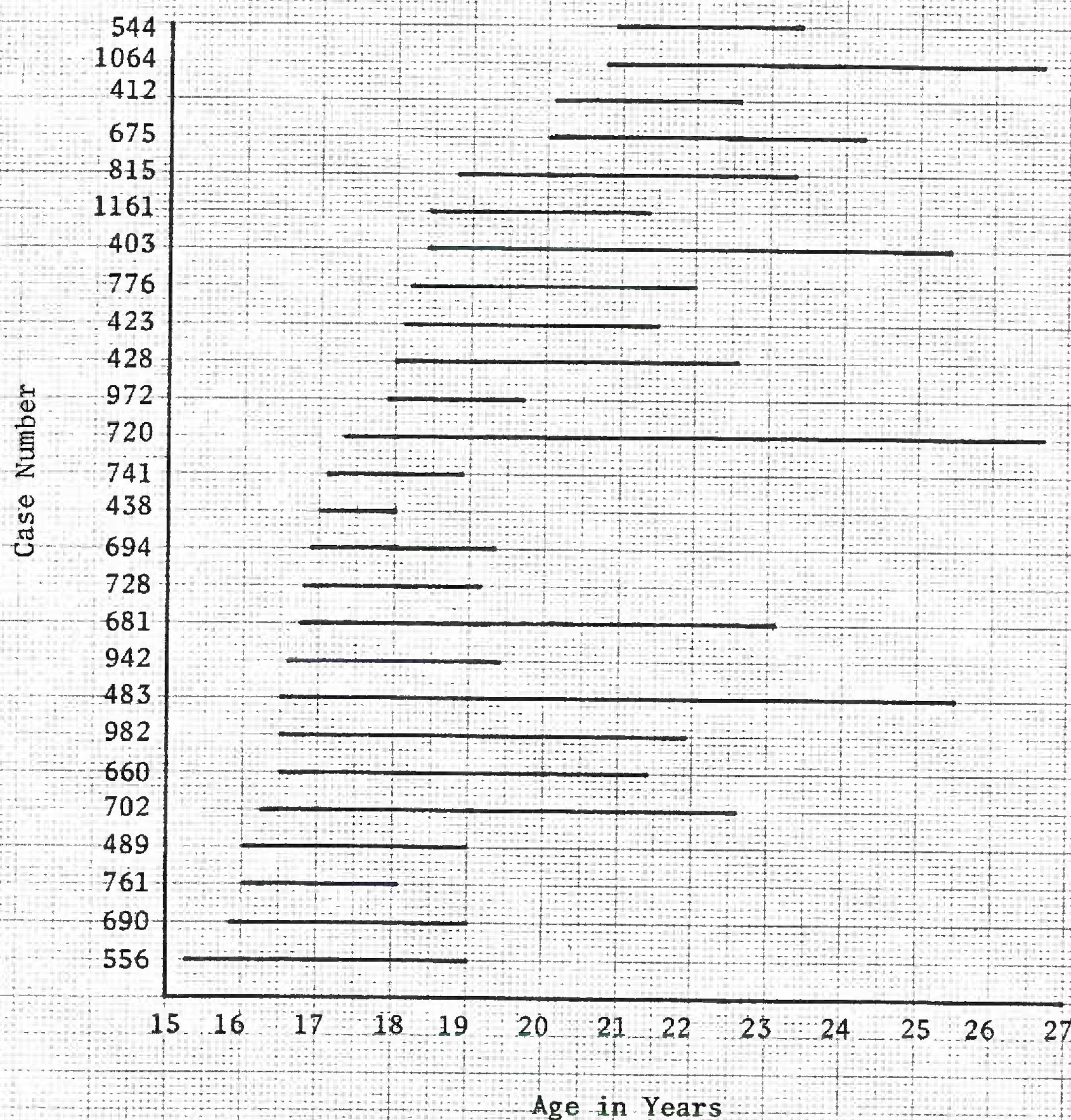

Fig. 1: Age Range of Sample

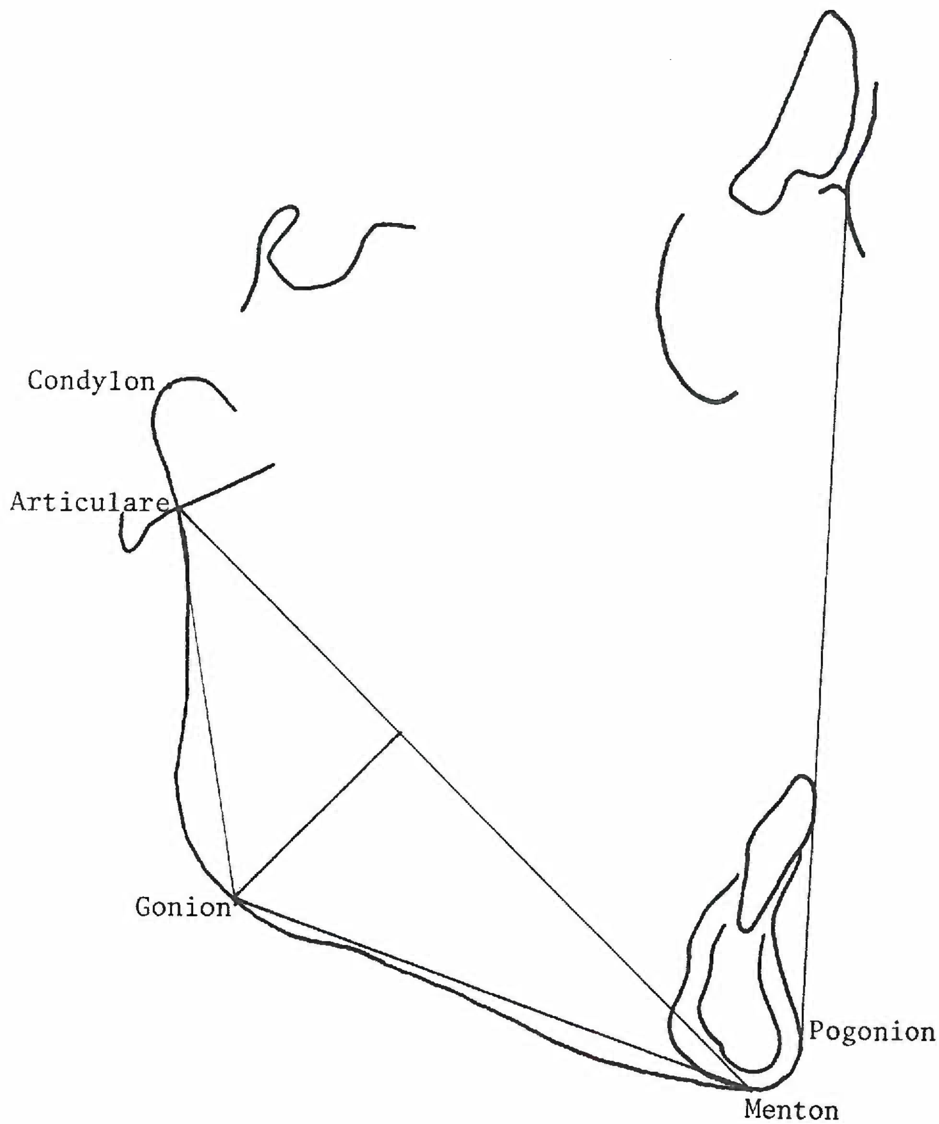

Fig. 2: Cephalometric Landmarks

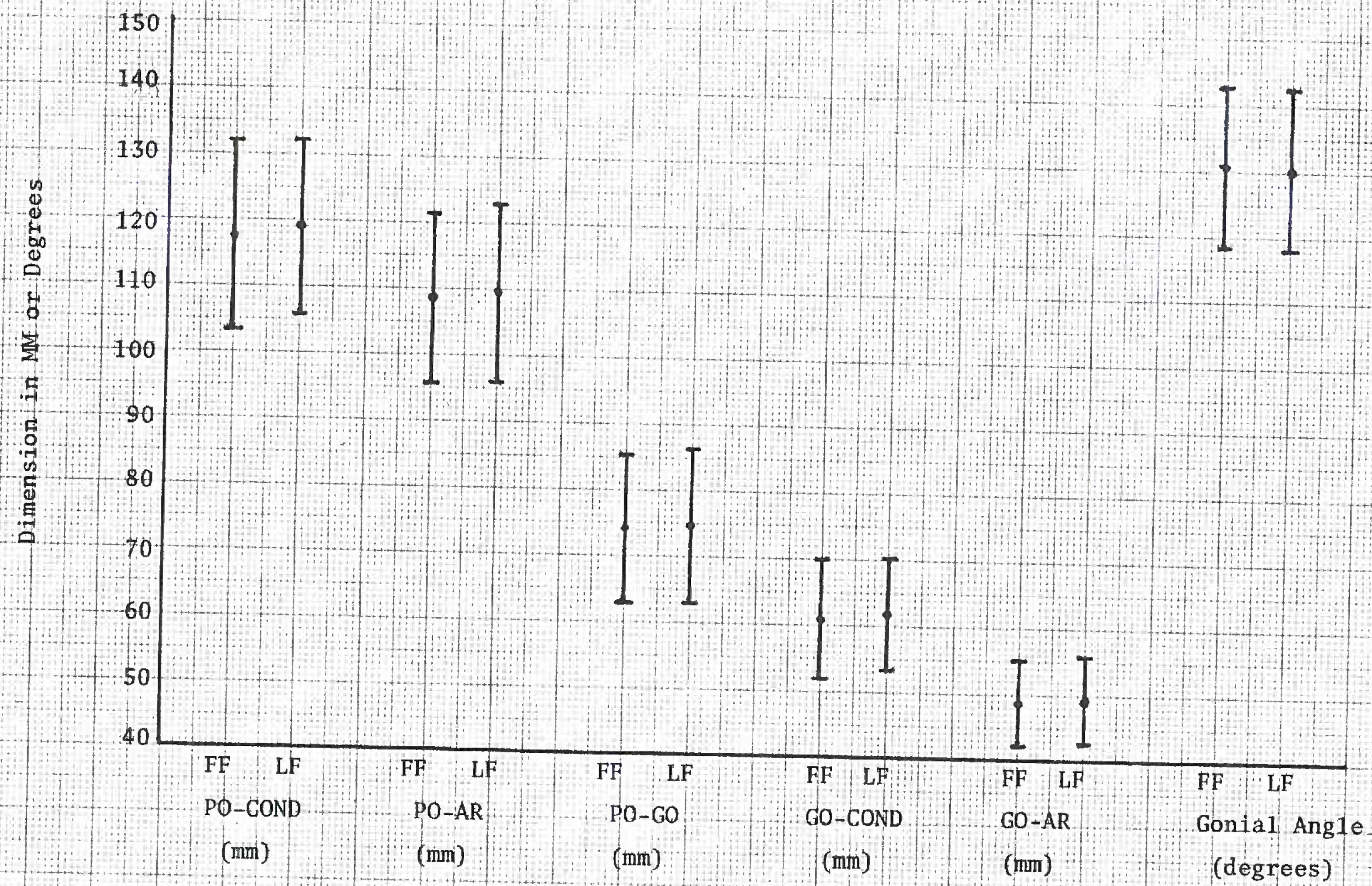

Fig. 3: The Mean Plus and Minus Two Standard Deviations for the Dimensions Indicated (N=26)