Longitudinal Study Of Mandibular Growth Between Nine And Thirteen Years As A Basis For An Attempt Of Its Prediction*

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Some years ago we began a longitudinal study with the object of establishing the annual changes in the growing craniofacial skeleton and in its component parts.

Three principal patterns of facial growth can be distinguished: the first has a mainly forward direction, the second a mainly downward, and the third an intermediate oblique direction (Fig. 1).

The material was constituted, at the beginning, by a sample of 40 children of both sexes, aged 9 years, all with normal occlusion of teeth.

Of these, only 28, 12 boys and 16 girls, cover the entire period of research. Serial lateral headplates have been taken at annual intervals, from 9 to 13 years. The research is continuing. However, we consider it useful to report here the observations concerning the growth of the mandible during this period since it is then that the majority of orthodontic treatments are undertaken.

The tracings of the five roentgenograms secured for each child have been analytically examined and compared by superimposition.

The analysis of the mandible has been made by means of the measurements employed in our method of cephalometric analysis (Fig. 2). The distance between the extreme point of the condyle and the point of the chin farthest from it (Co-M line) gives the total mandibular length.

Owing to the usual difficulty in fixing the exact position of gonion, we use the most distant position from Co-M line. Co-Go line gives the height of the rami. Go-M line the length of the body.

The shape of the mandible shows some differences in relation to the

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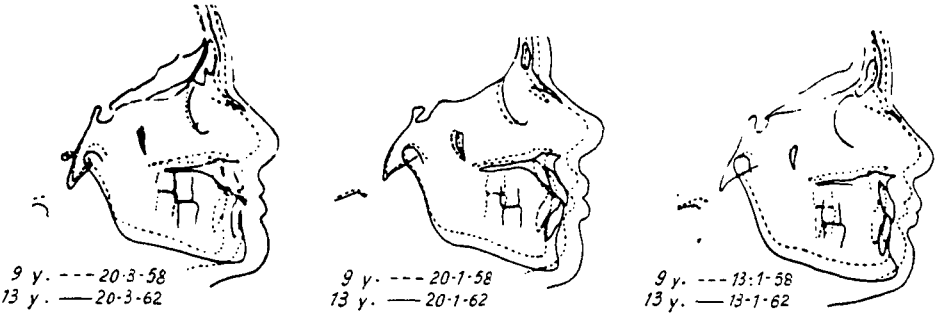

Fig. 1 Different types of facial growth. Forward direction (left), intermediate oblique direction (center), and downward direction (right). Superimposition on the anterior cranial base line.

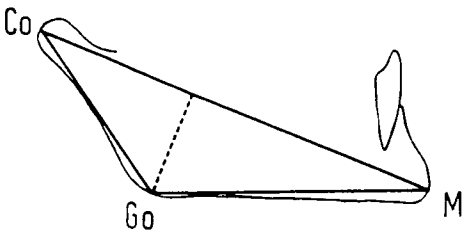

Fig. 2 Measurements employed in the mandibular analysis.

growth pattern of the face. The mandible is smaller in the forward-growing facial type and larger in the downward-growing one. In addition, in the latter type the rami are relatively predominant, while in the forward growing type the body is prevailing. Table I shows the mean values of the total mandibular length, length of the body, height of the rami and of the gonial angle at the age of nine years for each group of children.

No evident differences in relation to sex have been found except a smaller height of the rami and a greater opening of the gonial angle in the females.

Growth of the mandible as a whole. In the considered period, the total mandibular length has presented the increases reported in Table II. Percentage increments were calculated using the following formula given by Nanda: $\frac{Y_2 - Y_1}{\frac{Y_1 + Y_2}{2}} \times 100$, where Y_1 and Y_2 are the values at the beginning and the end of the time period, respectively.

In Figure 3, the tracings of the cases with the minimum and with the maximum growth increments between nine and thirteen years of age are shown.

There are no important differences in the quantitative growth of the mandible relative to the three facial types.

The computation of the correlation coefficient shows that a low positive correlation exists between the length of the anterior cranial base (N-S line) and the total mandibular length at 9

TABLE I

Mandibular dimensions in the different facial types at 9 years

	Forward growth direction Mean	Average inclined growth Mean	Downward growth direction Mean	General Mean	S.E. M.	S.D.	Range
Total length mm	93.21	98.75	100.30	97.63	0.63	3.32	89 to 109.5
Body length mm	58.09	62.09	61.40	60.97	0.60	3.20	55.5 to 68
Rami height mm	45.14	48.34	51.10	48.04	0.33	1.73	43 to 57.5
Gonial angle	126.30°	125.75°	125.00°	125.75°	0.36	1.94	117° to 134°

TABLE II

TOTAL GROWTH INCREMENTS IN THE MANDIBULAR LENGTH BETWEEN 9 AND 13 YEARS, IN PER CENT

	Sex	Mean	S.E. M.	S.D.	Range
Co-M distance	M	8.33	0.50	1.75	6.3 to 11.2
	F	10.13	0.56	2.16	6.3 to 13.7

Fig. 3 Range of variation in the mandibular growth. At right, the case showing the minimum growth increment in total mandibular length, on the left the case showing the maximum one.

years of age (r=0.43), No significant correlation exists between the relative increments of the two dimensions during the whole period considered (r= 0.28).

The most remarkable fact is that the growth pattern of the mandible shows a great variability in the individuals. First of all, in the great majority of cases, mandibular growth cannot be graphically represented by a straight, or almost straight, line. In only three cases has this behavior been found; in the other cases growth by spurts has been noticed. In almost all the tracings there is a section showing less steep than the others, which in general corresponds to the interval between the 11th and the 12th year of age. In other words, this interval corresponds to a quiescent period of growth (Fig. 4).

This finding is confirmed by the comparison of the average annual growth increments found in both sexes and reported in Table III.

Therefore, it seems substantiated that growth is not smooth, but occurs by an alternation of spurts of greater or lesser magnitude. Also, individual growth in length of the mandibular body and in height of the rami has been evaluated.

Growth of the mandibular body. In the whole considered time period the increments in length of the mandibular body do not show remarkable differences in relation to sex. The statistical data are reported in Table IV. In Figure 5, the cases with the minimum and the maximum growth increments are shown.

Growth of the rami. In the whole time period the increments in height of the rami show remarkable differences in relation to sex. In the females

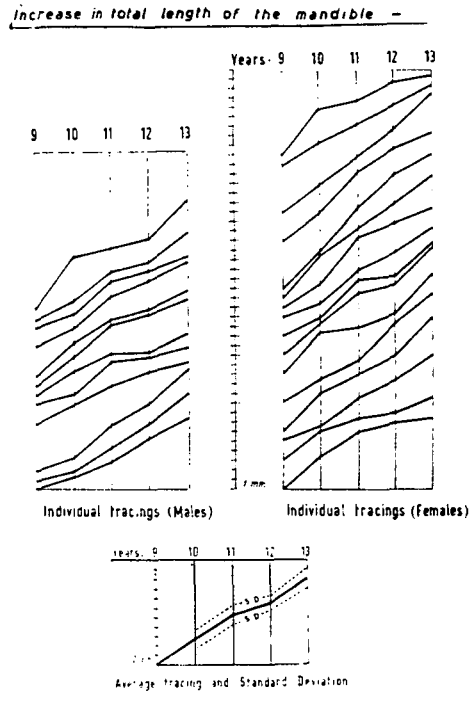

Fig. 4 Mandibular growth tracings of the whole sample. Top: males on the left, females on the right. Bottom: the average tracing and standard deviation.

TABLE III

ANNUAL PERCENTAGE INCREMENTS IN THE MANDIBLE LENGTH
(Co-M line)

Age interval	Sex	Mean	S.E. M.	S.D.	Range
9 to 10	M	2.13	0.58	2.00	0.9 to 5.3
	F	3.19	0.57	2.27	1.5 to 4.7
10 to 11	M	2.58	0.56	1.92	0.9 to 3.8
	F	2.62	0.61	2.45	0.5 to 4.9
11 to 12	M	1.12	0.37	1.66	00 to 2.2
	F	1.78	0.45	1.80	0.5 to 4.0
12 to 13	M	2.21	0.74	2.57	0.9 to 4.9
	F	2.23	0.55	2.19	0.5 to 3.8

TABLE IV

ANNUAL AND TOTAL PERCENTAGE GROWTH INCREMENTS IN MANDIBULAR BODY LENGTH

Age interval	Sex	Mean	S.E. M.	S.D.	Range
9 to 10	M	3.66	0.79	2.63	1.5 to 5.2
	F	3.37	0.49	1.96	1.7 to 5.1
10 to 11	M	2.37	0.66	2.30	0.8 to 4.6
	F	3.09	0.53	2.13	1.6 to 5.4
11 to 12	M	1.25	0.34	1.20	0.7 to 2.4
	F	1.75	0.33	1.31	0.7 to 3.0
12 to 13	M	2.02	0.67	2.34	0.0 to 4.2
	F	2.00	0.55	2.19	0.8 to 3.7
9 to 13	M	9.58	0.71		5.4 to 13.0
	F	10.19	0.42		8.2 to 13.2

TABLE V

ANNUAL AND TOTAL PERCENTAGE GROWTH INCREMENTS IN MANDIBULAR RAMI HEIGHT

Age interval	Sex	Mean	S.E. M.	S.D.	Range
9 to 10	M	1.64	1.49	5.16	0.9 to 3.9
	F	2.53	0.85	3.41	1.0 to 4.3
10 to 11	M	2.32	0.59	2.03	0.9 to 3.5
	F	3.46	0.75	3.03	1.9 to 5.7
11 to 12	M	2.29	0.89	3.11	0.9 to 3.5
	F	3.53	0.90	3.61	1.1 to 7.5
12 to 13	M	2.74	0.92	3.18	0.0 to 5.2
	F	3.37	0.78	3.14	0.9 to 6.2
9 to 13	M	9.00	0.69	2.39	6.7 to 13.0
	F	12.90	0.90	3.63	6.8 to 20.0

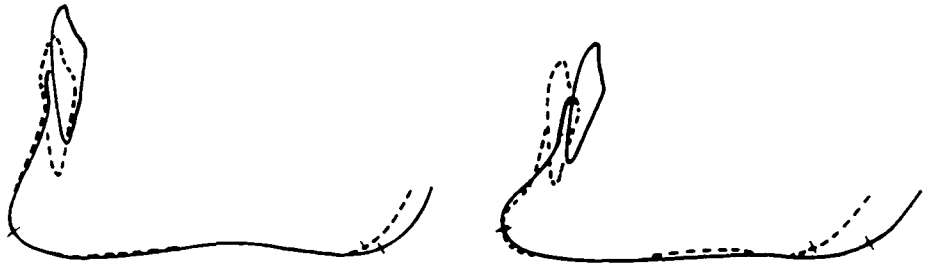

Fig. 5 The cases showing the minimum (left) and maximum (right) growth increments in length of the mandibular body.

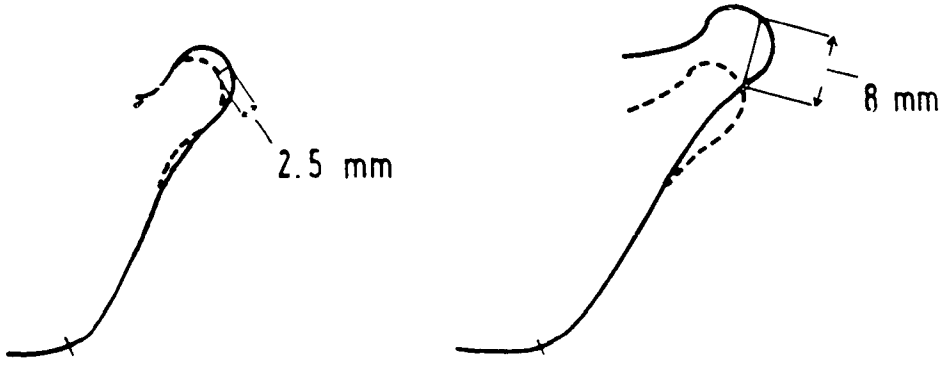

Fig. 6 The cases showing the minimum (left) and the maximum (right) growth increments in height of the rami.

the rate of increment is considerably greater. The statistical data are reported in Table V.

In Figure 6, the cases with the minimum and the maximum growth increments are shown.

Average growth of the mandibular body and the growth of the rami are expressed by broken lines, very variable in the individuals (Figs. 7 and 8). It seems that the growth of the mandibular body presents a quiescent period between 11 and 12 years of age; that of the rami between 9 to 10 years.

There is no relation between the individual growth of the mandibular body and of the rami, neither in quantity nor in time. Figure 9 shows two cases which belong to the same type of facial growth, in intermediate oblique direction: one presents a rather small growth increment of the body associated with a maximum increment of the rami; the other presents a great growth increment of the body associated with a minimum growth increment of the rami. Neither the growth of the mandibular body, nor the growth of the rami show significant differences with reference to the direction of the facial growth.

The calculation of the correlation coefficient shows that a high positive correlation ($r = 0.81$) exists between the relative increments of the total mandibular length and those of the rami. On the contrary, only a weak positive correlation ($r = 0.52$) exists between the relative increments of the total mandibular length and those of the mandibular body in the considered period.

No correlation exists between the relative increments in length of the

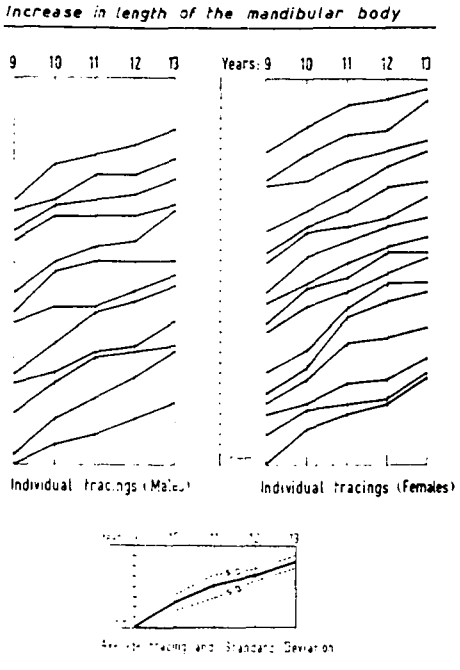

Fig. 7 The tracings of the growth increments in length of the mandibular body. Top: males (left) and females (right). Bottom: the average tracing and S.D.

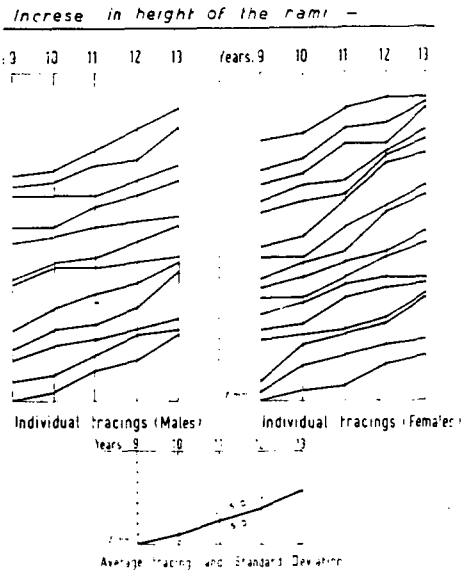

Fig. 8 The tracings of the growth increments in height of the rami. Top: males (left) and females (right). Bottom: the average tracing and S. D.

mandibular body and those in height of the rami in the same period ($r = 0.13$).

If the annual changes of the growing mandible are analyzed in the individual cases by superimposition, it can be noticed that in most cases the growth direction in the condylar region is not in a straight line. On the contrary, the growth direction often varies at the different age levels, so that its results are unpredictable, but only after a rather long interval.

Some examples are given in Figures 10 to 12. The mandibular tracings of each case have been superimposed on the mandibular plane with registration at the gonion point. This superimposition has been chosen in order to evaluate the respective amounts of growth in length of the body and in height of the

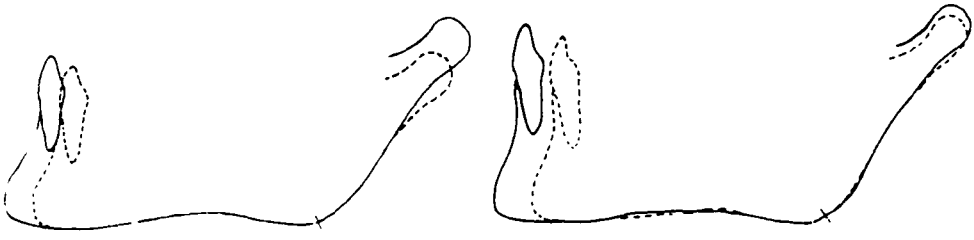

Fig. 9 Disrelation between the growth increments of the mandibular body and rami. At left, a case showing a rather small increase in length of the body associated with a maximum increase in height of the rami. On the right, a case in which a great increase in length of the body and a minimum increase in height of the rami are shown.

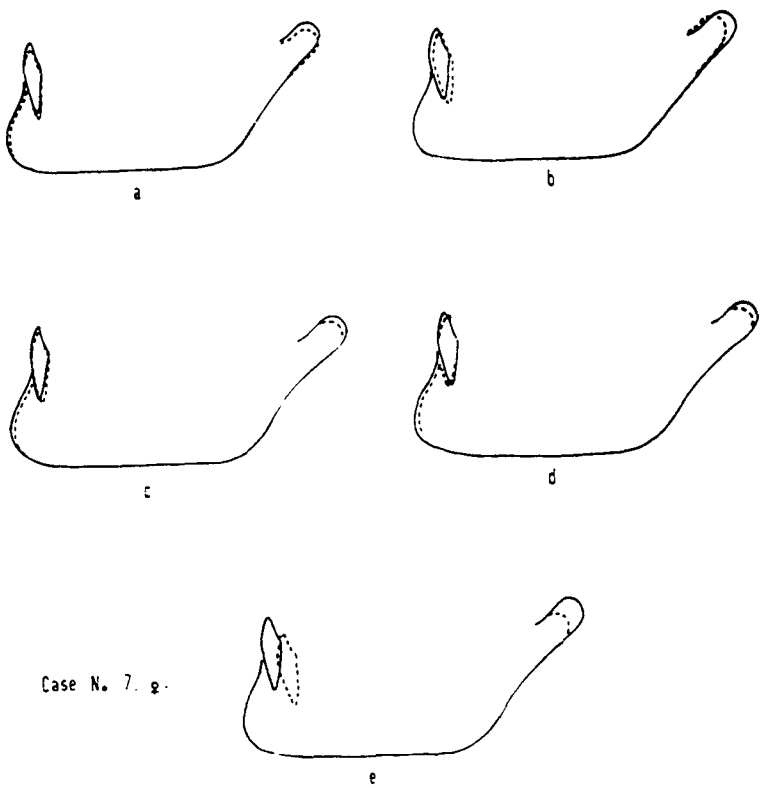

Fig. 10 Variation in growth direction of the condyle, Case No. 7—female. Vertical growth direction from 9 to 10 years (*a*), almost backward from 10 to 11 years (*b*). From 11 to 13 years (*c* and *d*), growth direction along the condylar axis. The resulting growth direction over the whole period from 9 to 13 years of age is shown (*e*).

rami, and to ascertain the growth direction of the condyle.

The resulting direction of the condylar growth has not proved to influence considerably the growth pattern of the mandible except for the variation of the gonial angle. When the condylar growth is mainly directed upwards, the angle tends to decrease; when the growth of the condyles is directed backward, the angle tends to become larger. Finally, the relationship between the annual growth increments in the total mandibular length and in the whole body height has been investigated.

The correlation coefficients of the growth increments of the two dimensions between 10 and 13 years have been calculated at the different age levels and in the whole period. A fairly high positive correlation exists between the growth increments in the two dimensions, from 10 to 13 years of age ($r = 0.63$). However, the values of the correlation coefficients at the various annual levels show significant differences. In fact, the rates of growth in the two dimensions show a low positive correlation from 10 to 11 ($r = 0.40$), a weak correlation from 11 to 12 ($r = 0.54$), and a remarkably high correlation from 12 to 13 years of age ($r = 0.72$).

From the reported data the following

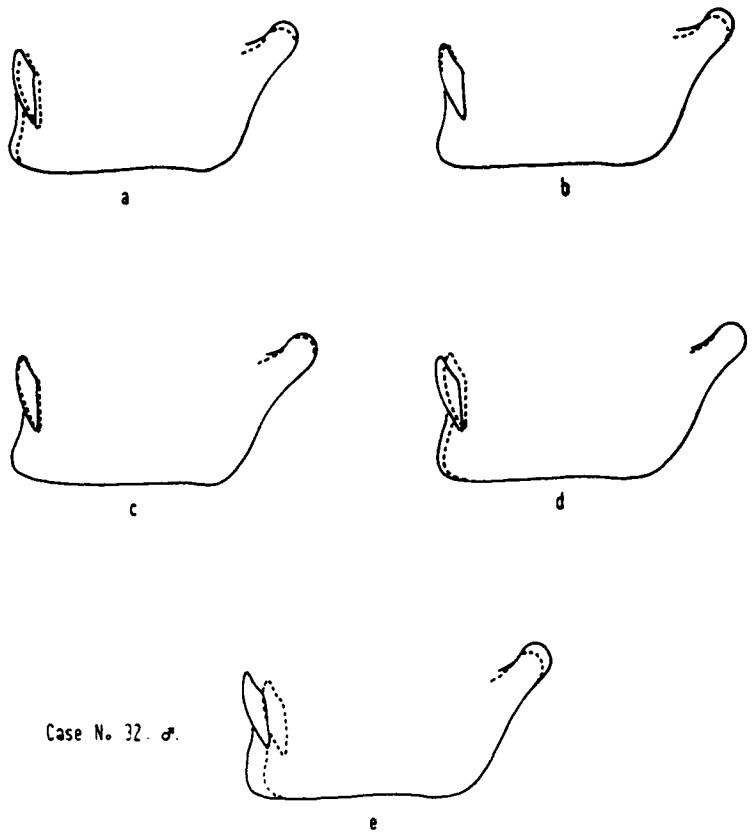

Fig. 11 Variation in growth direction of the condyle, Case No. 32—male. Vertical direction from 9 to 10 years (*a*). Rather backward direction from 10 to 11 (*b*) and less inclined one from 11 to 12 years (*c*). No growth increment is shown between 12 and 13 years (*d*). In (*e*) the resulting growth direction.

conclusions can be drawn:

1. The increase in the size of the mandible, from 9 to 13 years, is greater in the females than in the males. The difference is due to the fact that, in the females, the relative increase in height of the rami is about one third greater than in the males. On the contrary, no significant sex differences have been found in the average increase of the mandibular body length.
2. The mandibular growth is not smooth; the mandible grows by spurts.
3. The growth increments of the mandibular body and rami do not show any significant relation between themselves.
4. In most cases the direction of the condylar growth is not on a straight line, but varies at the different age levels considered in this study.
5. The general (forward, downward or oblique) direction of the facial growth is related, to a certain extent, to the shape of the mandible. However, no significant relation has been found between facial and mandibular growth.
6. The mandibular growth increments are not closely related to those in

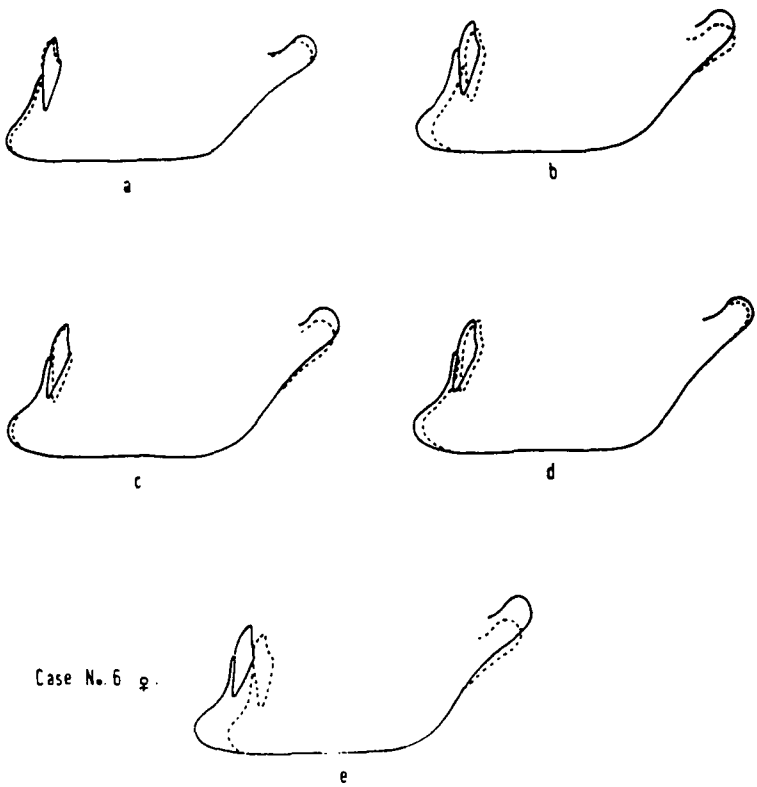

Fig. 12 Variation in growth direction of the condyle, Case No. 6—female. Backward direction from 9 to 10 years (*a*). Vertical direction from 10 to 12 years (*b* and *c*), and rather backward one from 12 to 13 years (*d*). The resulting growth direction over the whole period from 9 to 13 years of age (*e*) is almost vertical.

the whole body height.

The subsequent step was to study, on the same material, whether it is possible to predict, with a satisfactory confidence, the individual amount of mandibular growth which will take place from 9 to 13 years of age on the basis of the features or dimensions of the mandible at 9 years of age level (*).

First, we investigated the relationships between the relative increase in mandibular length found in our sample from 9 to 13 years, and the values at the 9 year level of the following dimensions:

1. length of the anterior cranial base (N-S line)
2. total mandibular length (Co-M distance)
3. length of the mandibular body (Go-M distance)
4. height of the mandibular rami (Co-Go distance)
5. gonial angle (M-Go-Co).

The computations of the Bravais method of correlation were made separately for the males, the females and for the whole sample, and are reported in Table VI.

In order to assess the significance of

(*) In the elaboration of this part of the research, Professor Paolo L. Lucchese has collaborated with the authors.

TABLE VI

	Males	Females	Whole sample
N-S and Co-M	+0.2650	—0.1977	—0.039
Co-M and Co-M	+0.0112	—0.3285	—0.186
Co-Go and Co-M	—0.0434	—0.5384	—0.375
M-Go and Co-M	+0.0196	—0.6525	—0.436
M-Go-Co and Co-M	+0.5837	+0.5057	+0.673

Correlation coefficients (r) for the relative percentage increments of the total mandibular length (Co-M) between 9 and 13 years, and length of the anterior cranial base (N-S), total mandibular length (Co-M line), height of the mandibular rami (Co-Go line), length of the mandibular body (Co-M line) and gonial angle (Co-Go-M) at 9 years of age.

the above correlation coefficients, the student's "t" test was applied. From these calculations the following conclusions may be drawn:

1. There does not seem to be a significant relation between the linear dimensions of the mandible at 9 years of age level and the relative growth increments in mandibular length from 9 to 13 years. However, this finding does not mean that in a greater sample a significant correlation may not be found.
2. On the contrary, there is a significant relation between the values of the gonial angle at 9 years of the age level and the relative growth increments in mandibular length from 9 to 13 years. More exactly, the greater the value of the gonial angle, the greater the mandibular growth in length.

The "*t*" test computation and the concordant behavior in both sexes support a high level of confidence in this relation.

Such a level of relation between the above two factors is quite satisfactory for practical purposes, that is, to predict the individual amount of mandibular growth in length between 9 and 13 years on the basis of the value of the gonial angle as shown at 9 years of age.

The coefficient of linear regression was calculated making it possible to state that, in the considered time period, the average relative increment in mandibular length is 0.329% for each degree of the gonial angle value.

The average value of the gonial angle at 9 years of age level was 125.85° and the average relative increment in mandibular length from 9 to 13 years was 9.392%.

The formula that gives the predictable amount of relative increment in mandibular length on the basis of the value of the gonial angle is as follows:

a) when $X > 125.85°$

(1) $y = 9.392 + 0.329\ (x - 125.85)$

b) when $X < 125.85°$

(2) $y = 9.392 - 0.329\ (125.85 - x)$

where y = relative increment of the mandibular length from 9 to 13 years,

and x = measure in degrees of the gonial angle at 9 years of age level.

The graph in Figure 13 shows the relation between the values of the gonial angle at 9 years (abscissae) and the relative increments in mandibular length from 9 to 13 years (ordinates). On the right, the values of the gonial angle and the corresponding theoretical

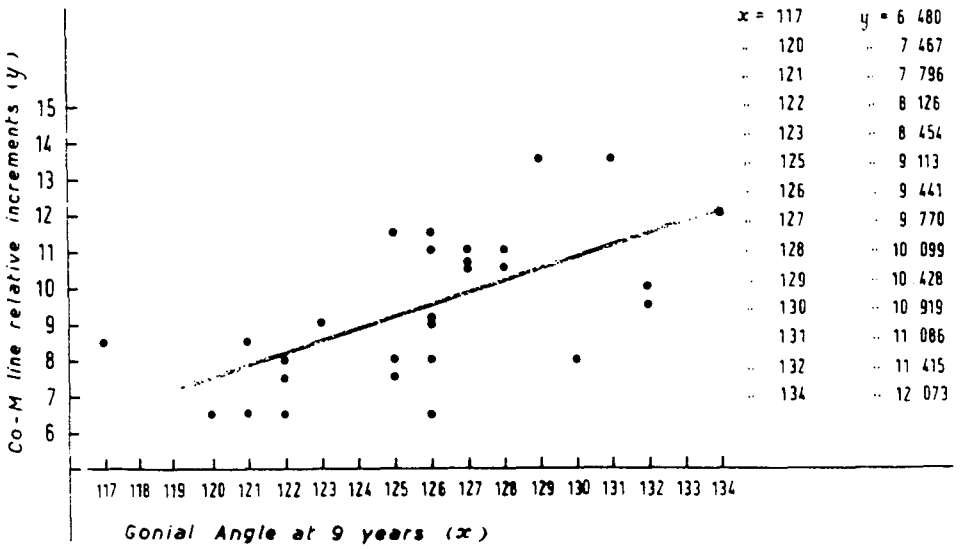

Fig. 13 Graph of the relation between the gonial angle values at 9 years and relative growth increments in total mandibular length from 9 to 13 years of age.

values of the increments in mandibular length are recorded.

Of course, these formulae express an average value which has been found on a rather small sample showing a wide range of variation.

The error of the mean is ± 1.576. It was obtained by means of the "residual variance" formula which is assumed as an estimation of the variation.

Therefore, the y value, obtained with the (1) or the (2) formula, shows an error that ranges ± 1.576.

Such an estimation means that there is a 68% level of possibility that the actual individual increase falls within the interval $y = \pm 1.576$ and a 95% level of possibility that the actual individual increase falls within the interval $y = \pm 3.152$.

Since we are aware of the exiguity of the material on which our study was performed, it is our sincere hope that this paper will be stimulating for orthodontists who possess longitudinal roentgenographic material covering the time period considered in our research to confirm the validity of our data.

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