COMPARATIVE MEASUREMENTS OF THE HARD PALATE IN NORMAL AND FEEBLE-MINDED INDIVIDUALS. A PRELIMINARY REPORT.

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The writers have taken up the question of the variability of the contour of the hard palate or what is popularly known as the roof of the mouth, because the assumption has been made that certain types of deformity are the correlates of feeble-mindedness. This assumption is so generally current that it is made a principle of diagnosis; and if it is valid, the form and size of the bones of the palate must be regarded as an important morphological determination. The ideal way of approaching the problem would be through the comparative measurements of the skulls of feeble-minded and normal individuals; but material of this kind is not available. Thus it becomes necessary to make observations upon the palates of living subjects. To this end Dr. Channing spent several years collecting casts of the hard palate. We shall not discuss here the advantages and disadvantages of this method, except to state that practical diagnosis is made upon the living and concerns itself with the same external aspect of the palate tissue as is revealed in the casts. The technique of the casting process has been developed in dentistry.

We present at this time a brief preliminary report upon the measurements of casts obtained from public school children and adults, selected at random, and from inmates of schools for the feeble-minded. The relative number of available casts is as follows:

	Male.	Female.	Total.
Normal	314	300	614
Abnormal	558	452	1010
Totals	872	752	1624

The measurements to be reported upon at this time are:

A. The minimum distance between the first molars, measured horizontally from the bases of the molars.

B. The maximum height of the palate, measured from the approximate plane of the gum line.

C. The distance from the line connecting the two first molars to the alveolar point.

D. The distance between the canines, measured horizontally from their bases.

Other measurements were made, but a discussion of them is not necessary for the present purpose. The determination as to what measurements were significant was made the preliminary problem of the research. With this point in view about 150 casts of normal adult males were measured in a great many ways and the results treated by the method of correlation until the most definitive measurements were discovered. From the standpoint of the ultimate problem—the variations in the form of the hard palate as correlated with mental abnormalities—it was desirable to discover the definitive measurements least affected by growth and accidental variation. The net result of this preliminary study, the details of which will be given at another time, was that the four measurements enumerated above best fulfilled the requirements.

The measurements were made with a machine constructed in such a way as to measure accurately in three planes from any given point. The cast to be measured was placed upon the table of the machine and supported by a ball of modeling clay, which permitted the adjustment of the plane of the palate to the horizontal plane of the machine; the indicators were then adjusted to the points to be measured and the readings recorded. Repeated measurements of the same casts made it evident that accuracy for distances less than one millimeter was not practicable, and in consequence the recording was always to the nearest millimeter.

In such a procedure the errors of measurement include those of reading and adjustment. It is necessary to know not only that all these measurements are considered accurate, but also the approximation of this accuracy. To this end the measurements from a series of 105 casts of normal adult males were repeated as nearly as possible under the same conditions. The values for the two measurements were:

$$A_1 = \underset{\text{Av.}}{35.07} \text{ mm.} \pm \underset{\sigma}{3.32} \text{ mm.}$$

$$A_2 = 35.27 \text{ mm.} \pm 3.19 \text{ mm.}$$

But in the nature of the case errors in measurement should not affect the average so long as they are accidental, because there should be as many negative deviations as positive, and if the conditions are constant the value of the standard deviation, or σ, should be approximately the same for each trial. Yet while the average is little affected by accidental errors, it is otherwise with the true value of σ, the standard deviation. Such errors always increase its magnitude because the possible limits of the variabilities in the series are extended by an amount equal to the error in measurement. When the differences between the two measurements of the different casts are tabulated, it appears that a little more than fifty per cent of the differences are zero and that the positive and negative differences are so distributed as to make the average — 0.26 mm. with a standard deviation, or σ, of $\pm$ 0.96. From this it appears that the most probable difference between the measurements of any given cast is less than one millimeter and an inspection of the series shows ninety per cent of these differences to be within the range of one millimeter. This is quite satisfactory as to accuracy, for no measurement can be more refined than the unit employed. The significance of the above is that in 90 cases out of 100 the error is less than one millimeter.

The general tables give the number of cases (n), the average measurement, and the standard deviation (σ) for each age until maturity.

In the first place it seems reasonable to assume that the values for the children of different ages will give a curve of growth. A hasty glance at the numerical averages in the table gives the impression of little or no growth from six years to the age of maturity. But while the amount of annual increment for this period of life is small and of little significance, certain interesting differences appear when the averages for the respective ages are plotted. The width of the palates of normal children as measured at the first molars shows a general tendency to increase for the successive ages from six to fourteen years, the curves for males and females having the same general direction. For males the maximum difference in average width occurs between the sixth and eleventh year—a difference of 1.69 mm. The probability of this difference is expressed by $1.69 \pm .72$, or about 0.965. Yet this is the extreme difference for the successive ages from six

to fourteen years, and some reduction must be made for accidental variation in the series measured. Moreover, the general trend of the curve indicates that the increment of growth for the whole seven years is not more than one millimeter. The average for the total of normal male children ($n = 192$) is 32.92 ± 2.28 mm. This average of approximately 33 mm. does not vary more than one millimeter from the value of any one year throughout the period. Unfortunately the series of normal palate measurements is not complete and it is necessary to compare this value directly with the average for normal adult males: $n = 126$. $A = 34.75 \pm 3.35$. The difference between these averages is 1.83 mm. At this point the importance of a precise method for estimating the magnitude of the allowance for accidental differences between the averages is apparent. This may be done by statistical methods, of which the following is a mere categorical statement.

The accidental range of averages can be estimated from the value of A and σ. A is the approximate average of the type, an unknown value, or the true average. If the first group of measurements gives an average of A_1, another group of measurements upon individuals of the same type, will give a value A_2, etc. These values for A will cluster around the true average, or type, in a symmetrical manner. The probable error (ϵ) of any average (A) is expressed by $\epsilon = \frac{\sigma}{\sqrt{n}}$. Now the width of the palate for normal male children is 32.92 ± 2.28 mm. Then for A_1

$$\epsilon = \pm \frac{2.28}{\sqrt{192}} = \pm 0.16.$$

$$\therefore A_1 \pm \epsilon = 32.92 \pm 0.16.$$

The extent or range of a series is found to be about 4.5 times the value of σ; for convenience we will take it at 5 times. Applying this to the above, we find the entire probable range of A to be ± 0.80, or a total of 1.60; however, 68% of the values for A should range within 0.16 (ϵ) above and 0.16 below the true average, a total range of 0.32 mm. Now for adult normal males the values are:

$$A_2 \pm \epsilon_2 = 34.75 \pm 0.30.$$

The extreme range $= \pm 1.50$.

Hence, we should expect the averages for other similar groups of the same number of normal males to fall between 33.25 mm. and 36.25 mm. So much must be allowed for accidental differences.

Obviously, so long as A_1 and A_2 do not differ from each other more than their combined accidental ranges of error, they belong to the same type. If they do belong to the same type they should not differ more than their combined error. The combined error of A_1 and $A_2 = \pm \sqrt{(\epsilon_1)^2 + (\epsilon_2)^2} = \pm \sqrt{(0.16)^2 + (0.30)^2} = \pm 0.33$. $(A_1 - A_2) = 1.83$, which is a little more than five times the extreme range $(0.33 \times 5 = 1.65)$. Hence, the difference is of such a magnitude that A_1 and A_2 may or may not belong to the same type, the chances favoring the latter possibility. Yet the difference for the averages in width for the ages from eleven to thirteen years falls within the limits of accidental error. Consequently, for male children over eleven years of age and adult males no certain difference in width at the first molar appears, and normal female children give the same result. Thus the absolute amount of growth in this dimension is negligible after the twelfth year.

In the series for abnormal individuals all ages from six to maturity are represented, but the result is the same as for normal children.

The width at the canines shows a more decisive increase among normal children until the eleventh or twelfth year, while the averages for adults show a decrease in the width. The averages for abnormal individuals show a general tendency to fall with increasing age. From the group averages in Table II and III it is apparent that this peculiarity is common to all classes. The difference is doubtless due to the development of the canine teeth. The permanent canines, as shown by the material, begin to show themselves in the tenth year and have appeared in most children by the thirteenth year. This corresponds to the period of maximum width at the canines as found in the measurements. We have, then, a small difference due to the growth of the teeth from which we may infer that there is no growth of the maxillary processes in front of the seat of the canine teeth after six years of age. The averages show that the measurements for the age of

six, seven, and eight are about on the same level as those over twenty-one, which is consistent with the above.

The averages for the length of the palate follow the same general direction as the above, but with greater variation. Those for normal children reach their maxima about the ninth year, and an examination of the casts shows that this is the average age for the eruption of the upper median incisors; consequently their growth would affect the measurements in a similar manner, causing an abrupt apparent increase in the length, followed by a subsequent gradual decrease. Also, the slight increase in the molar width may tend to shorten the length as measured.

This brings us to the height of the palate. With normal children there is no certain increase with age, but the averages for normal adults show a decided growth. Also the averages for the abnormal show a general tendency to increase between the age of twelve and twenty. The corresponding ages for the girls are slightly less, ranging from eleven to seventeen, which is consistent with the general growth differences between the sexes. From all this it appears certain that some increase in the height of the palate takes place during the period of puberty. The difference between heights for normal male children and adults is expressed by 3.86 ± 4.27 mm.—a positive difference.

Incidentally, the differences between girls and boys have been noted, but we may add that the averages for normal children follow the same directions of change with such small degrees of difference that it would be possible to treat them as one series. However, it is apparent that, even with such minute differences as do exist, the boys tend toward higher averages. Both with the abnormal and the normal, with children and with adults, the male palate is slightly larger than that of the female, there being no other apparent characteristic difference. During the growing periods there are suggestions of differences in relative maturity, but these are so uncertain that nothing can be concluded and, in any event, they are probably parallel to the general differences in the rates of growth for the sexes.

As to the absolute size of the palate of the normal and the feeble-minded the tables should give positive information. Since the plotting of the curves for the averages of the normal and abnormal children shows them to have the same general direc-

tions, throughout, we may disregard age and treat the children as a group in opposition to corresponding groups of adults. The averages for children between the ages of six and fourteen and for adults are given in the general tables from which the following table of differences can be calculated:

	Ages.	Male Difference.	Female Difference.
A	6-13	+ 0.94	— 0.56
	21 +	— 0.98	— 0.72
D	6-13	— 0.04	— 0.30
	21 +	— 0.63	— 0.47
C	6-13	+ 0.68	— 0.11
	21 +	+ 1.13	— 0.32
B	6-13	+ 1.25	+ 0.65
	21 +	+ 0.09	.....

With reference to *A, C, D,* the differences between the normal and the abnormal are seen to range from zero to one millimeter. The differences for the females are in the negative direction, while those for the males are both positive and negative. For both sexes the differences are the least for *D,* the certainty of which for males is:

Normal and abnormal children.....	0.04 ± 0.31
Normal and abnormal adults.....	0.63 ± 0.31

From these figures it is seen that the probability of finding a difference greater than one millimeter is exceedingly small. Consequently we must conclude that there is no significant difference between normal and abnormal individuals as respects the average width of the palate at the canines. For the measurement *A* the differences for males are:

Normal and abnormal children.....	0.94 ± 0.28
Normal and abnormal adults.....	0.98 ± 0.43

The probability that these differences will ever reach a magnitude of 1½ millimeters or more is very small. For the females the probability is still less. Here again, while there is not such a certain correspondence between the averages as in the case of the width at the canine, it is extremely probable that the normal and

the abnormal palates do not differ in width at the molars by an average amount greater than one millimeter.

For the length of the palate the differences for males are:

Normal and abnormal children.....	0.68 ± 0.31
Normal and abnormal adults.....	1.13 ± 0.46

Here we see that the difference for children is as insignificant as in the case of the width at the canines, and that the larger differences for adults are compensated for by the greater variability of the abnormal males, both cases falling entirely within the limits of the probable variation of the averages. We may summarize them by the statement that the observed differences between the average measurements of the breadths and lengths of the palates of normal individuals as compared with those in abnormal individuals represent the accidental deviations of the averages from the type. In other words there is no certain difference.

The height of the palate increases, apparently, between the ages of fourteen and twenty-one. Thus the measurements of children and adults represent two levels easily compared. For males we have:

Normal and abnormal children.....	1.25 ± 0.21
Normal and abnormal adults.....	0.09 ± 0.33

While we find no real difference for adult males, that for children has the characteristics of a real difference. The female children show no such difference, for while the average height for the abnormal is absolutely greater than for the normal, the difference is within the range of accidental deviation from the type. However, as the difference vanishes at maturity, it seems safe to assume that it is a phenomenon of time variation in growth.

So far we have considered differences in average measurements, ignoring probable differences in the variability of individuals. It is obvious that while the averages for the respective groups of palate casts may approximate one type, they may vary more in one direction than in another or in both. For example, in the width of the palate at the canines we may find more lower and higher values for the abnormal series than for the normal, or a yet greater range of value so balanced as not to change the average. The standard deviation, σ, is the approximate measure of

such differences. A summary of the values of σ for the age groups gives the following:

STANDARD DEVIATIONS.

	6–14				14–20				21+			
	N.		Ab.		N.		Ab.		N.		Ab.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
A	2.28	2.35	3.01	2.63	....		3.55	3.19	3.35	3.36	3.61	3.08
B	1.75	1.96	2.28	2.05	....		2.76	2.51	2.31	..	2.63	2.66
D	2.31	2.22	3.01	2.36	....		2.89	2.52	2.24	1.65	2.61	2.89
C	3.05	2.34	3.09	2.65	....		2.83	2.68	2.39	2.55	4.27	3.05

Thus for the abnormal or feeble-minded, we find a general tendency toward increased variability with age. While males and females show the same general tendencies, variability is usually greater with the former. As regards normal and abnormal individuals the variability of the latter is uniformly greater than that of the former. Thus we have a constant difference between the sexes on the one hand and between the normal and the feeble-minded on the other. Nevertheless, these differences are relatively small. For illustration, the difference between the values of σ for normal and abnormal male children in case of the canine width is $\pm$ 0.70; which means that the probable difference between the two extreme cases for the respective series is about 3.5 millimeters.

We may summarize this paper with the statement that the absolute size of the palate as measured by the three specified dimensions seems to be the same for feeble-minded as for normal individuals: that there is a relatively small difference in the variability of these dimensions, feeble-minded showing greater variations; that the width of the palate from the first permanent molar forward remains approximately unchanged from the ninth or tenth year of life; and that it is probable that there is no appreciable growth after the sixth year.

TABLE I.—ABNORMAL INDIVIDUALS.

	Width of palate at 1st Molar.						Height of palate.					
	Male.			Female.			Male.			Female.		
Age	n	Av.	σ	n	Av.	σ	n	Av.	σ	n	Av.	σ
6	2	.....	....	4	.....	....	2	.....	....	6	.....	....
7	5	.....	....	4	.....	....	5	.....	....	4	.....	....
8	17	33.94	2.43	14	30.42	3.10	17	12.61	2.16	13	13.23	2.61
9	16	34.68	2.01	11	32.36	2.65	16	12.19	2.34	11	13.00	1.12
10	31	33.77	2.86	14	32.85	2.35	32	14.43	1.93	14	12.00	1.96
11	40	34.00	3.43	20	32.15	2.77	39	13.69	2.01	18	12.50	1.66
12	44	33.66	3.71	24	32–54	3.32	42	13.90	2.31	25	12.85	2.41
13	20	33.06	3.72	32	32.81	2.16	21	13.00	2.37	32	13.53	2.26
6–13	175	33.86	3.01	123	32.25	2.63	174	13.39	2.28	123	12.96	2.05
14	53	33.28	3.56	38	33.71	3.32	51	13.13	2.68	38	13.58	2.30
15	37	34.29	3.48	33	32.78	4.20	37	14.24	2.97	33	14.78	2.36
16	43	34.65	2.41	37	32.59	3.07	42	13.92	2.67	37	14.13	2.40
17	37	33.25	3.31	25	32.80	3.05	36	14.55	2.60	25	15.64	1.92
18	34	34.76	3.31	28	32.18	3.28	34	15.55	2.90	28	15.47	2.71
19	17	35.64	2.86	27	32.11	3.00	17	15.41	2.50	27	15.59	2.65
20	37	35.75	3.92	23	32.86	3.46	36	16.00	2.08	20	14.95	2.56
14–20	258	34.29	3.55	211	32.77	3.19	253	14.35	2.76	208	14.76	2.51
21+	125	33.77	3.61	115	33.28	3.08	112	16.09	2.63	115	14.87	2.66
Total	558	34.04		449	32.80							

TABLE II.—ABNORMAL INDIVIDUALS.

	Length of Palate.						Width of palate at Canines.					
	Males.			Females.			Males.			Females.		
Age	n	Av.	σ	n	Av.	σ	n	Av.	σ	n	Av.	σ
6	1	.....	....	4	.....	....	2	.....	....	6	.....	....
7	3	.....	....	4	.....	....	5	.....	....	4	.....	....
8	14	31.15	2.01	14	29.78	....	17	22.17	2.31	14	22.64	2.45
9	16	31.00	2.81	11	32.30	....	16	24.93	3.48	11	23.27	1.90
10	32	31.59	2.61	14	30.00	....	32	24.84	3.66	14	22.50	2.13
11	39	31.46	3.21	20	30.45	2.23	40	23.32	1.87	20	21.75	2.33
12	43	32.11	3.18	23	30.82	3.30	44	23.25	2.77	25	22.96	2.35
13	21	31.33	3.25	32	30.53	2.87	21	23.66	3.48	33	23.03	2.46
6–13	169	31.36	3.09	122	30.59	2.65	177	23.53	3.01	127	22.68	2.36
14	54	31.27	2.91	38	28.63	2.85	53	23.66	2.65	38	23.10	1.97
15	35	30.00	2.07	32	29.03	2.22	37	23.89	2.15	33	21.60	3.43
16	42	29.47	3.35	36	29.63	2.32	42	23.83	2.28	37	22.00	3·10
17	37	30.16	2.66	24	29.04	2.33	36	22.44	2.53	24	21.75	2.28
18	34	29.44	2.38	28	29.89	2.70	34	22.94	2.68	28	21.57	2.63
19	16	28.81	2.32	27	28.22	3.01	16	23.50	2.50	27	20.88	2.72
20	36	30.83	2.80	21	30.53	3.42	35	23.51	3.20	23	21.95	2.33
14–20	254	30.32	2.83	206	29.01	2.68	253	23.34	2.89	210	21.77	2.52
21+	112	29.50	4.27	102	28.67	3.05	124	22.36	2.61	115	21.67	2.89

TABLE III.—NORMAL INDIVIDUALS.

	Length of Palate.						Width of palate at Canines.					
	Male.			Female.			Male.			Female.		
Age	n	Av.	σ	n	Av.	σ	n	Av.	σ	n	Av.	σ
6	15	29.73	2.71	38	29.08	1.65	16	23.00	1.87	46	21.30	1.96
7	25	30.86	3.07	36	29.91	1.72	27	22.37	1.86	38	22.50	2.32
8	27	31.15	2.86	29	30.93	2.17	26	23.61	2.15	31	23.00	2.25
9	36	31.16	3.27	43	31.65	2.15	35	23.67	1.96	43	23.60	2.02
10	30	31.33	2.91	34	30.85	2.12	30	24.13	2.28	34	23.70	2.17
11	22	30.77	1.65	31	31.54	2.98	21	24.33	2.17	31	23.48	2.07
12	21	23.98	3.21	23	31.13	2.02	21	23.43	2.80	23	24.17	2.41
13	12	30.75	3.43	16	30.87	3.31	11	23.09	1.48	15	23.20	2.26
6–13	188	30.68	3.05	250	30.70	2.34	187	23.57	2.31	261	22.98	2.22
21+	104	28.37	2.39	48	29.09	2.55	112	23.00	2.24	50	22.14	1.65

TABLE IV.—NORMAL INDIVIDUALS.

	Width of palate at 1st Molar.						Height of palate.					
	Male.			Female.			Male.			Female.		
Age	n	Av.	σ	n	Av.	σ	n	Av.	σ	n	Av.	σ
6	16	32.00	2.33	39	32.28	2.13	16	12.50	1.32	39	11.33	1.60
7	25	32.84	1.75	36	32.36	2.65	26	12.80	1.61	35	11.88	1.65
8	29	32.88	2.54	31	32.54	2.43	26	11.88	1.51	29	12.41	1.47
9	37	33.03	2.60	43	33.14	2.28	34	12.35	1.96	43	12.97	1.83
10	31	32.80	2.32	33	32.27	2.48	31	11.48	1.66	34	12.02	1.58
11	26	33.69	2.27	31	33.35	2.13	22	12.04	1.76	31	12.51	2.07
12	16	31.87	2.81	23	33.47	2.28	21	12.42	1.93	23	12.39	2.32
13	12	33.33	3.18	16	33.93	1.87	12	11.50	1.82	16	13.12	2.08
6–13	192	32.92	2.28	252	32.81	2.35	188	12.14	1.75	250	12.31	1.96
21+	126	34.75	3.35	49	34.00	3.36	112	16.00	2.31			