

Craniofacial changes in Icelandic children between 6 and 16 years of age – a longitudinal study

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SUMMARY The aim of the present study was to describe the craniofacial changes between 6 and 16 years of age in a sample of Icelandic children. Complete sets of lateral cephalometric radiographs were available from 95 males and 87 females. Twenty-two reference points were digitized and processed by standard methods, using the Dentofacial Planner® computer software program. Thirty-three angular and linear variables were calculated, including: basal sagittal and vertical measurements, facial ratio, and dental, cranial base and mandibular measurements.

For the angular measurements, gender differences were not statistically different for any of the measurements, in either age group, except for the variable s–n–na, which was larger in the 16-year-old boys ($P \leq 0.001$). Linear variables were consistently larger in the boys compared with the girls at both age levels. During the observation period mandibular prognathism increased but the basal sagittal jaw relationship, the jaw angle, the mandibular plane angle and cranial base flexure (n–s–ba) decreased in both genders ($P \leq 0.001$). Maxillary prognathism increased only in the boys from 6 to 16 years. Inclination of the lower incisors and all the cranial base dimensions increased in both genders during the observation period. When the Icelandic sample was compared with a similar Norwegian sample, small differences could be noted in the maxillary prognathism, mandibular plane angle and in the inclination of the maxilla. Larger differences were identified in the inclination of the lower incisors. These findings could be used as normative cephalometric standards for 6- and 16-year-old Icelandic children.

Introduction

Various longitudinal and semi-longitudinal growth studies have shown that different linear and angular cephalometric measurements vary between males and females and change with age (Björk, 1947; Ødegaard, 1970; Riolo *et al.*, 1974; Ingerslev and Solow, 1975; Bishara, 1981; Berg, 1983; El-Batouti *et al.*, 1994). Furthermore, differences have been demonstrated among races (Cotton *et al.*, 1951; Altemus, 1960; Miyajima *et al.*, 1996; Zeng *et al.*, 1998) and among Caucasians (Canut *et al.*, 1987; Argyropoulos and Sassouni, 1989; El-Batouti *et al.*, 1995). Differences have also been described among closely related and homogeneous ethnic groups, such as those from the Scandinavian countries (Solow and Sarnäs, 1982).

An understanding of the timing, magnitude and direction of facial growth enables orthodontists to plan the treatment of skeletal discrepancies in an attempt to achieve a more stable and pleasing result. Cephalometric analysis has proved to be a useful tool in diagnosis, evaluation and treatment planning of patients undergoing orthodontic treatment or orthognathic surgery and for evaluation of treatment progress and results. For orthodontic and other diagnostic procedures, therefore, it is an advantage to have cephalometric standards for different populations, gender, and age groups.

Due to external isolation for almost 1100 years, the low number of inhabitants, and the continuous and ever increasing interbreeding between people from different parts of the country, the Icelandic nation is considered genetically homogenous. Therefore, all studies undertaken on the Icelandic population should be interesting for epidemiological purposes and for comparative studies.

No longitudinal cephalometric growth studies of young Icelandic children and adolescents have been performed previously.

The purpose of this study was to describe, on lateral cephalograms, the craniofacial changes in an Icelandic sample of boys and girls between 6 and 16 years of age, to evaluate possible differences between the genders, and to compare the results with data obtained from a closely related ethnic group, i.e. the 'Nittedal' material from Oslo, Norway.

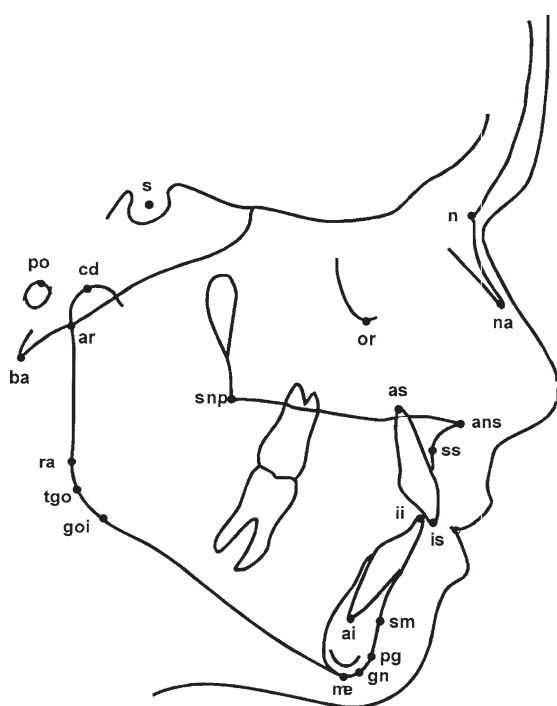
Material and methods

Subjects

The material for this study was collected at the Faculty of Odontology, University of Iceland, during the periods 1987–1988 and 1997–1998. Registrations included dental study models, and lateral cephalometric, postero-anterior skull and panoramic radiographs. All subjects were residents

Table 1 Definition of skeletal cephalometric landmarks.

Landmark	Abbreviation	Definition
Apex inferius	ai	The root apex of the most prominent lower incisor
Anterior nasal spine	ans	The apex of anterior nasal spine
Articulare	ar	The point of intersection of the dorsal contour of the condylar head and the contour of the external cranial base
Apex superius	as	The root apex of the most prominent upper incisor
Basion	ba	The most inferior posterior point in the sagittal plane on the anterior rim of the foramen magnum
Condylion	cd	A point on the contour of the condyle obtained by bisecting the angle formed by tangents to the upper and posterior borders of the condyle, the tangents being parallel and perpendicular to the mandibular line, respectively
Gnathion (American menton)	gn	The most inferior point of the mandibular symphysis
Gonion inferius	goi	The posterior tangent point of the mandibular inferior border near gonion
Incision inferius	ii	The midpoint on the incisor edge of the most labially positioned mandibular central incisor
Incision superius	is	The midpoint on the incisor edge of the most labially positioned maxillary central incisor
Nasion	n	The anterior limit of the nasofrontal suture
Nasale	na	The tip of the nasal bone
Orbitale	or	The deepest point on the infraorbital margin
Pogonion	pg	The most prominent point of the mandibular symphysis
Prognathion (American gnathion)	pgn	The point on the mandibular symphysis farthest from condylion
Porion	po	The mid-point on the upper contour of the external auditory canal
Ramus point	ra	The lower tangent point of the posterior border of the ramus
Sella	s	Centre of sella turcica
Spina nasalis posterior	snp	The point of intersection of the soft palate, the hard palate and fossa pterygopalatina
Supramentale (Downs point B)	sm	The deepest point on the contour of the mandibular alveolar process, between infradentale and pogonion
Subspinale (Downs point A)	ss	The deepest point on the contour of the maxillary alveolar process between anterior nasal spine and prosthion
Tangent gonion	tgo	The tangent intersection at gonion, the intersection between the mandibular line and ramus line

**Figure 1** Skeletal cephalometric landmarks. (For definitions see Table 1.)

of Reykjavik, the capital city of Iceland. Ethical and other approval for this study was obtained beforehand from the relevant authorities in Iceland and informed consent of the parents or guardians was obtained for their children.

The subjects included children born in 1981 and 1982, who reported for dental examination and registration in 1987 and 1988, respectively, while attending the first class in elementary school. The elementary schools were all located in Reykjavik and were selected randomly, five schools in 1987 and eight in 1988. All children attending the first class were invited to participate, making a total of 716 children. Of these, 402 accepted the invitation. Four subjects were excluded due to foreign origin and two for other reasons, giving a final sample of 396 6-year-old children. From the original sample of 396 children, lateral cephalometric radiographs of 371 subjects were available. The dropout of 25 children can be explained by the fact that some parents disapproved of having their child exposed to radiation, but were willing to let them participate in other parts of the study. Films of poor quality and those where the posterior teeth were not occluded were rejected, eight altogether. From an original group of 396 6-year-olds, therefore, cephalograms were obtained of 363 children, 184 (50.7 per cent) boys and 179 (49.3 per cent) girls. The material representing 6-year-olds has been described in detail previously (Arnlaugsson and Magnusson, 1996; Johannsdottir *et al.*, 1997, 1999).

From the original sample of 396 subjects, 275 (69.1 per cent) were willing to participate in a follow-up study 10 years later. Registrations included dental study models, lateral cephalometric, postero-anterior, and panoramic

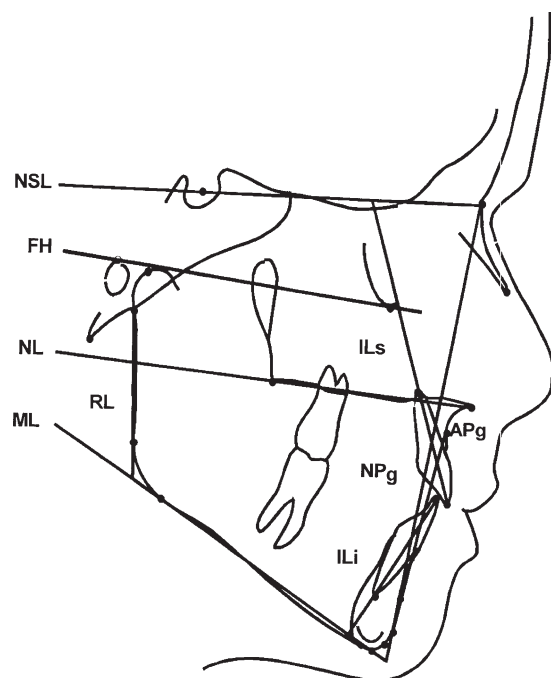


Figure 2 Reference lines. NSL: nasion–sella line (n–s); FH: Frankfort horizontal (po–or); NL: nasal line (sn–ans); ML: mandibular line (goi–gn); RL: ramus line (ra–ar); NPg: nasion–pogonion line (n–pg); APg: subspinale–pogonion line (ss–pg); ILs: long axis of the upper incisors (as–is); ILi: long axis of the lower incisors (ii–ai).

Table 2 Linear and angular measurements.

Basal sagittal measurements
Angular: s–n–ss, s–n–sm, s–n–pg, ss–n–sm, n–ss–pg (supplementary angle)
Linear: ss–n–pg
Basal vertical measurements
Angular: NSL/FH, NSL/NL, NL/ML, NSL/ML, RL/ML
Linear: n–gn (anterior face height), s–goi (posterior face height)
Ratio: n–ans/ans–gn (anterior face height ratio)
Mandibular length
Linear: cd–tgo, cd–pgn, ar–pgn
Dental measurements
Angular: ILs/NSL, ILs/NL, ILi/ML, ILs/ILi
Linear: is–ss–pg, is–n–ss, ii–ss–pg, ii–n–sm
Cranial base
Angular: n–s–ba, n–s–ar
Linear: s–n, s–ba, s–ar, n–ba
Nasal bone
Angular: s–n–na
Linear: n–na

radiographs and photographs of the face in profile. In addition, the participants were asked to answer a questionnaire concerning: self-esteem, an opinion on their appearance and their teeth, and questions regarding facial pain or problems concerning the temporomandibular joints (TMJs). Their age at this time, in 1997 and 1998, was 16 years. All subjects who had received any type of orthodontic

treatment were excluded from the investigation. In the present study, lateral cephalograms were used only of those that attended both when they were 6 and 16 years old. Thus, for analysis, sets of cephalometric films from 182 individuals were available, 95 (52.2 per cent) boys and 87 (47.8 per cent) girls. In the 6-year-old group, measurements of the dental variables were only carried out in individuals with the permanent incisors present.

Comparison of craniofacial morphology between Icelandic and Norwegian children

Based on an earlier investigation on plaster models (Johannsdottir *et al.*, 1997), all 6-year-old children that had an Angle Class I molar relationship on both sides could be identified. Of the original 200 6-year-old children in this normal occlusion group, 111 participated in the follow-up study 10 years later. Thus, sets of lateral cephalometric radiographs of this normal occlusion group were available from 55 (49.5 per cent) boys and 56 (50.5 per cent) girls.

Cephalometric analysis

The cephalometric recordings were obtained in a Lumex cephalostat (Tagarno). The focus–median plane distance was 180 cm and the focus–film distance 190 cm, producing a 5.6 per cent enlargement of the median plane structures. The cephalometric radiographs were taken with the subjects standing with their teeth occluded and the lips in a relaxed position. The films were traced on acetate paper and digitized using Numonics Digitizing Table® (Vertigraph Inc., Dallas, Texas, USA) and processed by the Dentofacial Planner® software (Dentofacial Software Inc., Toronto, Ontario, Canada). The magnification of the radiographs (5.6 per cent of midline structures) was corrected in the computer software program.

On each radiograph, 22 skeletal cephalometric landmarks were identified (Björk, 1947; Downs, 1948; Solow, 1966; Moyers, 1973; Kreiborg, 1981; Bhatia and Leighton, 1993) (Figure 1, Table 1). From the cephalometric landmarks and reference lines (Figure 2), 33 angular and linear measurements were analysed (Table 2).

Statistical method

Descriptive statistics including the mean, standard deviation, and maximum and minimum values were computed for each variable. A paired *t*-test was used to evaluate the difference between the two age groups, and two-sample *t*-tests to compare the means between the genders. Ninety-five per cent confidence intervals (CI) were also calculated. Gender differences were tested within each age group and the changes from 6 to 16 years of age were evaluated for each group separately.

Table 3 Craniofacial morphology of 6- and 16-year-old Icelandic children. The whole sample.

Measurement	Boys					Girls					Mean difference	95% CI	
	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max			
Basal sagittal 6 years													
s-n-ss (°)	95	81.6	3.1	74.9	91.3	87	82.0	3.2	75.2	90.4	-0.4	(-1.32/0.54)	
s-n-sm (°)	95	77.6	2.8	70.8	88.6	87	78.1	3.3	70.2	86.0	-0.5	(-1.39/0.42)	
s-n-pg (°)	95	77.7	2.9	70.5	89.2	87	78.2	3.3	70.1	86.4	-0.6	(-1.49/0.34)	
ss-n-sm (°)	95	4.0	1.8	-1.2	8.9	87	3.9	1.7	0.5	7.4	0.1	(-0.42/0.61)	
ss n-pg (mm)	95	3.2	1.6	-1.0	7.4	87	2.9	1.5	1.0	5.6	0.3	(-0.21/0.71)	
n-ss-pg (°)	95	8.2	4.2	-2.6	18.6	87	7.8	4.0	-3.0	15.1	0.4	(-0.80/1.60)	
Basal sagittal 16 years													
s-n-ss (°)	95	82.7	3.9	73.3	93.7	87	82.4	3.4	73.2	91.1	0.4	(-0.71/1.43)	
s-n-sm (°)	95	80.5	3.7	71.2	91.1	87	80.0	3.6	72.6	89.1	0.5	(-0.55/1.58)	
s-n-pg (°)	95	81.7	3.8	72.2	91.7	87	81.2	3.7	73.2	90.3	0.5	(-0.62/1.57)	
ss-n-sm (°)	95	2.3	2.2	-3.5	9.0	87	2.4	1.7	-1.9	6.1	-0.1	(-0.71/0.45)	
ss n-pg (mm)	95	1.1	2.6	-6.7	8.9	87	1.1	2.0	-5.7	5.7	-0.0	(-0.71/0.64)	
n-ss-pg (°)	95	-2.3	5.5	-17.6	14.1	87	-2.5	4.5	-12.3	14.2	0.2	(-1.27/1.68)	
Basal vertical 6 years													
NSL/FH (°)	95	8.5	2.4	-0.4	12.8	87	8.4	2.7	2.2	13.9	0.1	(-0.67/0.82)	
NSL/NL (°)	95	5.7	2.8	-1.3	12.4	87	5.4	2.7	-1.9	13.3	0.4	(-0.45/1.15)	
NL/ML (°)	95	27.3	4.4	17.8	36.4	87	27.5	3.8	19.4	36.5	-0.2	(-1.37/1.05)	
NSL/ML (°)	95	33.0	4.1	23.8	44.4	87	32.9	4.3	20.8	43.0	0.2	(-1.05/1.42)	
n-ans/ans-gn (%)	95	77.0	6.8	65.0	100.2	87	76.1	6.0	61.6	89.2	1.0	(-0.96/2.81)	
n-gn (anterior face height; mm)	95	95.7	4.7	85.5	105.4	87	92.9	3.8	82.9	103	2.7	(1.50/3.99)	***
s-goi (posterior face height; mm)	95	61.1	3.7	52.4	69.3	87	59.2	3.0	51.5	66.4	1.9	(0.92/2.91)	***
RL/ML (°)	95	128.2	5.2	114.0	143.3	87	127.2	5.3	113.2	143.3	1.0	(-0.51/2.56)	
Basal vertical 16 years													
NSL/FH (°)	95	9.6	2.8	4.2	16.3	87	9.8	2.8	2.8	15.9	-0.2	(-0.99/0.66)	
NSL/NL (°)	95	6.1	3.4	-5.1	14.5	87	6.3	3.2	-1.0	18.6	-0.2	(-1.14/0.79)	
NL/ML (°)	95	21.4	5.1	4.4	35.0	87	21.9	5.1	4.7	33.3	-0.6	(-2.06/0.95)	
NSL/ML (°)	95	27.5	5.3	15.9	38.5	87	28.2	5.2	10.6	42.2	-0.7	(-2.25/0.82)	
n-ans/ans-gn (%)	95	77.7	6.7	58.7	99.8	87	78.0	7.3	62.2	96.2	-0.4	(-2.43/1.65)	
n-gn (anterior face height; mm)	95	117.3	6.7	103.7	132.9	87	109.3	5.4	96.5	125.2	8.0	(6.20/9.78)	***
s-goi (posterior face height; mm)	95	82.4	5.8	69.4	97.2	87	75.7	4.7	63.6	90.6	6.7	(5.16/8.24)	***
RL/ML (°)	95	118.4	6.6	102.1	136.1	87	118.5	6.4	98.3	133.8	-0.1	(-1.99/1.83)	
Mandibular length 6 years													
cd-tgo (mm)	95	44.3	2.7	37.3	51.4	87	43.3	2.7	36.5	48.9	1.0	(0.24/1.83)	*
cd-pgn (mm)	95	92.6	3.8	84.1	100.9	87	90.8	3.9	78.0	100.3	1.8	(0.66/2.94)	**
ar-pgn (mm)	95	87.8	3.6	80.5	97.2	87	85.8	3.5	72.6	93.6	2.0	(0.97/3.07)	***
Mandibular length 16 years													
cd-tgo (mm)	95	61.6	4.3	51.4	72.3	87	58.9	3.8	45.6	69.3	4.8	(3.56/5.94)	***
cd-pgn (mm)	95	117.3	5.2	105.0	130.5	87	109.5	5.2	92.4	124.9	8.0	(6.27/9.31)	***
ar-pgn (mm)	95	110.3	5.2	97.4	123.9	87	102.8	5.0	87.3	116.3	7.5	(6.03/9.02)	***
Dental 6 years													
ILs/NSL (°)	19	102.4	6.6	92.3	118.2	34	100.0	6.3	88.6	113.1	2.4	(-1.42/6.16)	
ILs/NL (°)	19	107.5	8.4	93.8	126.2	34	105.5	6.7	94.6	118.6	2.0	(-2.61/6.57)	
is ss-pg (mm)	19	3.9	1.7	1.0	8.2	34	3.8	1.8	-0.1	7.1	0.1	(-0.93/1.09)	
is n-ss (mm)	19	1.6	1.8	-1.5	5.7	34	1.5	1.9	-2.3	6.0	0.1	(-1.02/1.12)	
ILi/ML (°)	67	89.9	7.1	72.4	110.9	74	89.6	7.1	70.1	104.4	0.3	(-2.07/2.68)	
ii ss-pg (mm)	67	0.5	1.8	-3.4	6.4	74	0.5	1.8	-3.3	5.6	-0.1	(-0.67/0.50)	
ii- n-sm (mm)	67	2.4	1.7	-2.5	8.8	74	2.3	1.8	-2.3	6.5	0.1	(-0.49/0.68)	
ILs/ILi (°)	19	133.6	10.0	118.1	147.2	32	135.5	10.8	119.0	165.0	-1.9	(-7.98/4.22)	
Dental 16 years													
ILs/NSL (°)	95	103.9	7.6	87.4	122.0	87	102.1	7.1	89.1	123.4	1.1	(-0.27/4.02)	
ILs/NL (°)	95	110.0	6.9	92.9	125.9	87	108.3	6.8	93.5	126.9	1.7	(-0.30/3.70)	
is ss-pg (mm)	95	5.4	2.4	0.2	11.7	87	4.9	2.1	0.5	9.2	0.6	(-0.10/1.21)	
is n-ss (mm)	95	4.6	2.6	-2.8	10.9	87	3.9	2.2	-1.0	8.6	0.6	(-0.07/1.34)	
ILi/ML (°)	95	98.3	6.3	80.3	114.3	87	97.7	6.4	81.9	113.2	0.6	(-1.28/2.46)	
ii ss-pg (mm)	95	2.4	2.1	-2.5	8.3	87	1.9	2.1	-2.2	6.8	0.5	(-0.13/1.09)	
ii- n-sm (mm)	95	4.7	2.1	-0.3	10.2	87	4.1	1.9	0.3	8.4	0.6	(-0.04/1.15)	
ILs/ILi (°)	95	130.3	9.0	107.8	150.9	87	132.0	9.8	110.2	151.2	-1.7	(-4.50/1.02)	

Table 3 (continued)

Measurement	Boys					Girls					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Cranial base 6 years</i>													
n-s-ba (°)	95	130.3	4.6	117.0	141.0	87	129.8	4.8	118.9	142.7	0.5	(-0.91/1.83)	
n-s-ar (°)	95	121.6	4.6	106.7	131.2	87	121.2	5	112.1	131.1	0.4	(-0.98/1.83)	
s-n (mm)	95	63.1	2.1	56.3	69.5	87	61.3	2.2	56.1	68.9	1.9	(1.16/2.59)	***
s-ba (mm)	95	37.3	2.5	32.0	42.5	87	36.8	2.2	31.3	41.7	0.6	(-1.14/1.23)	
s-ar (mm)	95	28.1	2.4	23.0	34.8	87	27.2	2.1	22.2	34.0	0.9	(0.20/1.55)	*
n-ba (mm)	95	91.7	3.6	83.7	100.4	87	89.3	3.2	82.9	97.5	2.4	(1.38/3.37)	***
<i>Cranial base 16 years</i>													
n-s-ba (°)	95	128.7	5.3	114.7	147.2	87	128.8	5.2	117.6	143.2	-0.1	(-1.62/1.45)	
n-s-ar (°)	95	123.1	5.4	111.1	137.8	87	123.2	5.6	112.6	136.5	-0.1	(-1.73/1.50)	
s-n (mm)	95	70.8	3.1	62.8	78.2	87	66.7	2.4	60.2	73.3	4.1	(3.27/4.89)	***
s-ba (mm)	95	46.0	2.8	39.4	52.3	87	43.0	2.7	34.8	52.3	2.9	(2.11/3.71)	***
s-ar (mm)	95	36.3	3.1	29.7	43.4	87	33.5	2.7	26.3	42.1	2.8	(1.95/3.66)	***
n-ba (mm)	95	105.7	4.2	95.7	114.6	87	99.4	3.8	90.9	107.7	6.3	(5.08/7.44)	***
<i>Nasal bone 6 years</i>													
n-na (mm)	95	18.2	2.5	12.6	23.7	87	17.8	2.4	11.1	24.1	0.4	(0.34/1.08)	
s-n-na (°)	95	104.6	5.1	93.9	118.9	87	104.8	5.5	92.3	121.2	-0.2	(-1.74/1.39)	
<i>Nasal bone 16 years</i>													
n-na (mm)	95	22.2	3.5	13.7	29.5	87	20.9	3.0	14.4	30.2	1.3	(0.36/2.26)	**
s-n-na (°)	95	115.9	6.6	103.2	136.7	87	112.0	6.6	97.9	128.2	3.9	(1.96/5.84)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

Reliability

A replicate measurement trial was performed on 30 randomly selected cephalograms of the 16-year-old children. The radiographs were traced and digitized again after an interval of at least two weeks. In order to estimate the measurement error, Dahlberg's formula $Se = \sqrt{(\sum d^2/2n)}$ was used, where d is the difference between repeated measurements and n is the number of paired measurements. Systematic error was estimated by a one-sample t -test, as suggested by Houston (1983). The same method was used to test intra-observer error in an earlier study of these children at the age of 6 years (Johannsdottir *et al.*, 1999). Since the cephalograms of 6-year-old children in a former study were traced and digitized by a different author (BJ), all tracings of 16-year-old children (made by AT) were double-checked by BJ to prevent inter-observer errors between the two studies in location of points.

Results

In general, the measurement errors were small; variables involving the dentition such as ILs/NSL, ILs/NL, ILi/ML and ILs/ILi showed the largest variation. No variable reached the 5 per cent level of significance in the paired t -test. The inter-observer agreement was in general good for most points. Corrections were most often required for points that are difficult to locate, such as orbitale, basion, porion and condylion.

The craniofacial morphology of 6- and 16-year-old Icelandic children (the whole sample) is presented in Tables 3–5. Gender differences within each age group are shown in Table 3 and changes from 6 to 16 years, evaluated separately for boys and girls, in Tables 4 and 5.

For all angular measurements the differences between the genders were not statistically significant in either age group, except for the variable s-n-na, which was significantly larger ($P \leq 0.001$) in boys at 16 years of age. Linear variables, such as anterior and posterior face heights, mandibular base and ramus lengths, cranial base dimensions and nasal bone length were consistently and significantly larger in boys than in girls at both ages (Table 3).

Boys showed a statistically significant increase in both maxillary and mandibular prognathism from the age of 6 to 16 years, the increase being larger in the mandible ($P \leq 0.001$; Table 4). In the girls, the increase in mandibular prognathism was also statistically significant ($P \leq 0.001$), but the change was not statistically significant (Table 5). Accordingly, there was a significant decrease in the basal sagittal jaw relationship (ss-n-sm) in both genders throughout the growth period ($P \leq 0.001$). The difference between the genders was not, however, significant in either age group for any of the sagittal measurements.

The inclination of the maxilla in relation to the anterior cranial base increased slightly during the growth period in both genders, but the mean increase was only statistically significant in girls ($P \leq 0.001$). On the other hand, the inclination of the mandible, both in relation to

Table 4 Changes in craniofacial morphology in Icelandic boys from 6 to 16 years of age. The whole sample.

Measurement	Boys 6 years					Boys 16 years					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Basal sagittal</i>													
s–n–ss (°)	95	81.6	3.1	74.9	91.3	95	82.7	3.9	73.3	93.7	1.1	(–1.60/–0.66)	***
s–n–sm (°)	95	77.6	2.8	70.8	88.6	95	80.5	3.7	71.2	91.1	2.9	(–3.34/–2.37)	***
s–n–pg (°)	95	77.6	2.9	70.5	89.2	95	81.7	3.8	72.2	91.7	4.1	(–4.55/–3.53)	***
ss–n–sm (°)	95	4.0	1.8	–1.2	8.9	95	2.3	2.2	–3.5	9.0	–1.7	(1.41/2.01)	***
ss n–pg (mm)	95	3.2	1.6	–1.0	7.4	95	1.1	2.6	–6.7	8.9	–2.1	(1.75/2.43)	***
n–ss–pg (°)	95	8.2	4.2	–2.6	18.6	95	–2.3	5.4	–17.6	14.1	–10.5	(8.66/12.36)	***
<i>Basal vertical</i>													
NSL/FH (°)	95	8.5	2.4	–0.4	12.8	95	9.6	2.8	4.2	16.3	1.1	(–1.52/–0.65)	***
NSL/NL (°)	95	5.7	2.8	–1.3	12.4	95	6.1	3.4	–5.1	14.5	0.4	(–0.95/0.22)	
NL/ML (°)	95	27.3	4.4	17.8	36.4	95	21.4	5.1	4.4	35.0	–6.0	(5.21/6.69)	***
NSL/ML (°)	95	33.0	4.1	23.8	44.4	95	27.5	5.3	15.9	38.5	–5.6	(4.87/6.27)	***
n–ans/ans–gn (%)	95	77.0	6.8	65.0	100.2	95	77.7	6.6	58.7	99.8	0.7	(–1.75/0.45)	
n–gn (anterior face height; mm)	95	95.7	4.7	85.5	105.4	95	117.3	6.7	103.7	132.9	21.6	(–22.43/–20.82)	***
s–goi (posterior face height; mm)	95	61.1	3.7	52.4	69.3	95	82.4	5.8	69.4	97.2	21.3	(–21.96/–20.54)	***
RL/ML (°)	95	128.2	5.2	114.0	143.3	95	118.4	6.6	102.1	136.1	–9.8	(9.09/10.60)	***
<i>Mandibular length</i>													
cd–tgo (mm)	95	44.3	2.7	37.3	51.4	95	61.6	4.3	51.4	72.3	17.3	(–18.00/–16.65)	***
cd–pgn (mm)	95	92.6	3.8	84.1	100.9	95	117.3	5.2	105.0	130.5	24.7	(–25.39/–23.98)	***
ar–pgn (mm)	95	87.8	3.6	80.5	97.2	95	110.3	5.2	97.4	123.9	22.5	(–23.15/–21.90)	***
<i>Dental</i>													
ILs/NSL (°)	19	102.4	6.6	92.3	118.2	19	106.1	8.8	87.4	122.0	3.8	(–7.62/0.03)	
ILs/NL (°)	19	107.5	8.4	93.8	126.2	19	110.9	8.7	92.9	125.9	3.4	(–7.44/0.68)	
is ss–pg (mm)	19	3.9	1.7	1.0	8.2	19	5.2	2.3	0.2	11.7	1.4	(–2.60/–0.19)	*
is n–ss (mm)	19	1.6	1.8	–1.5	5.7	19	4.6	2.6	–2.8	10.9	3.1	(–4.29/–1.85)	***
ILi/ML (°)	67	89.9	7.1	72.4	110.9	67	99.1	6.5	80.3	114.3	9.2	(–10.69/–7.63)	***
ii ss–pg (mm)	67	0.5	1.8	–3.4	6.4	67	2.5	2.1	–2.5	8.3	2.1	(–2.54/–1.64)	***
ii–n–sm (mm)	67	2.4	1.7	–2.5	8.8	67	5.0	2.1	–0.3	10.2	2.6	(–3.06/–2.14)	***
ILs/ILi (°)	19	133.6	10.0	118.1	147.2	19	129.6	8.4	107.8	150.9	–4.0	(–1.52/9.55)	
<i>Cranial base</i>													
n–s–ba (°)	95	130.3	4.6	117.0	141.0	95	128.7	5.3	114.7	147.2	–1.6	(0.88/2.28)	***
n–s–ar (°)	95	121.6	4.6	106.7	131.2	95	123.1	5.4	111.1	137.8	1.5	(–2.20/–0.75)	***
s–n (mm)	95	63.1	2.6	56.3	69.5	95	70.8	3.1	62.8	78.2	7.7	(–7.92/–7.41)	***
s–ba (mm)	95	37.3	2.5	32.0	42.5	95	46.0	2.8	39.4	52.3	8.6	(–9.12/–8.17)	***
s–ar (mm)	95	28.1	2.4	23.0	34.8	95	36.3	3.1	29.7	43.4	8.2	(–8.60/–7.79)	***
n–ba (mm)	95	91.7	3.6	83.7	100.4	95	105.7	4.2	95.7	114.6	14.0	(–14.45/–13.50)	***
<i>Nasal bone</i>													
n–na (mm)	95	18.2	2.5	12.6	23.7	95	22.2	3.5	13.7	29.5	4.1	(–4.63/–3.52)	***
s–n–na (°)	95	104.6	5.1	93.9	118.9	95	115.9	6.6	103.2	136.7	11.3	(–12.15/–10.42)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

the maxilla and the anterior cranial base, decreased significantly ($P \leq 0.001$) in both genders from 6 to 16 years of age, indicating a mean anterior rotation of the lower jaw. The difference between genders in both age groups was not significant.

The mean increase in anterior and posterior face heights was statistically significant ($P \leq 0.001$) in both genders, with boys showing statistically significantly ($P \leq 0.001$) larger values than girls at 6 and 16 years of age.

Changes in the anterior face height ratio from 6 to 16 years of age were not significant for the boys, but increased significantly ($P \leq 0.001$) in the girls during that period. The difference between genders was not statistically significant.

The jaw angle (RL/ML) decreased significantly in both boys and girls from 6 to 16 years of age ($P \leq 0.001$), but the difference between the genders was not statistically significant.

The increase in mandibular length from 6 to 16 years of age was highly significant for both genders ($P \leq 0.001$). The mandibular length was significantly ($P \leq 0.05 - P \leq 0.001$) larger in boys compared with girls at both ages.

The inclination of the lower incisors increased significantly from 6 to 16 years of age in both boys and girls, as did all dental linear variables. The inclination of the upper incisors increased slightly in both genders, but the change was not statistically significant except for the

Table 5 Changes in craniofacial morphology in Icelandic girls from 6 to 16 years of age. The whole sample.

Measurement	Girls 6 years					Girls 16 years					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Basal sagittal</i>													
s-n-ss (°)	87	82.0	3.2	75.2	90.4	87	82.4	3.4	73.2	91.1	0.4	(-0.83/0.07)	
s-n-sm (°)	87	78.1	3.3	70.2	86.0	87	80.0	3.6	72.6	89.1	1.9	(-2.27/-1.44)	***
s-n-pg (°)	87	78.2	3.3	70.1	86.4	87	81.2	3.7	73.2	90.3	3.0	(-3.39/-2.60)	***
ss-n-sm (°)	87	3.9	1.7	0.5	7.4	87	2.4	1.7	-1.9	6.1	-1.5	(1.15/1.82)	***
ss n-pg (mm)	87	2.9	5.1	-1.0	5.6	87	1.1	2.0	-5.7	5.7	-1.8	(1.49/2.12)	***
n-ss-pg (°)	87	7.8	4.0	-3.0	15.1	87	-2.5	4.5	-12.3	14.2	-10.3	(8.64/11.99)	***
<i>Basal vertical</i>													
NSL/FH (°)	87	8.4	2.7	2.2	13.9	87	9.8	2.8	2.8	15.9	1.3	(-1.80/-0.85)	***
NSL/NL (°)	87	5.4	2.7	-1.9	13.3	87	6.3	3.2	-1.0	18.6	0.9	(-1.35/-0.43)	***
NL/ML (°)	87	27.5	3.8	19.4	36.5	87	21.9	5.1	4.7	33.3	-5.6	(4.91/6.20)	***
NSL/ML (°)	87	32.9	4.3	20.8	43.0	87	28.2	5.2	10.6	42.2	-4.7	(4.13/5.22)	***
n-ans/ans-gn (%)	87	76.1	6.0	61.6	89.2	87	78.0	7.3	62.2	96.2	2.0	(-2.95/-0.99)	***
n-gn (anterior)	87	92.9	3.8	82.9	103.0	87	109.3	5.4	96.5	125.2	16.4	(-17.01/-15.75)	***
face height; mm													
s-goi (posterior)	87	59.2	3.0	51.5	66.4	87	75.7	4.7	63.6	90.6	16.5	(-17.12/-15.82)	***
face height; mm													
RL/ML (°)	87	127.2	5.3	113.2	143.3	87	118.5	6.4	98.3	133.8	-8.7	(8.01/9.47)	***
<i>Mandibular length</i>													
cd-tgo (mm)	87	43.3	2.7	36.5	48.9	87	56.9	3.8	45.6	69.3	13.6	(-14.32/-12.91)	***
cd-pgn (mm)	87	90.8	3.9	78.0	100.3	87	109.5	5.2	92.4	129.4	18.7	(-19.49/-17.91)	***
ar-pgn (mm)	87	85.8	3.5	72.6	93.6	87	102.8	5.0	87.3	116.3	17.0	(-17.68/-16.35)	***
<i>Dental</i>													
ILs/NSL (°)	34	100.0	6.3	88.6	113.1	34	102.3	6.7	89.1	123.4	2.3	(-4.68/0.01)	
ILs/NL (°)	34	105.5	6.7	94.6	118.6	34	108.2	7.1	93.5	126.9	2.7	(-4.95/-0.45)	*
is ss-pg (mm)	34	3.8	1.8	-0.1	7.1	34	5.2	2.0	0.5	9.2	1.4	(-1.12/-0.68)	***
is n-ss (mm)	34	1.5	1.9	-2.3	6.0	34	4.0	2.5	-1.0	8.6	2.5	(-3.31/-1.62)	***
ILi/ML (°)	74	89.6	7.1	70.1	104.4	74	97.6	6.3	81.9	113.2	8.0	(-9.47/-6.57)	***
ii ss-pg (mm)	74	0.5	1.8	-3.3	5.6	74	2.0	2.0	-2.2	6.8	1.5	(-1.83/-1.11)	***
ii- n-sm (mm)	74	2.3	1.8	-2.3	6.5	74	4.2	1.8	0.3	8.4	1.9	(-2.23/-1.51)	***
ILs/ILi (°)	32	135.5	10.9	119.0	165.0	32	130.8	9.9	110.2	151.2	-4.6	(0.70/8.58)	*
<i>Cranial base</i>													
n-s-ba (°)	87	129.8	7.8	118.9	142.7	87	128.8	5.2	117.6	143.2	-1.0	(0.39/1.69)	**
n-s-ar (°)	87	121.2	5.0	112.1	131.1	87	123.2	5.6	112.6	136.5	2.0	(-2.66/-1.37)	***
s-n (mm)	87	61.3	2.2	56.1	68.9	87	66.7	2.4	60.2	73.3	5.5	(-5.70/-5.22)	***
s-ba (mm)	87	36.8	2.2	31.3	41.7	87	43.0	2.7	34.8	52.3	6.3	(-6.77/-5.80)	***
s-ar (mm)	87	27.2	2.1	22.2	34.0	87	33.5	2.7	26.3	42.1	6.3	(-6.64/-5.91)	***
n-ba (mm)	87	89.3	3.2	82.9	97.5	87	99.4	3.8	90.9	107.7	10.1	(-10.56/-9.63)	***
<i>Nasal bone</i>													
n-na (mm)	87	17.8	2.4	11.1	24.1	87	20.9	3.0	14.4	30.2	3.1	(-3.50/-2.78)	***
s-n-na (°)	87	104.8	5.5	92.3	121.2	87	112.0	6.6	97.9	128.2	7.2	(-7.98/-6.44)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

variable ILs/NL in girls ($P \leq 0.05$). The interincisal angle decreased slightly from 6 to 16 years of age, but the change was only significant in girls ($P \leq 0.05$). For all dental measurements, the difference between the genders was not significant in either of the age groups.

Anterior, posterior and total cranial base dimensions increased significantly in both genders during the observation period. The variable n-s-ba decreased significantly in both boys and girls during the observation period, while n-s-ar increased from 6 to 16 years, the difference being statistically significant for both genders ($P \leq 0.001$). Boys showed significantly larger mean values for cranial base dimensions at both ages ($P \leq 0.001$) except for posterior cranial base

length (s-ba) at 6 years of age, which did not differ significantly between the genders. There was no difference between boys and girls in cranial base flexure, either at 6 or at 16 years of age.

Both the length and the slope (s-n-na) of the nasal bone increased from the age of 6 to 16 years, and the change was highly significant for both genders ($P \leq 0.001$). The length of the nasal bone was significantly longer in boys at 16 years of age ($P \leq 0.01$) but at 6 years of age the difference between the genders was not significant. The slope of the nasal bone was the only angular measurement that differed significantly between genders, being larger in the boys ($P \leq 0.001$) but only at 16 years of age.

Table 6 Craniofacial morphology of 6- and 16-year-old Icelandic children. Normal occlusion subjects only.

Measurement	Boys					Girls					Mean difference	95% CI
	n	Mean	SD	Min	Max	n	Mean	SD	Min	Max		
Basal sagittal 6 years												
s-n-ss (°)	55	81.7	2.6	75.4	87.0	56	82.0	3.5	75.2	90.4	-0.3	(-1.48/0.86)
s-n-sm (°)	55	77.8	2.6	70.8	82.8	56	78.5	3.5	70.2	86.0	-0.7	(-1.83/0.50)
s-n-pg (°)	55	77.8	2.7	70.5	83.1	56	78.5	3.6	70.1	86.4	-0.8	(-1.98/0.42)
ss-n-sm (°)	55	3.9	1.4	0.4	6.5	56	3.5	1.7	0.5	6.7	0.4	(-0.24/0.93)
ss n-pg (mm)	55	3.1	1.3	-0.1	5.4	56	2.7	1.6	-1.0	5.3	0.5	(0.05/1.03)
n-ss-pg (°)	55	8.1	3.2	-0.2	14.0	56	7.1	4.1	-3.0	14.0	1.1	(-0.31/2.49)
Basal sagittal 16 years												
s-n-ss (°)	55	83.1	3.5	74.9	90.2	56	82.3	3.7	73.2	91.1	0.9	(-0.48/2.22)
s-n-sm (°)	55	81.1	3.7	71.2	89.4	56	80.3	3.9	72.6	89.1	0.8	(-0.63/2.21)
s-n-pg (°)	55	82.3	3.9	72.2	91.1	56	81.6	4.1	73.2	90.3	0.7	(-0.80/2.19)
ss-n-sm (°)	55	2.1	2.0	-3.2	6.5	56	1.9	1.7	-1.9	5.3	0.1	(-0.58/0.80)
ss n-pg (mm)	55	0.9	2.2	-4.1	5.8	56	0.7	1.9	-5.7	4.3	0.2	(-0.55/0.99)
n-ss-pg (°)	55	-2.0	4.7	-12.8	9.4	56	-1.5	4.4	-10.3	14.2	-0.5	(-2.21/1.22)
Basal vertical 6 years												
NSL/FH (°)	55	8.7	2.2	4.5	12.4	56	8.5	2.7	2.2	13.5	0.2	(-0.74/1.11)
NSL/NL (°)	55	5.9	2.8	-1.3	12.2	56	5.3	2.6	-1.9	13.3	0.6	(-0.44/1.62)
NL/ML (°)	55	27.1	4.5	17.8	34.1	56	28.2	3.8	19.4	35.5	-1.1	(-2.68/0.44)
NSL/ML (°)	55	32.9	4.2	23.8	40.8	56	33.5	4.4	20.8	40.7	-0.5	(-2.15/1.07)
n-ans/ans-gn (%)	55	77.2	6.3	67.5	100.2	56	75.0	5.9	61.6	89.2	2.3	(-0.04/4.58)
n-gn (anterior face height; mm)	55	95.7	4.9	87.4	104.1	56	93.1	3.9	82.9	100.4	2.6	(0.92/4.26) **
s-goi (posterior face height; mm)	55	61.2	3.4	52.4	66.5	56	58.9	3.0	51.5	63.8	2.4	(1.16/3.57) ***
RL/ML (°)	55	127.9	5.6	114.0	140.0	56	128.1	5.2	113.2	143.3	-0.3	(-2.28/1.79)
Basal vertical 16 years												
NSL/FH (°)	55	9.5	2.8	4.2	15.8	56	9.7	2.7	2.8	15.4	-0.3	(-1.30/0.77)
NSL/NL (°)	55	6.0	3.2	-0.4	14.5	56	6.0	3.2	-0.1	18.6	-0.1	(-1.29/1.12)
NL/ML (°)	55	20.7	5.2	11.7	30.3	56	22.8	5.4	4.7	33.3	-2.1	(-4.10/-0.11) *
NSL/ML (°)	55	26.7	5.6	15.9	36.9	56	28.9	5.8	10.6	42.2	-2.2	(-4.31/-0.06) *
n-ans/ans-gn (%)	55	78.0	5.4	66.4	91.1	56	76.6	7.3	66.2	96.2	1.4	(-1.05/3.78)
n-gn (anterior face height; mm)	55	116.2	6.7	103.7	132.9	56	110.2	5.9	96.5	125.2	6.0	(3.62/8.36) ***
s-goi (posterior face height; mm)	55	82.3	6.0	69.6	97.2	56	75.8	5.3	63.6	90.6	6.5	(4.38/8.63) ***
RL/ML (°)	55	117.7	6.9	102.1	131.6	56	119.3	6.5	98.3	133.8	-1.6	(-4.12/0.94)
Mandibular length 6 years												
cd-tgo (mm)	55	44.3	2.5	37.3	49.5	56	43.4	2.7	36.5	48.9	0.9	(-0.04/1.91)
cd-pgn (mm)	55	92.6	3.7	85.2	99.2	56	91.2	4.0	78.0	100.3	1.4	(-0.02/2.87)
ar-pgn (mm)	55	88.0	3.6	81.0	94.9	56	85.9	3.7	72.6	93.6	2.1	(0.73/3.46) **
Mandibular length 16 years												
cd-tgo (mm)	55	61.6	4.5	52.7	72.3	56	57.2	4.2	45.6	69.3	4.4	(2.71/6.00) ***
cd-pgn (mm)	55	116.9	5.1	107.1	130.5	56	110.4	5.6	92.4	124.9	6.6	(4.54/8.59) ***
ar-pgn (mm)	55	110.0	5.2	97.4	123.9	56	103.4	5.3	87.3	116.3	6.5	(4.56/8.53) ***
Dental 6 years												
ILs/NSL (°)	10	102.0	6.4	92.3	108.5	17	99.9	7.5	88.6	113.1	2.1	(-3.77/7.93)
ILs/NL (°)	10	107.7	8.2	93.8	117.0	17	105.1	8.1	94.8	118.6	2.7	(-4.10/9.46)
is ss-pg (mm)	10	3.7	1.3	1.6	5.3	17	3.6	1.9	-0.1	7.0	0.2	(-1.27/1.57)
is n-ss (mm)	10	1.5	1.3	-1.4	3.2	17	1.6	2.1	-1.2	6.0	-0.2	(-1.74/1.37)
ILi/ML (°)	39	90.8	7.0	77.1	110.9	47	88.5	6.9	70.1	102.0	2.3	(-0.72/5.31)
ii ss-pg (mm)	39	0.8	1.8	-2.3	6.4	47	0.8	1.9	-3.3	5.6	-0.0	(-0.81/0.78)
ii- n-sm (mm)	39	2.7	1.7	-0.2	8.8	47	2.4	1.9	-2.3	6.5	0.3	(-0.47/1.10)
ILs/ILi (°)	10	134.1	10.1	118.4	147.2	16	134.9	10.1	120.4	155.2	-0.8	(-9.33/7.72)
Dental 16 years												
ILs/NSL (°)	55	104.8	7.5	88.2	120.3	56	102.7	7.7	89.1	123.4	2.1	(-0.74/4.99)
ILs/NL (°)	55	110.8	6.9	92.9	125.9	56	108.7	7.4	93.5	126.9	2.0	(-0.65/4.73)
is ss-pg (mm)	55	5.3	2.2	0.9	10.9	56	4.8	2.0	0.5	9.0	0.6	(-0.24/1.34)
is n-ss (mm)	55	4.6	2.4	-0.2	10.5	56	4.2	2.3	-0.1	8.6	0.4	(-0.48/1.29)
ILi/ML (°)	55	98.3	6.0	85.7	114.3	56	96.2	6.2	81.9	111.5	2.1	(-0.21/4.39)
ii ss-pg (mm)	55	2.5	2.0	-2.2	8.3	56	2.0	2.2	-2.2	6.8	0.5	(-0.33/1.23)
ii- n-sm (mm)	55	4.6	1.8	0.4	9.8	56	4.0	1.9	0.3	8.2	0.6	(-0.10/1.30)
ILs/ILi (°)	55	130.3	8.5	107.8	146.2	56	132.3	9.9	111.8	151.2	-2.0	(-5.50/1.44)

Table 6 (continued)

Measurement	Boys					Girls					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Cranial base 6 years</i>													
n-s-ba (°)	55	130.2	4.6	117.0	138.7	56	129.0	4.4	118.9	140.7	0.9	(-0.54/2.84)	
n-s-ar (°)	55	121.6	4.8	106.7	131.2	56	120.5	4.5	112.1	128.5	1.1	(-0.61/2.88)	
s-n (mm)	55	63.1	2.8	56.3	69.5	56	61.2	2.1	56.1	65.4	2.0	(1.04/2.91)	***
s-ba (mm)	55	37.0	2.4	32.0	42.5	56	36.5	1.9	31.3	41.0	0.5	(-0.30/1.35)	
s-ar (mm)	55	28.0	2.2	23.0	33.7	56	26.9	1.9	22.2	30.2	1.1	(0.29/1.84)	**
n-ba (mm)	55	91.4	3.6	83.7	100.4	56	88.7	2.8	82.9	94.3	2.7	(1.47/3.89)	***
<i>Cranial base 16 years</i>													
n-s-ba (°)	55	128.3	5.1	116.9	138.4	56	128.3	5.3	117.6	143.2	-0.0	(-1.97/1.93)	
n-s-ar (°)	55	122.6	5.1	111.1	133.0	56	122.8	5.5	112.6	133.6	-0.2	(-2.16/1.82)	
s-n (mm)	55	70.6	3.3	62.8	76.7	56	66.6	2.3	60.8	72.9	4.0	(2.96/5.10)	***
s-ba (mm)	55	45.6	2.6	39.4	51.0	56	42.8	2.8	34.8	52.3	2.8	(1.81/3.86)	***
s-ar (mm)	55	36.2	3.0	31.0	43.4	56	33.5	2.8	26.3	42.1	2.7	(1.60/3.78)	***
n-ba (mm)	55	105.1	4.3	95.7	113.7	56	98.9	3.4	90.9	107.3	6.2	(4.71/7.66)	***
<i>Nasal bone 6 years</i>													
n-na (mm)	55	18.3	2.5	13.2	23.7	56	17.8	2.5	12.0	24.1	0.5	(-0.48/1.40)	
s-n-na (°)	55	104.5	4.2	97.0	113.7	56	104.8	5.3	92.3	115.3	-0.3	(-2.12/1.49)	
<i>Nasal bone 16 years</i>													
n-na (mm)	55	21.9	3.4	13.7	28.3	56	21.0	3.3	15.2	30.2	0.9	(-0.40/2.14)	
s-n-na (°)	55	115.9	5.7	105.6	129.7	56	111.6	6.8	97.9	128.2	4.4	(1.98/6.71)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

The craniofacial morphology of those children registered with a normal occlusion at the age of 6 years, is presented in Tables 6–8. The difference in craniofacial morphology between the whole sample (Table 3) and the normal occlusion sample (Table 6) was in general very small. The variables showing the largest difference were: n-s-s-pg, n-ans/ans-gn (anterior face ratio), cd-tgo, ILi/ML and NL/ML for the 16-year-old girls. For the 6-year-old girls differences were seen in the variables n-ans/ans-gn (anterior face ratio) and ILi/ML.

When the differences between the genders in the whole sample (Table 3) were compared with the gender differences in the normal occlusion group (Table 6), small differences could be noted. The basal vertical variables NL/ML and NSL/ML were significantly larger in the girls compared with the boys in the normal occlusion group at 16 years of age ($P \leq 0.05$). In the normal occlusion group the gender difference in mandibular length at 6 years of age was not significant except for the variable ar-pgn ($P \leq 0.01$). The difference in the length of the nasal bone at 16 years of age was not statistically significant in the normal occlusion group.

The changes in craniofacial morphology from 6 to 16 years of age were very similar in the normal occlusion group and in the whole sample. For the boys (Tables 4 and 7) there was a consistent pattern of statistically significant changes. For the girls (Tables 5 and 8), there was an increased inclination of the upper incisors (ILs/NSL) from 6 to 16

years of age which was statistically significant ($P \leq 0.05$) in the normal occlusion group but not in the whole sample.

Discussion

Throughout the 20th century people from the countryside have been migrating to the Reykjavik district. In 1900 the total number of inhabitants in Iceland was 78,000, with 7.5 per cent living in Reykjavik. However, in 1987 when this study was initiated, the population of Iceland was 250,000, and 96,000 (38.1 per cent) lived in the capital. The sample was gathered from Reykjavik and is considered to represent the whole population of Iceland. Baseline measurements for this study population, at the age of 6 years, have been published previously (Johannsdottir *et al.*, 1997, 1999).

The present study reports changes in craniofacial parameters from 6 to 16 years of age. These indicate that marked age-related changes occur in several measurements. The most pronounced age changes were observed in the degree of prognathism of the maxilla and mandible and the mandibular plane angle. The marked increase in mandibular prognathism and reduction in sagittal jaw relationship noted in both genders is in agreement with other similar age-related studies (Björk, 1963; Kerr, 1979; Bishara *et al.*, 1984; El-Batouti *et al.*, 1994). The significant increase in maxillary prognathism in the boys, while little change was noted in the girls, from age the age of 6 to 16 years, is in accordance with the findings of others studying similar age

Table 7 Changes in craniofacial morphology in Icelandic boys from 6 to 16 years of age. Normal occlusion subjects only.

Measurement	Boys 6 years					Boys 16 years					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Basal sagittal</i>													
s–n–ss (°)	55	81.7	2.6	75.4	87.0	55	83.1	3.5	74.9	90.2	1.4	(–2.02/–0.86)	***
s–n–sm (°)	55	77.8	2.6	70.8	82.8	55	81.1	3.7	71.2	89.4	3.3	(–3.88/–2.63)	***
s–n–pg (°)	55	77.8	2.7	70.5	83.1	55	82.3	3.9	72.2	91.1	4.5	(–5.14/–3.84)	***
ss–n–sm (°)	55	3.9	1.4	0.4	6.5	55	2.1	2.0	–3.2	6.5	–1.8	(1.42/2.18)	***
ss n–pg (mm)	55	3.1	1.3	–0.1	5.4	55	0.9	2.2	–4.1	5.8	–2.3	(1.82/2.67)	***
n–ss–pg (°)	55	8.1	3.2	–0.2	14.0	55	–2.0	4.7	–12.8	9.4	–10.1	(8.13/12.10)	***
<i>Basal vertical</i>													
NSL/FH (°)	55	8.7	2.2	4.5	12.4	55	9.5	2.8	4.2	15.8	0.8	(–1.32/–0.27)	**
NSL/NL (°)	55	5.9	2.8	–1.3	12.2	55	6.0	3.2	–0.4	14.5	0.1	(–0.79/0.67)	
NL/ML (°)	55	27.1	4.5	17.8	34.1	55	20.7	5.2	11.7	30.3	–6.4	(5.39/7.32)	***
NSL/ML (°)	55	32.9	4.2	23.8	40.8	55	26.7	5.6	15.9	36.9	–6.3	(5.33/7.21)	***
n–ans/ans–gn (%)	55	77.2	6.3	67.5	100.2	55	78.0	5.4	66.4	91.1	0.8	(–2.24/0.67)	
n–gn (anterior face height; mm)	55	95.7	4.9	87.4	104.1	55	116.2	6.7	103.7	132.9	20.5	(–21.49/–19.49)	***
s–goi (posterior face height; mm)	55	61.2	3.4	52.4	66.5	55	82.3	6.0	69.6	97.2	21.1	(–22.14/–20.04)	***
RL/ML (°)	55	127.9	5.6	114.0	140.0	55	117.7	6.9	102.1	131.6	–10.2	(9.27/11.14)	***
<i>Mandibular length</i>													
cd–tgo (mm)	55	44.3	2.5	37.3	49.5	55	61.6	4.5	52.7	72.3	17.3	(–18.24/–16.32)	***
cd–pgn (mm)	55	92.6	3.7	85.2	99.2	55	116.9	5.1	107.1	130.5	24.3	(–25.20/–23.38)	***
ar–pgn (mm)	55	88.0	3.6	81.0	94.9	55	110.0	5.2	97.4	123.9	22.0	(–22.83/–21.13)	***
<i>Dental</i>													
ILs/NSL (°)	10	102.0	6.4	92.3	108.5	10	105.5	9.4	88.2	120.3	3.6	(–8.52/1.42)	
ILs/NL (°)	10	107.7	8.2	93.8	117.0	10	110.0	9.2	92.9	125.9	2.3	(–5.95/1.45)	
is ss–pg (mm)	10	3.7	1.3	1.6	5.3	10	4.4	1.2	0.9	10.9	0.7	(–1.64/0.32)	
is n–ss (mm)	10	1.5	1.3	–1.4	3.2	10	4.2	2.5	–0.2	10.5	2.8	(–4.40/–1.12)	**
ILi/ML (°)	39	90.8	7.0	77.1	110.9	39	98.8	6.4	85.7	114.3	8.1	(–10.00/–6.20)	***
ii ss–pg (mm)	39	0.8	1.8	–2.3	6.4	39	2.4	2.0	–2.2	8.3	1.6	(–2.12/–1.08)	***
ii–n–sm (mm)	39	2.7	1.7	–0.2	8.8	39	4.8	1.8	0.4	9.8	2.0	(–2.51/–1.56)	***
ILs/ILi (°)	10	134.1	10.1	118.4	147.2	10	131.6	7.5	107.8	146.2	–2.4	(–2.61/7.43)	
<i>Cranial base</i>													
n–s–ba (°)	55	130.2	4.6	117.0	138.7	55	128.3	5.1	116.9	138.4	–1.9	(0.98/2.73)	***
n–s–ar (°)	55	121.6	4.8	106.7	131.2	55	122.6	5.1	111.1	133.0	1.0	(–1.95/–0.02)	*
s–n (mm)	55	63.1	2.8	56.3	69.5	55	70.6	3.3	62.8	76.7	7.4	(–7.77/–7.11)	***
s–ba (mm)	55	37.0	2.4	32.0	42.5	55	45.6	2.6	39.4	51.0	8.7	(–9.29/–8.01)	***
s–ar (mm)	55	28.0	2.2	23.0	33.7	55	36.2	3.0	31.0	43.4	8.2	(–8.74/–7.64)	***
n–ba (mm)	55	91.4	3.6	83.7	100.4	55	105.1	4.3	95.7	113.7	13.7	(–14.28/–13.05)	***
<i>Nasal bone</i>													
n–na (mm)	55	18.3	2.5	13.2	23.7	55	21.9	3.4	13.7	28.3	3.6	(–4.30/–2.90)	***
s–n–na (°)	55	104.5	4.2	97.0	113.7	55	115.9	5.7	105.6	129.7	11.4	(–12.61/–10.22)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

groups (Broadbent *et al.*, 1975; Bishara *et al.*, 1984; El-Batouti *et al.*, 1994). On the other hand, Kerr (1979) did not find gender difference regarding maxillary prognathism. In the present study, the mandibular plane angle decreased significantly with age in both boys and girls, which is in agreement with previous studies (Lande, 1952; Björk, 1963; Kerr, 1979; Bishara, 1981; Bishara *et al.*, 1984; El-Batouti *et al.*, 1994).

According to written and other demographic sources, Iceland was settled in the 9th century and most of the settlers were of Scandinavian origin, including Norwegians. Many of the settlers were Vikings who plundered neighbouring countries, including the British Isles, and

brought captives as slaves with them to Iceland. These unwilling settlers of course contributed to the genetic composition of the present population of Iceland. Recent findings based on studies of the Y-chromosome suggest that 20–25 per cent of Iceland's founding males had Gaelic ancestry, with the remainder having Norse ancestry. On the other hand, research suggests that the majority of females in the Icelandic founding population had Gaelic ancestry (Helgason *et al.*, 2000a,b).

In the light of the close genetic relationship between the Icelandic population and the Norwegians, it was considered that it would be interesting to compare the findings with a similar Norwegian study group, the Nittedal growth material

Table 8 Changes in craniofacial morphology in Icelandic girls from 6 to 16 years of age. Normal occlusion subjects only.

Measurement	Girls 6 years					Girls 16 years					Mean difference	95% CI	
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max			
<i>Basal sagittal</i>													
s-n-ss (°)	56	82.0	3.5	75.2	90.4	56	82.3	3.7	73.2	91.1	0.3	(-0.85/0.34)	
s-n-sm (°)	56	78.5	3.5	70.2	86.0	56	80.3	3.9	72.6	89.1	1.8	(-2.35/-1.27)	***
s-n-pg (°)	56	78.5	3.6	70.1	86.4	56	81.6	4.1	73.2	90.3	3.0	(-3.54/-2.50)	***
ss-n-sm (°)	56	3.5	1.7	0.5	6.7	56	1.9	1.7	-1.9	5.3	-1.6	(1.13/2.00)	***
ss n-pg (mm)	56	2.7	1.6	-1.0	5.3	56	0.7	1.9	-5.7	4.3	-2.0	(1.59/2.36)	***
n-ss-pg (°)	56	7.1	4.1	-3.0	14.0	56	-1.5	4.4	-10.3	14.2	-8.5	(6.44/10.61)	***
<i>Basal vertical</i>													
NSL/FH (°)	56	8.5	2.7	2.2	13.5	56	9.7	2.7	2.8	15.4	1.3	(-1.86/-0.64)	***
NSL/NL (°)	56	5.3	2.6	-1.9	13.3	56	6.0	3.2	-0.1	18.6	0.7	(-1.26/-0.21)	**
NL/ML (°)	56	28.2	3.8	19.4	35.5	56	22.8	5.4	4.7	33.3	-5.4	(4.54/6.19)	***
NSL/ML (°)	56	33.5	4.4	20.8	40.7	56	28.9	5.8	10.6	42.2	-4.6	(3.87/5.39)	***
n-ans/ans-gn (%)	56	75.0	5.9	61.6	89.2	56	76.6	7.3	66.2	96.2	1.7	(-2.87/-0.51)	**
n-gn (anterior face height; mm)	56	93.1	3.9	82.9	100.4	56	110.2	5.9	96.5	125.2	17.1	(-17.96/-16.24)	***
s-goi (posterior face height; mm)	56	58.9	3.0	51.5	63.8	56	75.8	5.3	63.6	90.6	17.0	(-17.87/-16.03)	***
RL/ML (°)	56	128.1	5.2	113.2	143.3	56	119.3	6.5	98.3	133.8	-8.9	(7.89/9.82)	***
<i>Mandibular length</i>													
cd-tgo (mm)	56	43.4	2.7	36.5	48.9	56	57.2	4.2	45.6	69.3	13.9	(-14.79/-12.92)	***
cd-pgn (mm)	56	91.2	4.0	78.0	100.3	56	110.4	5.6	92.4	124.9	19.2	(-20.23/-18.06)	***
ar-pgn (mm)	56	85.9	3.7	72.6	93.6	56	103.4	5.3	87.3	116.3	17.5	(-18.46/-16.60)	***
<i>Dental</i>													
ILs/NSL (°)	17	99.9	7.5	88.6	113.1	17	104.1	7.2	89.1	123.4	4.2	(-7.80/-0.64)	*
ILs/NL (°)	17	105.1	8.1	94.8	118.6	17	109.2	8.3	93.5	126.9	4.2	(-7.84/-0.49)	*
is ss-pg (mm)	17	3.6	1.9	-0.1	7.0	17	5.6	1.9	0.5	9.0	2.0	(-3.05/-0.88)	**
is n-ss (mm)	17	1.6	2.1	-1.2	6.0	17	4.9	2.5	-0.1	8.6	3.2	(-4.44/-2.02)	***
ILi/ML (°)	47	88.5	6.9	70.1	102.0	47	96.5	6.6	81.9	111.5	8.1	(-9.98/-6.13)	***
ii ss-pg (mm)	47	0.8	1.9	-3.3	5.6	47	2.3	2.1	-2.2	6.8	1.5	(-1.95/-0.94)	***
ii- n-sm (mm)	47	2.4	1.9	-2.3	6.5	47	4.2	1.9	0.3	8.2	1.8	(-2.29/-1.32)	***
ILs/ILi (°)	16	134.9	10.1	120.4	155.2	16	128.0	10.0	111.8	151.2	-6.9	(0.94/12.79)	*
<i>Cranial base</i>													
n-s-ba (°)	56	129.0	4.4	118.9	140.7	56	128.3	5.3	117.6	143.2	-0.7	(-0.11/1.48)	
n-s-ar (°)	56	120.5	4.5	112.1	128.5	56	122.8	5.5	112.6	133.6	2.3	(-3.09/-1.49)	***
s-n (mm)	56	61.2	2.1	56.1	65.4	56	66.6	2.3	60.8	72.9	5.4	(-5.68/-5.11)	***
s-ba (mm)	56	36.5	1.9	31.3	41.0	56	42.8	2.8	34.8	52.3	6.3	(-7.00/-5.68)	***
s-ar (mm)	56	26.9	1.9	22.2	30.2	56	33.5	2.8	26.3	42.1	6.5	(-7.06/-6.07)	***
n-ba (mm)	56	88.7	2.8	82.9	94.3	56	98.9	3.4	90.9	107.3	10.2	(-10.78/-9.55)	***
<i>Nasal bone</i>													
n-na (mm)	56	17.8	2.5	12.0	24.1	56	21.0	3.3	15.2	30.2	3.2	(-3.71/-2.67)	***
s-n-na (°)	56	104.8	5.3	92.3	115.3	56	111.6	6.8	97.9	128.2	6.8	(-7.72/-5.80)	***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

(El-Batouti *et al.* 1994). In that study, Norwegians from 6 to 18 years of age with clinically acceptable normal occlusion were investigated. For this purpose, individuals in the present study group registered with an Angle Class I molar relationship (Johannsdottir *et al.*, 1997) were identified and the results of the craniofacial morphology of that group, the 'normal occlusion' group, used for comparison (Tables 9 and 10).

When the 6-year-old groups were compared (Table 9), small differences could be noted. The Norwegian boys had slightly more maxillary prognathism, and facial convexity could be seen in the Norwegian group. The mandibular plane angle was smaller in the Icelandic sample and the inclination of the maxilla was also smaller in the Icelandic

girls. The cranial base flexure was similar in the two groups.

Comparison of the 16-year-old Icelandic group with the Norwegian 15-year-old group is presented in Table 10. As before, the Norwegian boys had more maxillary prognathism and facial convexity. The mandibular plane angle was, as before, smaller in the Icelandic sample and the inclination of the maxilla was smaller in the Icelandic girls. The cranial base flexure was similar.

The largest difference both at 6 and 15/16 years of age was in the inclination of the lower incisors, which were more proclined in the Icelandic sample. In the 6-year-old groups this difference was also reflected in a much smaller

Table 9 Comparison of linear and angular measurements for Norwegian 6-year-old children (El-Batouti *et al.*, 1994) and for the Icelandic children in the 6-year-old normal occlusion group.

Measurement	Norwegian sample*				Icelandic sample§			
	Boys (n = 35)		Girls (n = 39)		Boys (n = 55)		Girls (n = 56)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Basal sagittal</i>								
s-n-ss (°)	82.7	3.0	82.1	3.5	81.7	2.6	82.0	3.5
s-n-sm (°)	78.3	3.1	77.9	3.4	77.8	2.6	78.5	3.5
ss-n-sm (°)	4.4	2.3	4.2	2.0	3.9	1.4	3.5	1.7
ss n-pg (mm)	3.8	2.2	3.5	2.1	3.1 (3.3)	1.3	2.7 (2.9)	1.6
n-ss-pg (°)	9.2	5.1	8.8	5.1	8.1	3.2	7.1	4.1
<i>Basal vertical</i>								
NSL/FH (°)	8.3	2.4	7.6	2.8	8.7	2.2	8.5	2.7
NSL/NL (°)	6.0	1.9	7.4	2.7	5.9	2.8	5.3	2.6
NSL/ML (°)	34.8	5.4	35.5	4.6	32.9	4.2	33.5	4.4
n-ans/ans-gn (%)	76.7	5.4	80.0	6.9	77.2	6.3	75.0	5.9
s-goi (posterior face height; mm)	64.0	3.4	61.7	3.1	61.2 (64.6)	3.4	58.9 (62.2)	3.0
<i>Dental#</i>								
is ss-pg (mm)	3.5	1.3	3.0	1.5	3.7 (3.9)	1.3	3.6 (3.8)	1.9
ILi/ML (°)	87.5	6.4	85.9	6.0	90.8	7.0	88.5	6.9
ii ss-pg (mm)	0.8	1.4	0.5	1.7	0.8 (0.8)	1.8	0.8 (0.8)	1.9
ILs/ILi (°)	143.3	8.1	144.0	10.4	134.1	10.1	134.9	10.1
<i>Cranial base</i>								
n-s-ba (°)	130.6	4.7	130.5	4.7	130.2	4.6	129.0	4.4

*5.6 per cent enlargement.

§Linear values in parentheses with 5.6 per cent calculated enlargement.

SD, standard deviation.

#In the Icelandic sample, measurements of the dental variables were only carried out in individuals with the permanent incisors present.

Table 10 Comparison of linear and angular measurements for Norwegian 15-year-old children (El-Batouti *et al.*, 1994) and for the Icelandic children in the 16-year-old normal occlusion group.

Measurement	Norwegian sample*				Icelandic sample§			
	Boys (n = 35)		Girls (n = 39)		Boys (n = 55)		Girls (n = 56)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Basal sagittal</i>								
s-n-ss (°)	84.9	2.7	82.6	3.4	83.1	3.5	82.3	3.7
s-n-sm (°)	81.3	3.7	80.1	3.1	81.1	3.7	80.3	3.9
ss-n-sm (°)	3.6	2.2	2.5	2.4	2.1	2.0	1.9	1.7
ss n-pg (mm)	2.8	2.6	1.3	2.8	0.9 (1.0)	2.2	0.7 (0.7)	1.9
n-ss-pg (°)	5.6	5.2	2.6	6.1	-2.0	4.7	-1.5	4.4
<i>Basal vertical</i>								
NSL/FH (°)	7.7	2.7	7.9	2.5	9.5	2.8	9.7	2.7
NSL/NL (°)	6.0	2.9	7.6	2.8	6.0	3.2	6.0	3.2
NSL/ML (°)	30.8	6.3	31.7	5.0	26.7	5.6	28.9	5.8
n-ans/ans-gn (%)	78.9	6.3	81.4	7.4	78.0	5.4	76.6	7.3
s-goi (posterior face height; mm)	81.7	4.7	77.4	3.7	82.3 (86.9)	6.0	75.8 (80.0)	5.3
<i>Dental</i>								
is ss-pg (mm)	6.0	2.3	5.1	2.4	5.3 (5.6)	2.2	4.8 (5.1)	2.0
ILi/ML (°)	95.6	6.7	91.8	6.4	98.3	6.0	96.2	6.2
ii ss-pg (mm)	2.7	2.3	2.1	2.4	2.5 (2.6)	2.0	2.0 (2.1)	2.2
ILs/ILi (°)	127.4	6.4	133.3	9.7	130.3	8.5	132.3	9.9
<i>Cranial base</i>								
n-s-ba (°)	128.7	4.6	130.0	4.7	128.3	5.1	128.3	5.3

*5.6 per cent enlargement.

§Linear values in parentheses with 5.6 per cent calculated enlargement.

SD, standard deviation.

interincisal angle in the Icelandic sample. As the two groups are clearly similar, the difference in the inclination of the lower incisors could have an explanation other than population differences. In the Icelandic sample, at 6 years of age, measurements of the dental variables were only carried out in individuals where the permanent incisors were present, which can partly explain this discrepancy. However, as the difference in the inclination of the lower incisors was still present at 15/16 years of age, but the interincisal angle was now similar in the two groups, it can be concluded that a minimal but true difference does exist between the two populations.

When the results for the whole sample, $n = 182$, were compared with the normal occlusion group, $n = 111$, (Tables 3 and 6) the differences between the groups were small. This suggests that individuals with severe malocclusions and craniofacial discrepancies did not choose to participate in the study or they had already received orthodontic treatment and were therefore excluded. Consequently, the results from the whole sample, including the 182 individuals, could be regarded as normative cephalometric standards for 6- and 16-year-old Icelandic children.

Conclusion

The study confirms that marked age-related changes occur in craniofacial morphology from 6 to 16 years of age, in both genders, the most marked being increases in mandibular prognathism, the mandibular plane angle and the inclination of the lower incisors. When the Icelandic sample is compared to a closely related ethnic group such as the Norwegians, some differences are present at both age levels. The most apparent differences are an increase in the lower mandibular plane angle and greater inclination of the lower incisors in the Icelandic sample, and greater maxillary prognathism in the Norwegian boys.

The results of the craniofacial morphology at 6 and 16 years of age can be regarded as normative cephalometric standards for these age groups in Iceland.

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