Acta odont scand 1972 *30:* 539—554

Keywords:
Skull
Jaw
Cephalometry
Radiography
Body height

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SECULAR CHANGES IN THE MORPHOLOGY OF THE SKULL IN SWEDISH MEN

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Three hundred and twelve Swedish inductees (average age 18.7 years) were compared with skulls from men aged 18—25 who had died in 1810 regarding skull morphology and the dimensions of the dental arches.

The skull morphology was analysed roentgen-cephalometrically with profile and postero-anterior roentgenograms. The sizes of the dental arches were measured on casts and directly on the skulls.

The cranium was found to be larger in the inductees than in the skull material. The cranial base was more curved in the inductees, which also showed more maxillary alveolar prognathism, proclination of the upper incisors and larger gonion angle. The width of the dental arches between the first molars was smaller in the present day material, while the length of the dental arches was longer.

The results show that parallel to the secular increase in body height there is also secularisation of the morphology of the cranium, including changes also in the cranial base, which suggests a change in the genetic constitution of the population in western Sweden during the last 160 years.

Secular increase of stature in the population in general has been found to be accompanied by secular changes in the classical anthropometric cranio-facial dimensions (*Udjus,* 1964; *Lewin & Hedegård,* 1970, 1971). During the initial phases of secular increase in stature there is a simultaneous tendency of the skull to become more dolichocephalic and of the facial index to decrease because the skull increases in length and the face in height relatively more than in width. In more advanced secularisation, when increase in body height is constant for several decades or tends to cease, on the other hand, there is a tendency of the skull to become brachycephalic and to an increase in the facial index. This is because the secular increase in length of the skull and in height of the face decreases, while the width of the skull and the face

Received for publication, September 15, 1972.

continues to increase. The knowledge as to how variables of, or related to, the cranial base behave during secular changes in the calvarium and the face is, however, scanty. During growth the cranial base is presumably less sensitive to local external factors than the calvarium and the facial skeleton (*van Limborgh*, 1970), for which reason the secular changes in the cranial base may perhaps be different both quantitatively and qualitatively from those in the cranial vault and facial skeleton. It was therefore thought to be of interest to elucidate secular changes in roentgen cephalometric variables by a comparison between present-day adult males in the western Sweden and adult men who lived there more than 160 years ago.

MATERIAL AND METHODS

The present-day material consisted of 312 men selected at random from inductees in west Sweden (*Lewin*, 1972). They ranged in age from 18 to 26 years, but mostly from 18 to 19 years, so that the mean age was 18.7 years. As for their dentitions, it might be mentioned that they had between 20 and 30 natural teeth (mean 28).

Men living in the west of Sweden 160 years ago were represented by skeletal material from a mass grave of soldiers who died in west Sweden during an epidemic of typhus in 1810. The material was so well preserved that 35 crania with, and 25 without, a mandible could be analysed cephalometrically as well as 11 separate mandibles. In addition, the size of the dental arches and the height of the palatal vault could be measured in 20 crania without a mandible, and the size of the dental arch in 18 separate mandibles which were partly defective. An earlier investigation has shown that this skeletal material is representative of the healthy male population in the age classes of 18–25 years in the south-west of Sweden in the beginning of the last century (*Engström, Lewin & Öberg*, 1972). Judging from our knowledge of secular increase in body height in the swedish male population (*Hultkrantz*, 1927) and body height statistics of soldiers from the end of the 18th century (*Kajava*, 1927), the average height was about 168 cm. Body height, calculated from the long bones of the limbs, also suggested a mean height of 168 cm. Body height in the inductees studied was, on the average, 179 cm.

Recording

The inductees were examined when they were mustered. At the examination profile and postero-anterior roentgenograms were obtained of the skull and impressions for dental casts were taken. At roentgen examination the head was fixed in a cephalostat with the Frankfort plane horizontal and with the mandible in intercuspal position. For structures in the median plane the linear enlargement in profile views was 5.6 % and in postero-anterior projections in the frontal plane through the porion on both sides it was 8.6 %. The impressions for the casts were made in alginate and the casts were prepared in stone.

For examination the skulls were mounted in the cephalostat and lateral and postero-anterior views were obtained with the mandible fastened in intercuspal position. Similar roentgenograms were also obtained of the mandible separately. Roentgenograms were taken with the skull in the same position in the cephalostat and with the same degree of magnification as for the inductees. At roentgenography of the mandible separately the bone was oriented in the cephalostat with the aid of special holders so that the projection was the same as if it were united with the cranium.

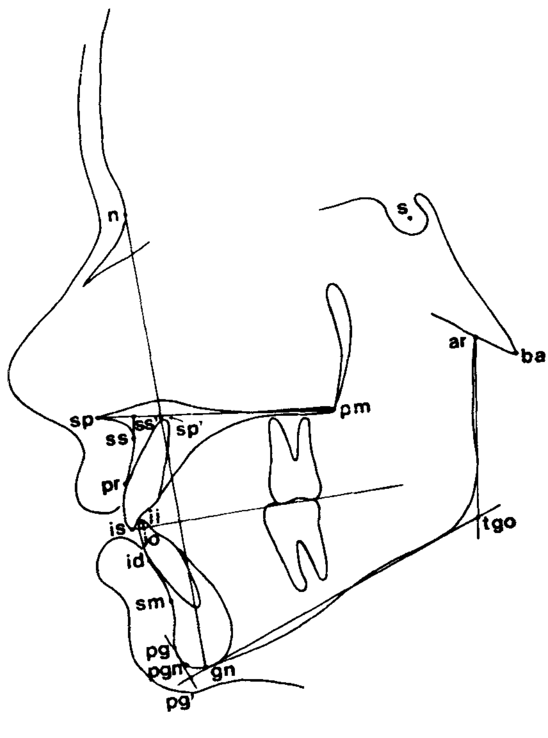

Fig. 1. Reference points used in profile roentgen cephalometric analysis.

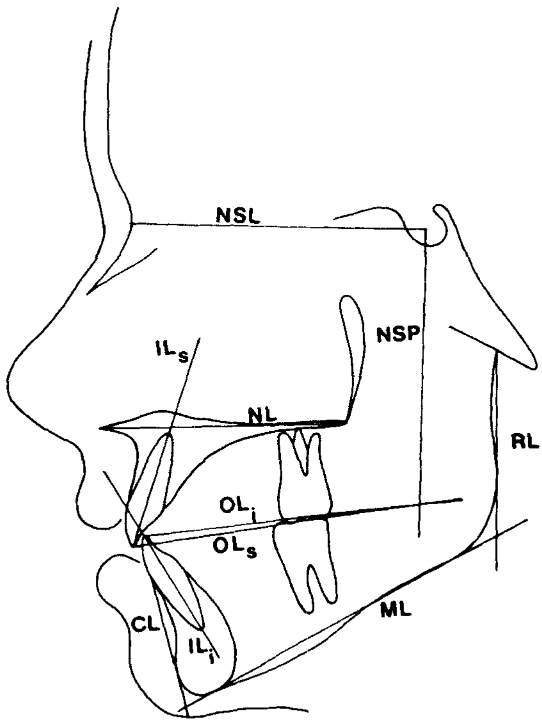

Fig. 2. Reference lines used in profile roentgen cephalometric analysis.

Roentgen cephalometric analysis

The reference points and reference lines used are given in Figs. 1, 2, 3 and 4. The points and lines in the profile roentgen cephalometric analysis were those defined by *Solow* (1966), but with the following modifications.

- cd' Origo in a coordinate system with the axes tangenting the upper and posterior outline of the mandibular condyle and with the x-axis parallel to ML.
- ii Incision inferius. The mid-point of the incisal edge of the most prominent lower central incisor.
- io Incision occlusale. The projection of *ii* on OL_s.
- is Incision superius. The mid-point of the incisal edge of the most prominent upper central incisor.
- pg' The intersection between ML and a perpendicular to this line forming a tangent to the chin.

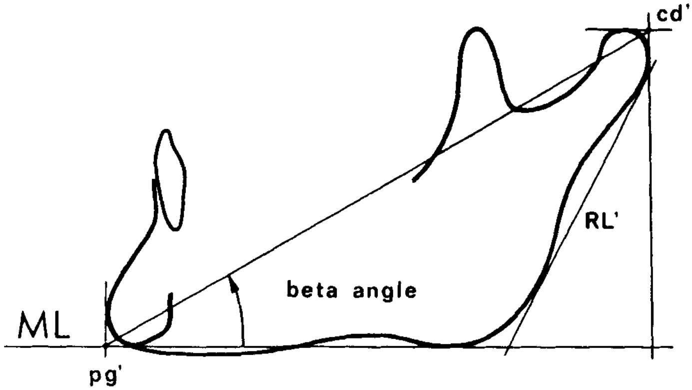

Fig. 3. Reference points pg', cd', beta angle and reference line RL'.

sp' A point on the line joining *n* and *gn* at the same distance from *n* as the point *sp*.

NSP Nasion-sella perpendicular. The perpendicular to NSL through *s*.

RL Ramus line. The tangent to the posterior border of the mandible through *ar*.

RL' The tangent to the posterior border of the mandible.

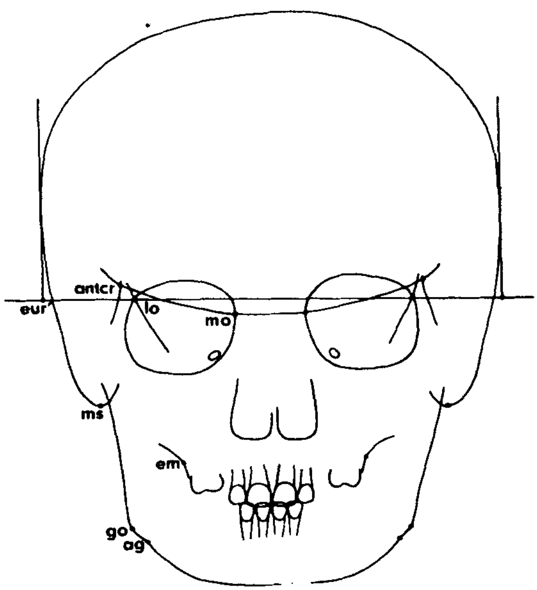

Fig. 4. Reference points used in analysis of postero-anterior roentgenograms.

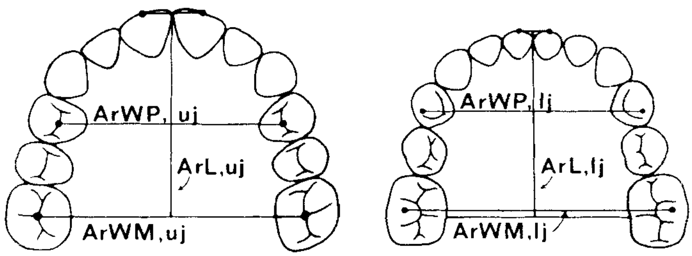

Fig. 5. Points used for measuring the size of the dental arches.

On profile roentgenograms measurements were made of the linear dimensions (var. 1—18) given in Table I and the angles given in Table III (var. 19—38).

Measurements on the profile roentgenogram were made with the method described by *Björk* and *Solow* (1962). The variables 16, 37 and 38 were measured only on the skull material (on roentgenograms of mandible). Linear measurements were made to the nearest half millimeter and angles to the nearest half degree.

The reference points used for the measurements of the postero-anterior roentgenograms have been described previously (*Ingervall & Lennartsson*, 1972). The measurements were made directly on the roentgenograms to the nearest half millimeter. Variables 39—46 (Table II) were recorded on the postero-anterior roentgenograms.

The measurements made at the roentgen cephalometric analysis were not corrected for linear enlargement.

Measurement of dental arch and height of palatal vault

The recorded width and length dimensions of the dental arches are given in Fig. 5. The measuring points for measurement of the width and the measuring method have been described previously by *Ingervall*, *Seeman* and *Thilander* (1972). The points and methods used for measuring the length of the dental arch have been described previously (*Ingervall*, 1970). Besides the size of the dental arch, measurements were made also of the height of the palatal vault *a.m. Lundström* (1948). Variables 47—53 (Table IV) were recorded. The measurements were made directly on the skulls and in the present-day material on the dental casts.

Statistical methods and error of the method

Differences between distributions were tested with Mann-Whitney's U-test. The number of possibly false significances were calculated according to *Eklund* and *Seeger* (1965).

The errors of the method of the roentgen cephalometric analysis of the profile measurements were studied in a previous investigation (*Ingervall*, 1970) and of measurement of postero-anterior roentgenograms, by *Ingervall* and *Lennartsson* (1972). The errors of measurement of the size of the dental arches have also been reported previously (*Ingervall*, 1970; *Ingervall, Seeman & Thilander*, 1972). The methods used proved to permit recording with good precision.

RESULTS

The results of the roentgen cephalometric analysis are given in Tables I, II and III.

On comparison of the size of the cranium, as measured in skulls and in the inductees, most variables showed significant differences. The linear measurements were throughout significantly larger in the inductees than in the skulls (Table I). An exception was found on profile analysis of variable 4 (*s-ar*) and the overjet and overbite (var. 17 and 18) for which no significant differences could be demonstrated. As for the two last mentioned variables, however, the number of observations in the skull material was very small. For var. 15 (*ar-tgo*) the relationship was opposite to that of the other linear measurements, i.e. this variable was smaller in the inductees than in the skull material.

Also the width measurements were significantly larger in the inductees than in the skulls (Table II). Thus, the calotte (var. 39), maxilla (var. 44) and mandible (var. 46) were wider in the inductees. Significant differences were also found in the distance between the mastoid processes (var. 40) and between the outer borders of the orbitae (var. 42).

As for the shape of the face and the cranial base, significant differences were found for more than half of the variables (Table III). There was a tendency to a more pronounced curvature of the cranial base in the inductees than in the skulls (var. 19 and 20). Maxillary prognathism was somewhat less pronounced in the inductees than in the skulls (var. 21). The inductees, on the other hand, showed more maxillary alveolar prognathism (var. 24) and a larger proclination of the upper incisors (var. 30), resulting in a smaller interincisal angle (var. 31). The inclination of the maxilla (var. 26) was some-

Table I.

Number of observations, n, mean, M, standard deviation, S.D. and range of variation in mm, of linear measurements on profile roentgenograms

	Inductees				Skulls				
Variable	n	M	S.D.	Range	n	M	S.D.	Range	Difference
1. n-s	310	74.86	3.54	64.0— 87.5	57	68.40	3.25	58.0— 77.0	6.26***
2. n-ar	261	101.20	4.55	85.0—113.5	31	96.42	5.11	86.5—105.5	4.78***
3. n-ba	249	113.41	4.97	98.5—127.0	59	104.91	5.57	94.5—123.5	8.50***
4. s-ar	261	38.14	3.57	29.0— 48.0	29	37.26	3.33	29.5— 42.0	0.88
5. s-ba	249	49.24	3.74	37.0— 61.5	57	45.21	3.18	38.0— 51.5	4.03***
6. sp-pm	310	57.87	3.54	48.0— 69.0	47	52.23	3.56	41.0— 60.5	5.64***
7. ss-pm	310	51.30	3.11	40.0— 58.5	56	49.14	3.69	37.5— 58.5	2.16***
8. ss'-pm	310	50.90	3.08	40.0— 58.5	56	48.96	3.69	37.5— 58.5	1.94***
9. pm-NSL	310	48.87	3.31	42.0— 70.0	57	45.12	2.87	37.5— 52.0	3.75***
10. pm-NSP	310	16.63	3.52	6.5— 26.5	57	14.75	4.08	4.0— 23.0	1.88**
11. n-gn	297	126.14	7.21	107.0—152.0	33	121.82	6.74	110.5—138.0	4.32***
12. n-sp	310	56.31	3.82	46.5— 71.5	48	53.57	3.50	46.0— 61.5	2.74***
13. sp'-gn	297	69.78	5.58	55.0— 86.5	28	68.20	6.09	61.0— 82.0	1.58*
14. pg'-tgo	254	83.24	5.01	72.5—101.5	31	78.71	5.54	70.5— 91.0	4.53***
15. ar-tgo	254	53.12	4.54	38.5— 68.5	30	57.48	5.57	48.5— 71.0	—4.81***
16. pg'-cd'					42	120.43	6.18	108.0—134.5	
17. is-io	295	3.68	1.88	—2.0— 16.0	7	4.21	1.66	2.0— 7.0	—0.53
18. ii-io	295	2.83	1.77	—1.5— 9.0	7	2.21	2.86	—1.0— 8.0	0.62

* = 0.01 < P < 0.05   ** = 0.001 < P < 0.01   *** = P < 0.001

Expected number of false significances at 5 %-level at most 1 (6 %), at 1 %-level 0 (3 %) and at 0.1 %-level 0 (0.1 %).

Table II.

Number of observations, n, mean, M, standard deviation, S.D. and range of variation, in mm, of width dimensions measured on postero-anterior roentgenograms

	Inductees				Skulls				
Variable	n	M	S.D.	Range	n	M	S.D.	Range	Difference
39. eur'-eur'	310	156.93	5.81	138.5—172.5	59	152.90	5.57	139.0—165.5	4.08***
40. ms-ms	312	118.49	5.18	101.0—132.0	42	110.87	5.94	92.5—123.0	7.62***
41. anter-anter	311	102.99	4.14	90.5—118.0	60	102.78	4.01	94.0—114.0	0.21
42. lo-lo	310	93.62	3.52	82.5—103.0	59	91.92	3.41	84.0—100.5	1.70***
43. mo-mo	311	28.55	2.95	22.0— 35.5	60	28.14	2.87	22.0— 37.0	0.41
44. em-em	312	65.46	3.73	51.0— 75.0	59	63.47	3.35	57.0— 71.0	1.99***
45. ag-ag	312	91.73	5.29	80.0—112.5	43	92.73	7.53	78.5—111.0	—1.00
46. go-go	312	105.85	6.12	89.0—121.0	40	101.63	10.16	80.5—123.0	4.22*

* = 0.01 < P < 0.05   *** = P < 0.001

Expected number of false significances at 5 %-level 0 (8 %) and at 0.1 %-level 0 (0.2 %)

Table III.

Number of observations, n, mean, M, standard deviation, S.D. and range of variation, in degrees, of angles measured on profile roentgenograms

	Inductees				Skulls				
Variable	n	M	S.D.	Range	n	M	S.D.	Range	Difference
19. n-s-ba	247	131.18	5.46	118.5—147.5	57	133.23	7.02	114.5—151.5	—2.05*
20. n-s-ar	261	123.96	5.90	109.0—175.0	29	129.10	6.56	117.5—149.5	—5.14***
21. s-n-ss	310	82.16	3.51	72.0— 91.0	54	83.62	4.34	74.5— 97.5	—1.66*
22. s-n-pr	310	85.01	3.46	76.0— 94.0	46	85.10	4.46	75.5— 99.0	—0.09
23. s-n-pg	297	81.52	3.42	72.5— 93.5	30	81.92	3.75	73.0— 91.0	—0.40
24. pr-n-ss	310	2.89	1.29	0.0— 7.5	47	1.56	1.09	0.0— 4.5	0.27***
25. ss-n-sm	296	2.55	2.36	—8.0— 9.0	29	3.17	3.01	—3.0— 9.0	—0.62
26. NSL/NL	310	7.40	3.41	—4.0— 17.0	56	8.80	3.11	1.5— 17.5	—1.40**
27. NSL/ML	295	29.29	6.29	14.0— 50.0	30	27.03	6.87	8.0— 45.5	2.26
28. NL/ML	295	21.92	5.90	8.5— 44.5	31	17.87	6.35	3.5— 28.0	4.05**
29. NL/OL_s	309	7.85	3.63	—5.5— 20.0	18	9.75	5.36	2.5— 19.5	—1.90
30. IL_s/NL	310	113.08	6.33	91.0—138.0	47	104.76	7.39	85.0—117.0	8.32***
31. IL_s/IL_i	295	127.28	9.22	99.0—151.0	22	136.86	10.64	122.5—163.0	—9.58***
32. IL_i/ML	309	97.59	7.61	79.0—121.5	40	96.29	7.22	79.5—111.5	1.30
33. ML/CL	309	69.96	6.21	55.5— 92.5	46	70.03	6.05	52.5— 83.0	—0.07
34. OL_i/ML	309	18.86	4.64	6.0— 34.5	23	14.87	5.85	3.0— 24.5	3.93**
35. s-ar-tgo	254	143.87	6.90	101.0—167.0	29	139.43	6.73	123.0—151.5	4.44**
36. ML/RL	254	121.48	6.99	95.5—141.0	31	118.11	7.11	105.0—133.0	3.37*
37. ML/RL'					42	118.41	7.00	106.0—132.5	
38. Beta					42	30.10	4.01	23.0— 41.5	

* = $0.01<P<0.05$ ** = $0.001<P<0.01$ *** = $P<0.001$

Expected number of false significances at 5 %-level at most 1 (8 %), at 1 %-level 0 (2 %) and at 0.1 %-level 0 (0.5 %).

what less in the inductees than in the skulls, while the angle between the nasal line and the mandibular line (var. 28) was larger in the inductees.

The gonion angle (var. 36) was somewhat larger in the inductees. There was a tendency for the mandibular occlusal line and the mandibular line (var. 34) to be less parallel in the inductees. The angle between the posterior cranial base and the ramus line (var. 35) was larger in the inductees than in the skulls.

In those cases where the upper and lower central incisors in the skulls had been lost post mortem and the contour of the alveolus was distinct in profile roentgenograms, the longitudinal axes of the upper and lower incisors were deduced from the direction of the alveolus. The means for variables

Table IV.

Number of observations, n, mean, M, standard deviation, S.D. and range of variation, in mm, for width and length of dental arches and height of palatal vault

	Inductees				Skulls				
Variable	n	M	S.D.	Range	n	M	S.D.	Range	Difference
47. ArWP, uj	248	36.71	2.52	24.5—43.6	44	36.42	2.17	31.9—43.4	0.28
48. ArWM, uj	306	47.35	3.41	37.0—56.0	63	48.94	3.03	41.0—55.8	—1.59**
49. ArWP, lj	257	36.86	2.47	28.6—43.3	33	36.74	2.41	29.5—42.5	0.12
50. ArWM, lj	301	48.77	3.44	34.5—59.1	52	50.80	3.06	44.3—59.4	—2.03***
51. ArL, uj	298	32.39	2.81	22.0—39.6	17	29.09	2.83	24.1—34.5	3.30***
52. ArL, lj	291	29.85	2.81	20.8—39.7	30	26.00	1.80	21.8—30.2	3.85***
53. Height of palatal vault	294	19.29	2.23	13.7—26.8	16	18.41	2.68	15.1—24.0	0.88

** = $0.001 < P < 0.01$ *** = $P < 0.001$

Expected number of false significances at 1 %-level 0 (2 %) and at 0.1 %-level 0 (0.2 %)

Table V.

Comparison of mean values of profile roentgen cephalometric linear dimensions found in in the present and earlier Scandinavian investigations

Variable	Inductees	Skulls	*Björk* (1947)	*Lindegård* (1953)	*Sarnäs* (1959)	*Solow* (1966)
1. n-s	74.9	68.4	73.2	73.9		73.6
2. n-ar	101.2	96.4	98.1			
3. n-ba	113.4	104.9				111.4
4. s-ar	38.1	37.3	37.0			38.9
5. s-ba	49.2	45.2		48.9*		49.3
6. sp-pm	57.9	52.2	56.8			57.9
7. ss-pm	51.3	49.1		52.8		
8. ss'-pm	50.9	49.0				51.5
9. pm-NSL	48.9	45.1		48.3	48.2	
10. pm-NSP	16.6	14.8		14.0	13.8	
11. n-gn	126.1	121.8	128.3	128.9	129.9	126.6
12. n-sp	56.3	53.6	55.5	56.3		55.9
13. sp'-gn	69.8	68.2		72.8	72.7	
14. pg'-tgo	83.2	78.7				82.3
15. ar-tgo	53.1	57.5	53.2*			
16. pg'-cd'		120.4				
17. is-io	3.7	4.2	3.0		3.5	
18. ii-io	2.8	2.2	2.0		2.7	

* denotes that the reference point was not exactly the same as that in the present investigation.

Table VI.

Comparison between mean values found for angles on profile roentgen cephalometric analysis in the present and earlier Scandinavian investigations

Variable	Inductees	Skulls	*Björk* (1947)	*Lindegård* (1953)	*Sarnäs* (1959)	*Solow* (1966)
19. n-s-ba	131.2	133.2		131.8*	130.3*	129.6
20. n-s-ar	124.0	129.1	123.1			123.8
21. s-n-ss	82.2	83.3		82.4	82.5	82.0
22. s-n-pr	85.0	85.1				
23. s-n-pg	81.5	81.9	81.7	80.7	81.5	81.2
24. pr-n-ss	2.9	1.6				
25. ss-n-sm	2.6	3.7			2.7	2.4
26. NSL/NL	7.4	8.8		7.6	7.9	7.7
27. NSL/ML	29.3	27.0			31.3	28.2
28. NL/ML	21.9	17.9			23.3	21.0
29. NL/OL_s	7.9	9.8	8.8	8.7	6.4	7.5
30. IL_s/NL	113.1	104.8			107.5	110.2
31. IL_s/IL_i	127.3	136.9	137.4	130.3	138.6	128.5
32. IL_i/ML	97.6	96.3			90.6	96.7
33. ML/CL	70.0	70.0				70.4
34. OL_i/ML	18.9	14.9				17.3
35. s-ar-tgo	143.9	139.4	143.3*			
36. ML/RL	121.5	118.1	130.9*	127.7*		
37. ML/RL'		118.4			125.1	120.4
38. Beta		30.1		25.1*	27.4	28.9

* denotes that the reference point was not exactly the same as that in the present investigation.

30, 31 and 32 (Table III) include observations made in this way. To find out whether recording with the aid of the direction of the alveolus gave a correct picture of the inclination of the incisors the means were calculated separately for those cases where the incisors were present and where recording could therefore be made in the usual way. The means in the cases with incisors were: for var. 30, IL_s/NL, 102.3° (n = 18), for var. 31, IL_s/IL_i, 138.9° (n = 7) and for var. 32, IL_i/ML, 96.4° (n = 24). The means for these cases agreed well with those given in Table III. The observations that the upper incisors were more proclined and the interincisal angle was smaller in the inductees than in the skulls therefore appear to be correct.

The parameters for the variables for the size of the dental arches and the height of the palatal vault are given in Table IV.

Table VII.

Comparison between mean values found for size of dental arch and height of palatal vault in the present and earlier Scandinavian investigations

Variable	Inductees	Skulls	*Seipel* (1946)	*Lundström* (1936)	*Lundström* (1948)*	*Grahnén* and *Ingervall* (1963)
47. ArWP, uj	36.7	36.4	36.1	34.9	34.6	36.2
48. ArWM, uj	47.4	48.9	46.6	47.3	46.3	48.9
49. ArWP, lj	36.9	36.7	35.2			36.1
50. ArWM, lj	48.8	50.8	47.6			49.4
51. ArL, uj	32.4	29.1			30.8	30.4
52. ArL, lj	29.9	26.0				
53. Height of palatal vault	19.3	18.4		19.9	19.6	19.2

* men aged 16 to 40 years.

The width of the dental arches as measured between the first molars (var. 48 and 50) was smaller in the inductees than in the skulls, but no difference was found in width between first premolars and in the height of the palatal vault. The dental arches, on the other hand, were longer in the inductees in the upper (var. 51) as well as in the lower jaw (var. 52).

Tables V and VI compare the results of the profile roentgen cephalometric analysis of the material in the present and in other Scandinavian investigations of present-day populations of adult males examined with similar methods.

As for the size of the dental arches, Table VII compares the materials studied in the present investigation and other Swedish investigations of the present-day population of men studied with the same methods.

DISCUSSION

The comparisons (Tables V and VI) show that the inductees studied in the present investigation agree well in cranial morphology with other Scandinavian series. The conclusion that the cranial dimensions of the skulls were smaller than in present-day material therefore appears to be correct not only on comparison with the inductees in the present investigation but also with other modern series.

The possibilities of comparing the roentgen cephalometric width dimensions are, however, limited because only few investigations of modern series are available. The width of the maxilla and mandible on postero-anterior roentgenograms has been examined by *Solow* (1966) with the same method as that used in the present investigation. The means found by Solow were 67.0 mm for var. 44 (*em-em*) and 89.7 mm for var. 45 (*ag-ag*). The conclusion that the maxilla is wider in modern series than in the skull material thus appears to hold also on comparison with Solow's material. Concerning var. 45 (*ag-ag*) no conclusion can be drawn with certainty.

The smaller size of the cranium in the skull material than in the inductees may be due partly to postmortal changes. According to *Welcker, Czekanowski* and *Todd* (cit. from *Slagsvold*, 1969) the shrinkage of dried skulls is on the average about 1 % and at most 2 % for linear measurements. But postmortal shrinkage of this order would not be sufficient by itself to explain the smaller size of the cranium in the skulls.

The inductees in the present investigation and other Scandinavian series agreed well also regarding the shape of the face and the cranial base (Table VI). The differences in shape found between modern series and the skull material therefore seem to be true differences. A reservation, however, should be made for variables comprising reference point *ar*, especially var. 20 and 35. Experience has shown that when fitting the mandible to the maxilla in anatomic preparations it is difficult to achieve the same close contact between the dental arches as in natural occlusion. The mandible may therefore be somewhat lowered in its posterior part, compared with its position in living individuals. That this may be the case is suggested by the fact that var. 15 (*ar-tgo*), in contrast with other profile roentgen cephalometric linear measurements, was larger for the skulls than in the inductees. The smaller angle between the nasal line and the mandibular line (var. 28) in the skulls than in the inductees may perhaps be an artefact due to incomplete posterior contact between the maxilla and the mandible. There might, however, also be a true difference between the materials owing to differences in morphology in the region of the gonion. The mandibles in the skull material appeared to have a larger mass of bone at the attachments of the muscles on the gonion angle, which may be explained by chewing with greater force in earlier centuries. That there is a difference in gonion morphology between the materials is suggested by the fact that the gonion angle (var. 36, ML/RL) and the angle OL_i/ML (var. 34) was smaller in the skulls than in the inductees. A difference in gonion morphology may perhaps also explain why a difference between the materials was not demonstrated for variable 45, *ag-ag*, though a difference was found for the variable 46, *go-go*.

The less pronounced proclination of the upper incisors in the skull material than in the inductees was in agreement with the finding by *Lysell* and *Filipsson* (1958) that skulls with severe abrasion of the teeth have more retroclined upper incisors than those without abrasion. They also point out that there is reason to expect an effect on the inclination of the upper incisors also in the presence of less pronounced abrasion. Though the present skulls originated from relatively young persons, occlusal as well as approximal abrasion was distinctly visible and was notably more pronounced than in the inductees. The smaller proclination of the upper incisors in the skulls is therefore probably due to abrasion. The maxillary alveolar retrognathism and the large interincisal angle in the skulls appears in turn to be due to an upright position of the upper incisors.

In the present skull material the cranial base was somewhat flatter and the gonion angle (ML/RL) smaller than in the inductees and in the other comparable modern series. Also the Swedish skulls dating back to the Middle Ages and examined by *Lysell* and *Filipsson* (1958) had a lateral cranial base angle (*n-s-ar*), which was larger, and a gonion angle that was smaller, than in modern series. The agreement in the results between this series and that of Lysell and Filipsson suggests a true difference in curvature of the cranial base and size of the gonion angle between modern series and skulls dating far back in history.

The width of the dental arch (Table VII) between the first molars is greatest in the skulls, both on comparison with the inductees examined here and, with but few exceptions, also on comparison with the other materials. The smaller width of the dental arch between the first molars in the inductees may therefore be regarded as confirmed and in line with the findings by *Lundström* (1946), *Lundström* and *Lysell* (1953) and *Lysell* (1958) in their comparisons between skulls dating back to the Middle Ages and present-day material. In contrast with what was seen in the present investigation, these authors also found a greater width between the upper first premolars in the skull materials examined. The distance between the premolars in the present skulls showed good agreement with the values found in modern series. In the above investigations by Lundström and Lysell, however, the difference in width between the skull materials and the present-day materials was greater at the first molars than at the first premolars.

No definite difference in the height of the palatal vault was found between the inductees and the skulls. It might, however, be objected that measurement of the height of the palatal vault in casts and in skulls are not comparable because the skulls have no soft tissue parts, which tend to result in exaggerated height of the palatal vault compared with measurements on casts. On the

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other hand, when measuring on casts one must allow for the thickness of occlusal fillings which presumably are higher than the floor of the natural fossae. The thickness of the palatal mucosa and elevations owing to occlusal fillings are probably of the same order, so that one may in practice regard measurement of the palatal vault on skulls and on casts of present-day material as comparable. The mean palatal height in the present skulls agreed well with the corresponding value (18.3 mm) in skulls dating back to the Middle Ages (*Lundström & Lysell*, 1953).

A survey of the results shows that parallel to the secular increase in body height, which mainly reflects improved nutrition, there has also been a secularisation of the morphology of the cranium, which also includes changes in the cranial base. Since the growth of the skull is governed above all by genetic factors (*van Limborgh*, 1970), during the last 160 years there has probably occurred a change in the genetic constitution in the population in the west of Sweden, which has also influenced cranial morphology. Genetic drift and increased hybridisation may explain this change.

Comparisons between the present inductees and the skull material, on one hand, and the present skull material and other older skull materials, on the other hand, suggest that the biological distance in question increased most during the last 160 years. Whether the size of the teeth and their morphological characteristics are also included in this process is receiving attention.

This investigation is part of a research project concerned with anthropometric morphologic studies of inductees and has been supported by F.M.F.D. Project number U 65/1971, grant number 5633, Försvarets materialverk och Sjukvårdsstyrelse.

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