Sex differences in craniofacial morphology

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An x-ray cephalometric study was performed in a male and a female group of Danish dental students with the object of examining the sex-determined component of the cranial morphology, and of obtaining a control material for subsequent studies of pathologic samples. The cranial morphology was examined on the basis of measurements on x-ray cephalometric lateral and postero-anterior radiographs. The cranium was, on an average, smaller in the female than the male group except as regards the nasal bone, the foramen magnum and the inner orbital distance. The female group showed a more prominent frontal bone, and a less prominent nasal bone, than the male group.

Key-words: Craniofacial morphology; x-ray cephalometry; sex factors; adult

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There has been a growing interest in the study of human cranial morphology, both normal and pathologic, in recent years. A male group to be used as a control material in the study of pathologic material has been available at our institute for some years whereas a female control group has been lacking. The purpose of this study was to collect a female control group and to examine the sex-determined component of the cranial morphology.

MATERIAL AND METHODS

Material. The study was performed on a male and a female group. The male group (*Solow*, 1966) consisted of 102 dental students aged from 20 to 30 years. It contained no persons who had had orthodontic treatment or had any permanent teeth missing, other than third molars. The female group consisted of 51 dental students with ages ranging from 22 to 27 years. It was selected by the first author according to the same criteria as the male group.

The male and female groups are not representative of the Danish population as a whole, but the differences between them would be expected to be of the same magnitude as those between the sexes in the Danish population.

Method. For each subject lateral and postero-anterior radiographs of the head and a radiograph of the right forearm were taken.

The cephalometric films were taken by the techniques described by *Björk* (1968) (female group) and *Solow* (1966) (male group), using a movable grid and intensifying screens. For the lateral films the subject was seated with the right side

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of the head towards the film. The enlargement of the median plane was 5.6 per cent. One film was taken with the mouth open and one with the teeth in natural occlusion. The postero-anterior films were taken with the head oriented with the Frankfort plane horizontal and the teeth in natural occlusion. The enlargement of the plane through the ear-rods was 8.6 per cent in the male group and 8.3 per cent in the female group. The difference in enlargement of the postero-anterior films did not affect the significance level of the differences between the male and female transversal measurements. The radiograph of the forearm was taken on non-screen film with the arm in contact with the film. No grid or intensifying screen was used. The film was positioned in the film-holder so that the central ray was incident on the middle of the forearm. The enlargement of the transverse dimension was 1 per cent and of the longitudinal dimension 1.3 per cent.

On the lateral films 29 angular and 27 linear measurements were obtained, and on the postero-anterior films 4 linear measurements. All measurements used in the present study were made by one of the authors (*C.H.I.*), the male material thus being remeasured in order to avoid systematical error. The definitions of the reference points and lines are presented in Figures 1—3. All but a few of them are identical with the definitions of *Björk* (1960) and *Solow* (1966).

In order to relate the cranial development to the general bodily development 5 linear measurements were obtained on the films of the right forearm (Table I).

In the statistical analysis the estimates of the parameters were calculated according to *Solow* (1966). The significance of differences between the means was tested by Student's t-test. The 5 per cent and 1 per cent levels of significance are indicated in the tables by one and two asterisks.

Table I. *Measurements on the forearm films*

No.		Variable
57	RML	Radius, maximal length (7.1)
58	RHW	Radius, head width (7.4(1))
59	RDW	Radius, distal width (7.5 (6))
60	UML	Ulna, maximal length (8.1)
61	UHW	Ulna, head width. The longest diameter of the ulnar head

The numbers in brackets refer to the osteometric definitions of *Martin* (1928).

The angular measurements were read to the nearest half degree and the linear measurements to the nearest half millimetre — except for the transverse measurements of the radius and ulna, which were read to the nearest tenth of a millimetre. The statistical calculations of the 61 distributions were performed at an IBM 360/75 installation at NEUCC, The Northern Europe University Computing Center, Copenhagen.

RESULTS

Statistics

The statistical description of the distributions and the mean differences are presented in Table II.

For two of the 29 angular dimensions the differences between the means for the sexes were significant at the 1 per cent level, and for three at the 5 per cent level.

For 18 of the 27 linear measurements the sex differences were significant at the 1 per cent level and for one at the 5 per cent level. Deviations from the normal distribution form were few and differed for the two groups. There was no agreement between the occurrence of skewness and kurtosis within each group.

Table II. *Statistical data for male (M) and female (F) group*

Variable	Group	N	min.	max.	$\bar{x}$	S.E.	S.D.	Skewness $\sqrt{b1}$	Kurtosis b2	Kurtosis a	Diff.
1. f—n—s	M	102	74.5	93.0	85.62	0.350	3.53	—0.370	3.45	0.7777	—2.38**
	F	51	81.0	93.5	88.00	0.405	2.89	—0.426	2.62	0.8018	
2. n—s—ba	M	102	118.0	145.0	130.51	0.534	5.39	0.205	2.64	0.8349*	0.14
	F	51	121.0	144.5	130.37	0.691	4.93	0.205	2.83	0.8193	
3. eth—s—ba	M	102	111.0	137.0	125.20	0.555	5.60	0.058	2.37	0.8429*	—0.72
	F	51	114.0	135.5	125.92	0.796	5.68	—0.491	2.36	0.8260	
4. NSL/FMP	M	102	74.5	101.0	91.10	0.448	4.52	—0.729**	4.27*	0.7725	0.89
	F	51	80.5	96.0	90.21	0.512	3.65	—0.444	2.97	0.7852	
5. n—s—cd	M	102	116.5	149.5	134.29	0.592	5.98	0.030	3.06	0.7957	—0.57
	F	51	119.0	150.5	134.86	0.907	6.48	0.070	2.65	0.8285	
6. n—s—ar	M	102	112.5	136.5	124.19	0.496	5.00	0.117	2.50	0.8323	0.85
	F	51	113.0	134.0	123.34	0.711	5.08	—0.007	2.19	0.8320	
7. n—s—pm	M	102	67.0	82.5	74.26	0.302	3.05	0.044	2.72	0.8182	0.48
	F	51	66.0	80.0	73.78	0.386	2.76	—0.468	3.57	0.8059	
8. pm—s—ba	M	102	46.0	69.0	56.39	0.501	5.06	0.279	3.07	0.7714	—0.52
	F	51	48.0	69.5	56.91	0.628	4.48	0.330	3.17	0.7971	
9. s—n—na	M	102	99.0	135.5	117.37	0.608	6.14	—0.378	3.52	0.7838	2.98**
	F	51	100.0	126.5	114.39	0.839	5.99	0.120	2.49	0.8280	
10. s—n—sp	M	102	81.0	96.5	87.74	0.328	3.31	0.229	2.66	0.8027	0.29
	F	51	80.5	96.0	87.45	0.504	3.60	0.682*	2.90	0.7993	
11. s—n—ss	M	102	75.0	90.0	81.38	0.311	3.14	0.369	2.78	0.7888	—0.15
	F	51	75.0	90.0	81.53	0.491	3.50	0.401	2.75	0.7950	
12. NSL/NL	M	102	2.5	16.5	7.62	0.292	2.95	0.486*	3.08	0.8168	0.49
	F	51	0.5	13.5	7.13	0.446	3.19	—0.009	2.43	0.7080	
13. s—n—pr	M	102	78.5	92.0	84.45	0.301	3.04	0.444*	2.68	0.8059	—0.19
	F	51	78.0	93.0	84.64	0.469	3.35	0.352	2.63	0.8157	
14. IL_s/NL	M	102	93.0	128.0	110.85	0.644	6.51	—0.326	3.01	0.7953	1.00
	F	51	95.0	126.0	109.85	0.866	6.19	—0.079	3.29	0.7866	
15. OL_s/NL	M	102	—2.5	18.0	7.51	0.340	3.44	0.190	3.98*	0.7670	—0.54
	F	51	2.5	14.5	8.05	0.410	2.93	0.227	2.40	0.8099	
16. NSL/OL_s	M	102	5.0	27.5	15.44	0.411	4.15	0.155	3.40	0.7671	—0.41
	F	51	7.0	23.5	15.85	0.509	3.64	0.158	2.29	0.8572*	
17. s—n—is	M	102	76.5	93.0	84.81	0.315	3.18	0.208	2.86	0.7923	—0.20
	F	51	79.0	93.5	85.01	0.465	3.32	0.328	2.32	0.8563*	
18. s—n—pg	M	102	73.0	90.0	80.97	0.318	3.21	0.155	3.09	0.7914	0.52
	F	51	75.0	88.0	80.45	0.449	3.21	0.146	2.32	0.8270	
19. s—n—id	M	102	72.5	88.5	81.41	0.295	2.97	0.094	2.97	0.8076	0.35
	F	51	74.5	88.0	81.06	0.450	3.22	0.015	2.23	0.8558*	
20. n—s—tgo	M	102	95.5	112.0	103.44	0.360	3.63	0.336	2.62	0.8108	0.06
	F	51	96.5	111.5	103.38	0.481	3.43	—0.072	2.34	0.8340	

Variable	Group	N	min.	max.	$\bar{x}$	S.E.	S.D.	Skewness $\sqrt{b1}$	Kurtosis b2	a	Diff.
21. NSL/ML	M	102	13.5	46.5	28.00	0.583	5.89	0.071	3.19	0.7903	—1.64
	F	51	16.0	40.5	29.64	0.801	5.72	—0.099	2.22	0.8544*	
22. NSL/MBL	M	102	46.0	67.5	54.77	0.387	3.91	0.362	3.31	0.7825	—0.41
	F	51	47.0	62.0	55.18	0.517	3.69	—0.218	2.23	0.8362	
23. ML/RL	M	102	103.5	134.5	120.14	0.627	6.33	—0.369	2.99	0.7776	—1.03
	F	51	108.0	131.5	121.17	0.728	5.20	—0.236	2.63	0.8255	
24. CL/ML	M	102	55.0	87.0	70.47	0.667	6.74	0.138	2.75	0.7951	—0.97
	F	51	62.0	83.5	71.44	0.697	4.98	0.032	2.53	0.8196	
25. IL_i/ML	M	102	80.5	119.0	98.47	0.719	7.26	0.042	2.90	0.7928	—0.63
	F	51	82.5	111.5	99.10	0.925	6.61	—0.360	2.92	0.7976	
26. OL_i/ML	M	102	6.5	29.5	17.40	0.411	4.15	0.235	3.12	0.7995	0.84
	F	51	10.0	22.5	16.56	0.448	3.20	—0.292	2.59	0.8039	
27. ss—n—pg	M	102	—7.0	8.5	0.23	0.299	3.01	0.270	3.31	0.7857	—0.79*
	F	51	—2.0	4.5	1.02	0.259	1.85	—0.038	1.88	0.8659**	
28. NL/ML	M	102	7.5	35.5	20.34	0.570	5.75	0.338	2.99	0.8084	—1.61*
	F	51	11.5	31.5	21.95	0.711	5.08	—0.283	2.43	0.8068	
29. IL_s/IL_i	M	102	107.5	160.0	131.73	1.087	10.98	—0.014	2.85	0.8010	3.39*
	F	51	107.5	149.0	128.34	1.414	10.10	0.218	2.51	0.8016	
30. s—f	M	102	86.5	108.0	96.21	0.443	4.47	0.136	2.81	0.8069	1.02
	F	51	86.5	106.0	95.19	0.520	3.71	0.262	3.63	0.7746	
31. s—br	M	102	94.0	120.5	108.96	0.476	4.80	—0.036	3.54	0.7569	2.54**
	F	51	97.0	117.5	106.42	0.582	4.16	0.237	3.33	0.7853	
32. br—l	M	97	118.0	152.5	132.53	0.624	6.15	0.275	3.19	0.7953	1.31
	F	51	117.5	146.0	131.22	0.950	6.79	0.297	2.61	0.7985	
33. l—ba	M	96	113.0	140.5	127.25	0.534	5.23	—0.009	2.97	0.6036	4.23**
	F	51	110.5	135.5	123.02	0.715	5.10	0.031	3.00	0.7719	
34. n—s	M	102	67.0	81.0	73.38	0.308	3.11	0.191	2.40	0.8270	2.94**
	F	51	65.5	77.0	70.44	0.326	2.33	0.623	3.79	0.7251**	
35. s—ba	M	102	42.5	55.0	48.93	0.283	2.86	—0.085	2.36	0.8336	2.79**
	F	51	40.0	51.5	46.14	0.337	2.41	—0.067	2.80	0.7971	
36. ba—o	M	102	30.0	45.5	36.79	0.325	3.28	0.133	2.55	0.8270	0.90
	F	51	29.0	43.0	35.89	0.435	3.11	0.123	2.47	0.8261	
37. pm—ba	M	102	38.5	54.5	46.10	0.318	3.21	0.054	2.74	0.8109	1.52**
	F	51	37.0	49.0	44.58	0.375	2.68	—0.506	2.92	0.8053	
38. n—na	M	102	18.0	33.5	25.02	0.295	2.98	0.195	3.02	0.8053	0.63
	F	51	18.5	29.0	24.39	0.340	2.43	—0.302	2.47	0.8289	
39. mo—mo	M	102	21.5	32.5	26.15	0.229	2.31	—0.122	2.50	0.8307	0.13
	F	51	22.5	34.5	26.02	0.349	2.49	1.064**	4.22	0.7815	
40. lo—lo	M	102	89.5	104.5	96.77	0.300	3.03	—0.069	2.94	0.7939	2.01**
	F	51	86.0	101.5	94.76	0.431	3.08	—0.049	3.44	0.7872	
41. sp—pm	M	102	51.0	65.0	58.16	0.281	2.83	—0.000	2.65	0.8062	3.17**
	F	51	49.5	60.5	54.99	0.367	2.62	0.010	2.21	0.8281	

Variable	Group	N	min.	max.	x	S.E.	S.D.	Skewness $\sqrt{b1}$	Kurtosis b2	a	Diff.
42. ss—pm	M	102	46.5	60.0	52.92	0.238	2.41	0.117	3.15	0.7934	2.56**
	F	51	44.5	55.5	50.36	0.330	2.36	—0.150	2.78	0.8012	
43. em—em	M	102	60.5	74.5	67.01	0.313	3.17	0.094	2.60	0.8032	3.54**
	F	51	56.5	71.0	63.47	0.413	2.95	0.045	2.86	0.8157	
44. n—sp	M	102	48.5	64.0	55.66	0.304	3.07	0.013	2.85	0.7865	2.70**
	F	51	48.0	60.0	52.96	0.361	2.58	0.460	3.16	0.7990	
45. s—pm	M	102	44.5	58.5	50.22	0.286	2.88	0.131	2.63	0.8294	2.76**
	F	51	42.0	51.5	47.46	0.300	2.14	—0.416	2.69	0.7985	
46. sp—is	M	102	23.5	37.0	30.70	0.271	2.74	—0.121	2.66	0.7985	0.90*
	F	51	24.5	35.0	29.80	0.362	2.58	0.122	2.15	0.7443	
47. pr—pr'	M	102	11.5	23.0	16.68	0.238	2.41	0.028	2.87	0.7799	0.64
	F	51	10.0	21.5	16.04	0.337	2.40	0.193	2.74	0.8096	
48. pgn—cd	M	102	114.5	141.0	125.85	0.492	4.97	0.276	3.45	0.7768	6.94**
	F	51	110.5	133.0	118.91	0.688	4.91	0.654*	3.54	0.7698	
49. ag—ag	M	102	79.0	102.0	90.16	0.436	4.40	0.186	2.89	0.8119	4.55**
	F	51	78.0	92.5	85.61	0.494	3.52	—0.206	2.63	0.7864	
50. sp—gn	M	102	58.5	86.5	72.24	0.519	5.24	0.083	2.96	0.7980	4.15**
	F	51	58.0	78.0	68.09	0.684	4.89	0.002	2.32	0.8168	
51. s—ar	M	102	32.0	47.5	38.80	0.331	3.35	0.446*	2.87	0.7926	3.12**
	F	51	31.5	44.0	35.68	0.382	2.73	0.374	3.08	0.8062	
52. s—tgo	M	102	75.5	101.5	89.89	0.558	5.63	—0.298	2.90	0.7857	7.21**
	F	51	74.0	93.0	82.68	0.623	4.45	0.078	2.74	0.8018	
53. cd"—tgo	M	102	57.5	82.0	68.35	0.462	4.67	—0.110	2.77	0.8038	4.77**
	F	51	55.0	72.0	63.58	0.547	3.91	—0.363	2.74	0.7964	
54. id—id'	M	102	27.5	41.5	32.78	0.264	2.66	0.374	3.32	0.7961	2.36**
	F	51	24.5	37.0	30.42	0.344	2.46	0.095	3.37	0.7597	
55. is—io	M	102	—1.0	9.5	3.21	0.149	1.50	1.179**	6.51**	0.7246**	—0.08
	F	51	1.5	6.5	3.29	0.157	1.12	0.920**	3.67	0.7736	
56. ii—io	M	102	—1.0	7.5	2.72	0.159	1.60	0.042	2.83	0.8179	0.02
	F	51	0.0	5.0	2.70	0.164	1.17	—0.320	2.77	0.8218	
57. RML	M	102	235.5	290.0	261.82	1.218	12.30	—0.041	2.10**	0.8562**	24.99**
	F	51	211.0	266.0	236.83	1.740	12.42	—0.088	2.59	0.8263	
58. RHW	M	102	21.5	27.0	24.15	0.120	1.21	0.035	2.69	0.8129	3.51**
	F	51	18.4	23.8	20.64	0.176	1.26	0.422	2.65	0.8189	
59. RDW	M	102	32.2	40.3	35.91	0.179	1.81	0.160	2.36	0.8256	5.18**
	F	51	26.8	34.4	30.73	0.243	1.73	—0.008	2.63	0.8343	
60. UML	M	102	249.5	305.5	281.84	1.221	12.34	—0.161	2.34*	0.8398*	27.05**
	F	51	231.0	288.0	254.79	1.721	12.29	0.138	2.85	0.8144	
61. UHW	M	102	14.7	20.9	18.41	0.116	1.17	—0.286	3.17	0.7900	2.66**
	F	51	13.2	18.6	15.75	0.152	1.09	0.779*	4.08	0.7387*	

* $p \leq 0.05$ ** $p \leq 0.01$ Significance levels for b2 in female group not indicated, as significance limits are not available for this sample size.

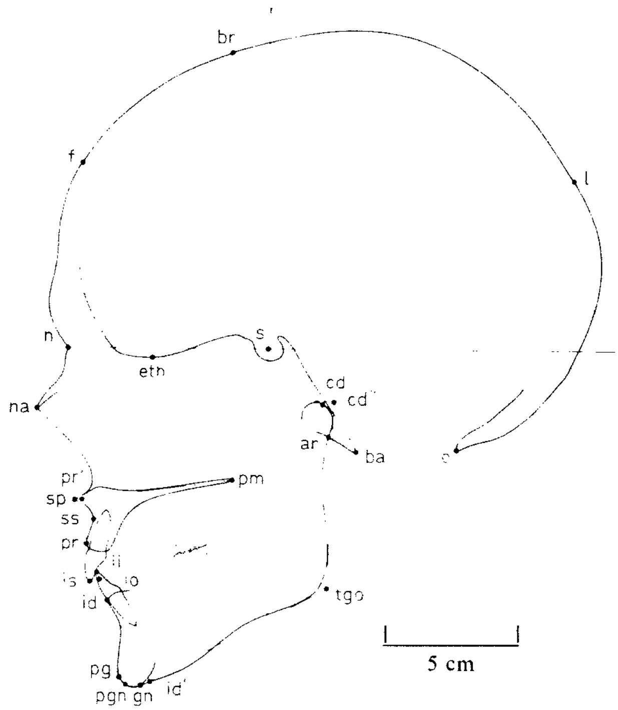

Fig. 1. Reference points on the profile cephalometric radiographs. Tracing based on mean dimensions for male group.
ar: Articulare, *ba:* Basion, *br:* Bregma, *cd:* Condylion, *cd":* Condylion (Kisling 1966), *eth:* Ethmoidale, *f:* Frontale, *gn:* Gnathion, *id:* Infradentale, *id':* Projection of *id* on the mandibular line, *ii:* Incision inferius, *io:* Incision occlusale, *is:* Incision superius, *l:* Lambda, *n:* Nasion, *na:* Nasal apex, *o:* Opisthion, *pg:* Pogonion, *pgn:* Prognathion, *pm:* Pterygomaxillare, *pr:* Prosthion, *pr':* Projection of *pr* on the nasal line, *s:* Sella, *sp:* Spinal point, *ss:* Subspinale, *tgo:* Tangent intersection at gonion.

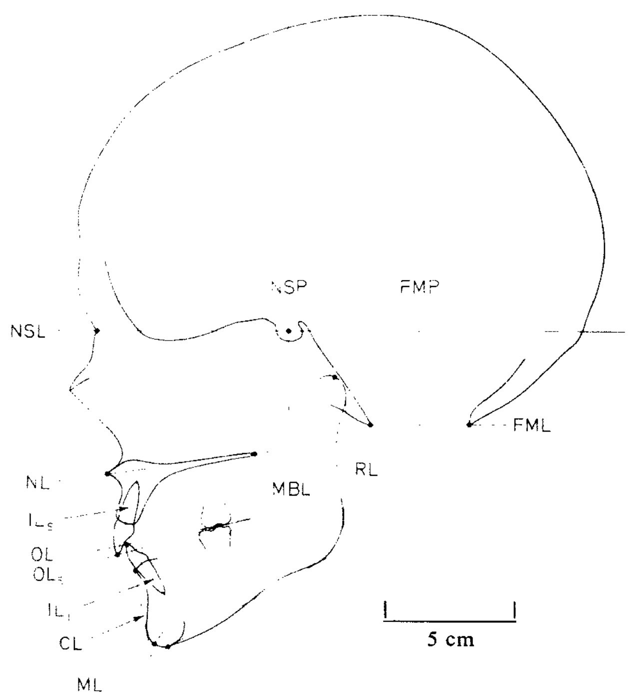

Fig. 2. Reference lines on the profile cephalometric radiographs. Free-hand tracing based on mean dimensions for female group.
CL: Chin line, FML: Foramen magnum line, FMP: Foramen magnum perpendicular, IL_i: Lower incisal line, IL_s: Upper incisal line, ML: Mandibular line, MBL: Mandibular base line, NL: Nasal line, NSL: Nasion sella line, OL_i: Lower occlusal line, OL_s: Upper occlusal line, RL: Ramus line.

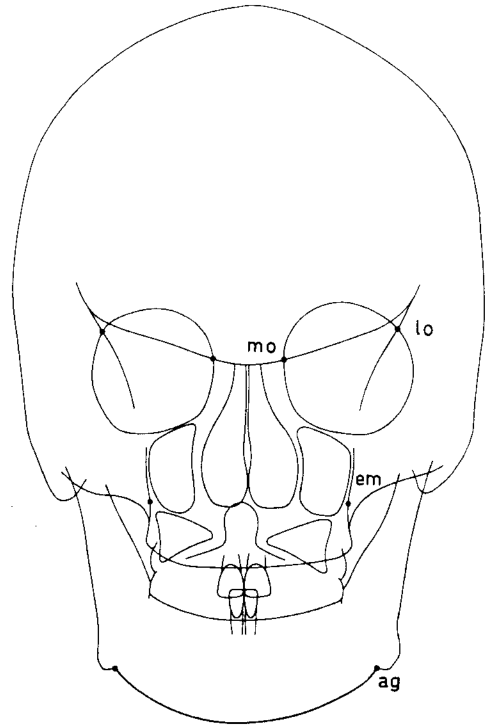

Fig. 3. Reference points on the posteroanterior cephalometric radiographs: *ag:* Antegonion, *em:* Ectomaxillare, *lo:* Latero-orbitale (Sassouni 1960), *mo:* Medio-orbitale.

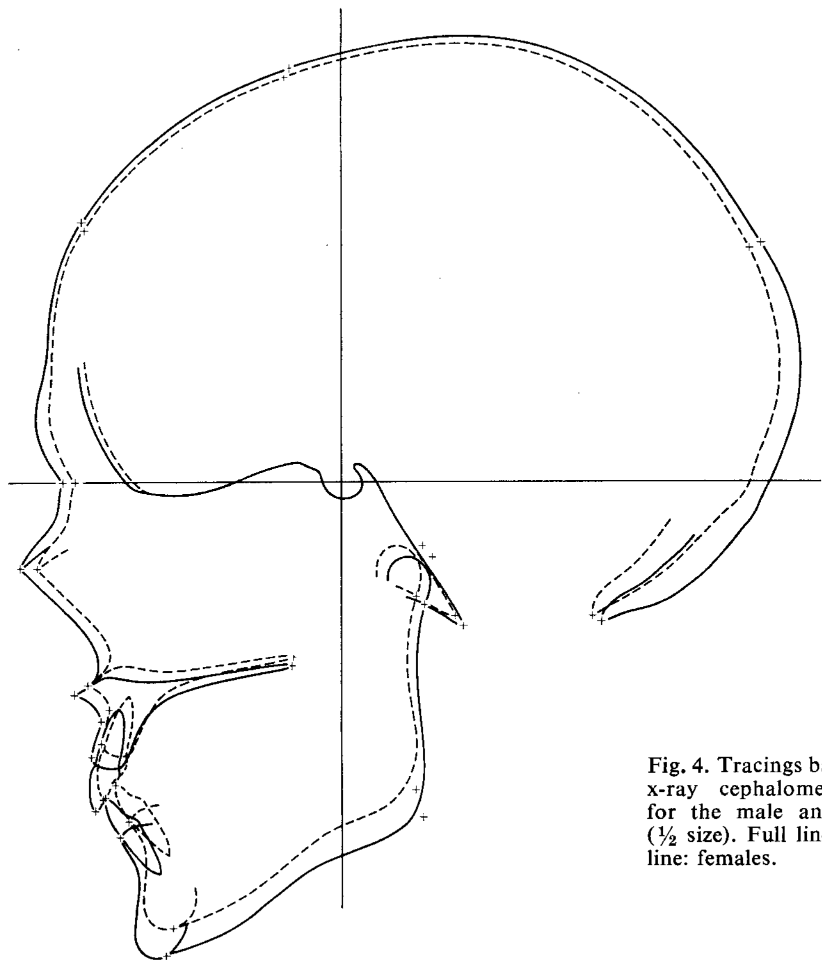

Fig. 4. Tracings based on the mean x-ray cephalometric dimensions for the male and female groups (½ size). Full line: males. Broken line: females.

The cranial morphology is shown in Figures 1, 2 and 4, which are based on the mean dimensions for the two groups.

Morphology

Calvarium. Among the linear dimensions of the calvarium, s—br and l—ba were found to be smaller for the female than for the male group. The frontal bone was more prominent, f—n—s, in the women.

Cranial base. The cranial base had the same shape in the two groups, both medially, n—s—ba, and laterally, n—s—cd and n—s—ar. The cranial base lengths, n—s and s—ba, were smaller in the women than the men. There was, however, no significant difference in the antero-posterior diameter of the foramen magnum, ba—o.

Pharynx. The pharyngeal angle, pm—s—ba, did not differ significantly in the two groups but the pharyngeal depth, pm—ba, was smaller for the female than for the male group.

Nasal bone. The nasal bone had almost the same length, n—na, in the two groups but was less protruded in the women, s—n—na.

Orbits. The transverse dimension outer orbital distance, lo—lo, was significantly smaller in the women.

Maxilla and Mandible. The lengths and widths of the maxilla and the mandible, sp—pm, ss—pm, pgn—cd, em—em, ag—ag, and the anterior and posterior upper, lower and total facial heights, n—sp, s—pm, sp—gn, cd''—tgo, s—tgo, were significantly smaller in the female than the male group.

Maxillary and mandibular prognathism and inclination, as measured in relation to the cranial base, s—n—sp, s—n—ss s—n—pg, NSL/NL, NSL/ML, NSL/MBL, did not differ significantly in the two groups, nor was there a significant difference for the gonial angle, ML/RL.

For maxillary and mandibular incisal inclination, IL_s/NL, IL_i/ML, and occlusal plane inclination, OL_s/NL, NSL/OL_s, OL_i/ML, there was no significant difference between the groups.

Intermaxillary relationship. The sagittal and vertical jaw relationship, ss—n—pg and NL/ML were somewhat greater in the female group, and the interincisal angle IL_s/IL_i, somewhat smaller. However, the differences were not significant at the 1 per cent level. Neither overjet nor overbite, is—io and ii—io, differed in the two groups.

Right radius and ulna. All the measurements on the right forearm showed significantly smaller values in the female group.

DISCUSSION

Statistics

The form of the 61 distributions for each of the two groups showed only small deviations from the normal distribution, as earlier reported for the male sample (*Solow*, 1966). There was significant leptokurtosis in the male group for overjet, as was found by *Björk* (1947) in a group of Swedish boys. For this measurement both groups showed positive skewness.

Morphology

Calvarium. The greater prominence of the frontal bone in the female group may be ascribed to a more strongly curved frontal bone rather than to a sex determined difference in the thickness of the bone.

Cranial base. The absence of a sex difference in cranial base flexion is consistent with the observations of *Sarnäs*

(1957), *Wei* (1969) and *Koski* (1960). All components of the base were, however, shorter in the female group except the diameter of the foramen magnum, for which there was no difference. The foramen was thus located higher and more forward in the women but the inclination, NSL/FMP, was the same.

The distance s—ar reflected the shorter cranial base in the female group, and, at the same time, indicated the higher and more forward position of the mandibular condyle.

Pharynx. The smaller pharyngeal depth in the women is probably associated with the shorter clivus and the higher position of the palate.

Nasal bone. In view of the constant increase in nasal protrusion during growth (*Stramrud*, 1959), the greater nasal protrusion in the men might be due to the longer period of male growth and the greater growth activity during adolescence (*Krogman*, 1938; *Nanda*, 1955; *Downs*, 1956; *Bambha*, 1961; *Tanner*, 1962). The angle s—n—na for the men in this study is the same as that reported by *Stramrud* (1959) for men of the same age. The absence of a significant sex difference in the length of the nasal bone would seem to be inconsistent with the difference in length of the soft-tissue nose found by *Subtelny* (1959).

Orbits. The significant sex difference in the outer orbital distance is probably due to the generally smaller absolute distances for the female group, which is more clearly reflected in the greater outer than inner orbital measurement. In his Chinese material *Wei* (1970) found a significant sex difference for both dimensions. The inconsistency with the result of the present study may be due to the racial difference.

Jaws and intermaxillary relations. The smaller linear dimensions of both jaws in the females and the absence of significant sex differences in the angular measures are consistent with the findings reported by *Wei* (1966) and other authors.

In summary, the comparison of the craniofacial morphology in the two groups showed that on an average, the cranium was significantly smaller in the women than in the men, except as regards the nasal bone, the foramen magnum and the inner orbital distance. As regards cranial shape the only differences significant at the 1 per cent level were, for the women, a more prominent frontal bone and a less prominent nasal bone.

The present investigation thus in detail confirms the view that the average sex determined shape differences in craniofacial morphology are few and small, and that the female skull is significantly smaller than the male.

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