From: The Department of Orthodontics (Head: Professor ANDERS LUNDSTRÖM), the Royal School of Dentistry, Stockholm

DETERMINATION OF THE CEPHALOMETRIC ORIENTATION OF THE JAWS

by

HÅKAN WERNER

In recent years increasing interest has been shown in cephalometric radiography as a supplement to the usual methods of orthodontic examination. Knowledge of the dentofacial relationships prepares the way for an analysis of the individual case with respect to characteristics of the facial skeleton and the structure of the jaws. The purpose of the study reported here has been primarily to derive a norm for lateral x-ray analysis for the use at this Dental School.

Since 1791 when *Camper* made craniometric studies of prognathism anthropologists have devoted attention to the facial profile. *Simon* (1922—25) and *Hellman* (1927) attempted by different paths to find a universal norm that might be of value in diagnosis. These investigations were gnathostatic.

The problem of cranial radiography was solved in the early 1920s by *Paccini* (1922) and others; the radiograph then eliminated the necessity for relying on the inexact reference points of the soft parts.

In 1931 *Broadbent* in America and *Hofrath* in Germany published almost simultaneously a procedure for radiographing the skull with the aid of a cephalostat and long distance x-rays (focus to film distance 5 feet). This marked the advent of a new era, and the cephalostat became a highly valued instrument in dental research.

Brodie (1941), *Björk* (1947), *Broadbent* (1948) and others used it for studying the growth and development of the cranium and the jaws. The clinical application of cephalometry has been a problem that has occupied the attention of many research workers, among them *Brodie*, 1938; *Thompson*, 1941, 1946, 1949; *Margolis*, 1947; *Downs*, 1948; *Bushra*, 1947; *Tweed*, 1952 and *Riedel*, 1952. Over the years a number of cephalometric analyses and systems have been evolved and more recently *Margolis*, *Downs* and *Riedel* have published papers of particular interest.

A difficulty inherent in the cephalometric orientation of the jaws is the location of the base plane in the cranium. Anthropologists have long used the Frankfort horizontal (orbitale — porion) — a natural choice. There are, however, several objections to the Frankfort plane for cephalometric purposes; the orbitale is difficult to locate and experience shows that the porion is rather inexact as a cephalometric point *(Björk)*. It is almost impossible to position the ear rods identically twice in succession.

In his investigations of developmental changes in children *Broadbent* (1937) considered the Frankfort plane insufficiently stable. He required a plane located in a part of the cranium where the growth was a minimum. From numerous measurements on crania he established that "landmarks" in the cranial base above the face were relatively more stable and therefore more fixed than those in the more rapidly growing lower face. On the basis of these and other investigations performed over seven years *Broadbent* reached the conclusion that the Bolton-nasion plane is a stable plane of orientation, and the point R in the region of the sphenoid bone the reference point of the head.

Margolis tried to use the nasion-R plane[1] as a basis for comparing two lateral radiographs. He, as *Broadbent*, concluded that the cephalometric plane of orientation should lie on the cranial base. The maximum growth takes place anterior and posterior to the basilar suture between the sphenoid and the occipital bones where the reference point was placed.

Björk made a systematic study of the errors of measurement

[1] R represents the suture between the sphenoid bone and the occipital bone.

for a number of reference points. He found that the orbitale, porion and Bolton points were unsuitable, the points forming the Björk cranial base triangle — the nasion, sella turcica and the articulare — being more appropriate.

Riedel published an investigation entitled "The relation of maxillary structures to cranium in malocclusion and in normal occlusion". He used the nasion — sella turcica as base plane instead of the Frankfort horizontal and after having tested several angles he concluded that only a few were necessary for defining the relation between the jaws. Those specified by *Riedel* appear to be of practical value and for this reason some of them were used in the present study.

MATERIAL

The study group comprised 31 subjects, 15 of them boys and 16 girls, all with "anatomically correct occlusion". They were pupils of elementary and secondary schools in Stockholm.

The 16 girls comprised 10.8 per cent of a group of 149 examined, and the 15 boys 6.9 per cent of 216 examined. They were selected according to the following criteria:

(1) All teeth present from the first molars, at least.

(2) Normal lateral relation. Over-jet in the molar region (first molars) not exceeding 3 millimetres.

(3) Overbite in the anterior region not exceeding 3 millimetres.

(4) Sagittal relation: anterior — overjet not exceeding 3 millimetres; lateral — measured at the first molars maximum deviation ¼ cusp distally or ½ cusp mesially.

(5) Some crowding permissible in lower anterior region but not in the maxilla.

Accordingly, children of ages 13 to 16 years were chosen — the period when shedding of the deciduous teeth is normally finished and the most important stages of the development of the dentition are completed.

The age distribution is given in Table 1. It is evident that both sexes display close uniformity.

Table 1.

Age distribution in the study group.

	Number examined	No. normal cases selected	Age (Yrs.) M $\pm$ ε (M)	σ
Boys	216	15	14.98 $\pm$ 0.41	1.59
Girls	149	16	14.56 $\pm$ 0.69	2.78
Total	365	31	14.80 $\pm$ 0.56	3.13

APPARATUS

The study was carried out with a modified Broadbent cephalostat (*Lönberg,* 1951). The x-ray apparatus was a Schönander MK-8, the exposures being of ¾ second, with 100 milliampères at 70 to 80 Kv. 24×36 cm film was loaded in cassettes with double intensifying screens.

The radiographs were all taken in norma lateralis. The central ray (focus to film distance of 5 feet) passed through both ear rods perpendicular to the median plane. The head was set with the median plane parallel to the film and at a distance of 90 millimetres, irrespective of the individual size of the head. The distance from the film to the median plane is based on *Lundborg & Linder's* (1926) investigations of the head width. The mean width of a Swedish group was found to be 150.44 ± 0.02 millimetres with a standard deviation of 5.10 millimetres. Three times the standard deviation gives a maximum of one half the head width of 82.9 millimetres. The focus-film distance of 5 feet gives approximately a six per cent enlargement. This is of little importance in respect of points in the median plane as an enlargement of the radiograph does not affect the size of the angles.

The patient, seated in a hydraulic chair, was adapted to the cephalostat. The chair was raised until the left external auditory canal was on a level with the ear rods. These were placed into the upper part of the external ear with gentle pressure so as not to interfere with the articular process and thus disturb the position of the mandible. The ear rods were centred so that the median plane was at the centre of the cephalostat. The head was then set in relation to the Frankfort plane.

The patient was required to bite together and to close the lips. Two determinations were made of the occlusal relationship. Between these the patient was encouraged to speak so as to change the closed position on the last radiographic exposure. The patient maintained the same position in the cephalostat throughout.

DEFINITIONS

The reference points and the planes used in the radiographic analysis of the profile were the following:

N *nasion:* The suture between the frontal and nasal bones.

S *sella turcica:* The centre of the sella turcica. It was marked by eye on the profile radiograph of the saddle. For serial radiographs the point was transferred from the first picture to the others by superimposing the sella turcica of later radiographs on that of the first.

Or *orbitale:* The lowest point of the infraorbital ridge. If both left and right ridges are recorded on the radiograph the orbitale is defined as a point mid-way between the lowest points of each contour.

Po *porion:* The highest point on the ear rods.

P *pogonion:* A point where a line perpendicular to the Frankfort horizontal touches the anterior part of the symphysis.

Sp The point of the anterior nasal spine.

Pr *prosthion:* A point at the junction of the crown of the most prominent upper incisor and the alveolar process.

Ifr *infra-dentale:* A point at the boundary of the most prominent lower incisor crown and the alveolar process.

A *(subspinale):* Upper apical base point. The point of intersection of the profile and the longest normal to the profile from the line connecting the anterior nasal spine and the prosthion.

B *(supra-mentale)*: Lower apical base point. The intersection of profile and the longest normal to profile from a line joining the pogonion and infradentale.

I_s *incision superior:* Incisal edge of the most prominent upper incisor.

I_i *incision inferior:* Incisal edge of the most prominent lower incisor.

Gn *gnathion:* Lowest point on the symphysis of the mandible through which may be drawn a tangent to the lower margin of the body (mandibular plane).

K The point mid-way between the two points where lines through Gn touch the most posterior part of the lower left and right borders of the body.

Co The point mid-way between the most dorsal points on the articular process through which may be drawn a tangent to the posterior margin of the ascending ramus.

K_1 The point mid-way between the tangent points of the lines through Co and the most posterior left and right parts of the ascending ramus at the angle.

Go *gonion:* Point of intersection of the lines Co — K_1 and Gn — K.

S — N sella — nasion:	line,	drawn	through	S	and	N
Fh Frankfort horizontal:	"	"	"	Or	"	Po
mandibular line:	"	"	"	Gn	"	Go
facial line:	"	"	"	N	"	P

The angle measurements carried out by *Riedel* (1952) provided the basis for the writer's profile analysis. The angles concerned were: S N A, S N B, A N B, +1+ S N, +1+ Fh, +1+ —1—, Gn Go N S (Fig. 1). Other angles used were: S N Fh, S N I_s, S N I_i, I_s N I_i, S N P, Fh N P, Gn Go Co (the mandibular angle).

Two base planes were used, viz. the sella — nasion (S — N) and the Frankfort horizontal (Fh) i.e. porion — orbitale (Po — Or).

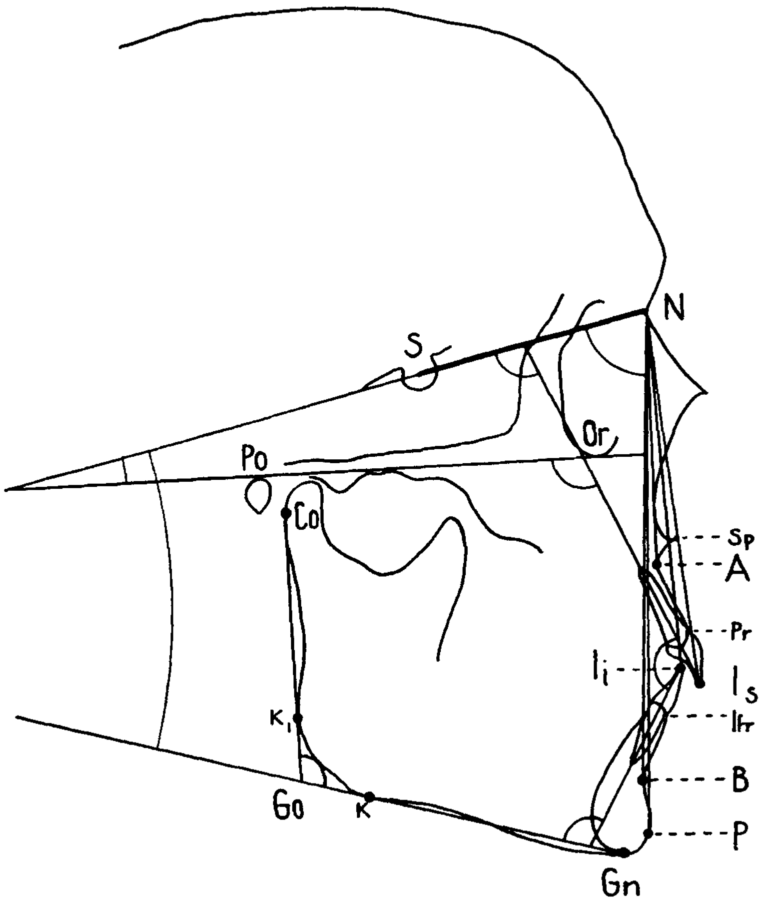

Fig. 1. The angles and planes used in the lateral radiographic analysis.

METHOD

The measurements were performed on tracing paper placed over the radiograph. After a test series on both boys and girls it was found that the results of the second measurement were considerably more accurate. This may be ascribed to the practice gained in the interpretation of radiographs and for this reason new measurements were made for the whole study group. The complete series of first radiographs was treated, followed by the others. This procedure possibly reduced the influence of the first placing of each reference point on the second.

RESULTS

Table 2 gives the angle values grouped according to sex, with mean error, standard deviation, and experimental error. There was no significant difference between the means and ranges for boys and girls, so that the results were expressed in terms of one mean for the whole study group. The experimental error was calculated for boys and girls together. It was small enough to be negligible for practical purposes. A possible shortcoming of the method which may have affected the results was that the patient was not removed from the cephalostat between the exposures. It is almost impossible to replace the patient in an identical position. When only one occlusal radiograph is taken there is clearly the likelihood of an error due to the setting of the head.

To determine whether this setting error might influence the experimental error a special study was made of nine patients (4 boys and 5 girls) from the same study group. Two occlusal radiographs were taken for each patient who was released from the cephalostat between the exposures. The existence of a setting error was tested by the formula $F = S_0^2/S_i^2$, where F = variance ratio (with 9 degrees of freedom in the numerator and 31 in the denominator, S_0^2 = square of the experimental error for the 9 patients examined, S_i^2 = square of the experimental error for the 31 patients examined. No significant value of F was obtained (Table 3); (the value of 2.47 for +1+SN is almost significant, but this may be neglected as due to justifiable chance in 15

Table 2.

Mean ($\bar{x}$), mean error $\varepsilon(\bar{x})$, dispersion (s) and standard error for the angle measurements.

		$\bar{x}$	$\varepsilon(\bar{x})$	s	s_i
S N — F H	♂	7.32	± 0.76	3.0	
	♀	5.41	± 0.78	3.1	
	Total	*6.33*	± *0,56*	*3.1*	*0.58*
S N A	♂	82.65	± 0.83	3.2	
	♀	81.98	± 1.00	4.0	
	Total	*82.31*	± *0.64*	*3.6*	*0.36*
S N I_s	♂	84.78	± 0.82	3.2	
	♀	85.09	± 0.86	3.5	
	Total	*84.94*	± *0.59*	*3.3*	*0.33*
S N B	♂	79.68	± 0.69	2.7	
	♀	79.98	± 0.76	3.0	
	Total	*79.84*	± *0.51*	*2.8*	*0.37*
S N I_i	♂	82.83	± 0.85	3.3	
	♀	83.27	± 0.88	3.5	
	Total	*83.06*	± *0.60*	*3.4*	*0.33*
A N B	♂	2.97	± 0.42	1.6	
	♀	2.50	± 0.53	2.1	
	Total	*2.73*	± *0.34*	*1.9*	*0.27*
I_s N I_i	♂	1.92	± 0.12	0.5	
	♀	1.86	± 0.09	0.4	
	Total	*1.89*	± *0.07*	*0.4*	*0.24*
S N P	♂	80.38	± 0.64	2.5	
	♀	80.80	± 0.79	3.2	
	Total	*80.60*	± *0.50*	*4.8*	*0.30*
+ 1 + — SN	♂	104.65	± 1.43	5.5	
	♀	102.67	± 1.62	6.5	
	Total	*103.63*	± *1.08*	*6.0*	*0.56*
+ 1 + — 1 —	♂	128.13	± 2.35	9.1	
	♀	131.39	± 1.70	6.8	
	Total	*129.81*	± *1.44*	*8.0*	*0.78*
— 1 — GnGo	♂	96.03	± 1.35	5.2	
	♀	93.89	± 1.40	5.6	
	Total	*94.93*	± *0.98*	*5.4*	*0.70*
GnGo — NS	♂	30.75	± 0.90	3.5	
	♀	31.61	± 1.36	5.4	
	Total	*31.19*	± *0.82*	*4.5*	*0.32*
GnGo — Co	♂	124.92	± 1.45	5.6	
	♀	125.94	± 1.43	5.7	
	Total	*125.44*	± *1.00*	*5.6*	*0.69*
FH — NP	♂	87.28	± 1.08	4.2	
	♀	85.92	± 0.77	3.1	
	Total	*86.58*	± *0.66*	*3.6*	*0.52*
+ 1 + — FH	♂	111.52	± 1.82	7.1	
	♀	108.08	± 1.73	6.9	
	Total	*109.74*	± *1.27*	*7.1*	*0.75*

Table 3.

Study of the setting error when placing the head in the cephalostat.

	$S_o^2 = \frac{\varepsilon d^2}{2n}$	S_i^2	$F = \frac{S_o^2}{S_i^2}$
SN — FH	0.0417	0.3347	0.12
SNA	0.1528	0.1290	1.18
SNI_s	0.1111	0.1089	1.02
SNB	0.1528	0.1371	1.11
SNI_i	0.0972	0.1089	0.89
ANB	0.0556	0.0726	0.77
I_sNI_i	0.0417	0.0565	0.74
SNP	0.1389	0.0887	1.57
+ 1 + — SN	0.7778	0.3145	2.47+
+ 1 + — — 1 —	0.9028	0.6068	1.50
— 1 — GnGo	0.6389	0.4879	1.31
GnGo — NS	0.1528	0.1048	1.46
GnGo — Co	0.7639	0.4798	1.59
FH — NP	0.0139	0.2661	0.05
+ 1 + — FH	0.4306	0.5565	0.77

comparisons). The setting error was thus small enough for the dispersions S in Table 2 to be considered for practical purposes as an estimate of the dispersion between the true values of the patients.

A grouping of the patients according to age for calculation of the significance between the means for the various age groups gave no positive result. The number of cases in each group was small, however, and a larger study group might display such a difference.

A comparison between similar investigations made on patients with anatomically correct occlusion by *Downs* (1948), *Bushra* (1948), *Mayne* (1948), and *Riedel* (1952) showed that the differences between the various means and dispersions are small — especially in the case of *Riedel* and the present writer. *Thörne* (1951) found that the values obtained by *Downs* (20 patients aged 12 to 18 years), *Bushra* (20 subjects aged 18 to 67 years) and *Mayne* (50 cases aged 18 to 36 years) for the facial angle NP — Fh, the mandibular plane angle (Gn Go — Fh) and the inclination of the occlusal plane to the Frankfort horizontal were strikingly similar. The values of *Riedel* and *Werner* agree fairly closely while those of *Downs* show some differences. A weakness in such comparisons between different study groups is that the authors do not define their terms clearly. An example is the concept "normal" or "anatomically correct" occlusion used by several authors.

It is clear from these investigations, however, that there is a large variation within the limits of the normal. They demonstrate that the value of one angle in the profile analysis does not give sufficient information; only when the angles are seen in association with one another does the analysis assume its proper value.

Table 4.

Comparison between means ($\bar{x}$) and dispersions (s) obtained by *Downs, Riedel* and *Werner*.

	Downs		Riedel		Werner	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
S N — FH	—	—	6.5	—	6.3	3.1
S N A	—	—	80.8	3.9	82.3	3.6
S N B	—	—	78.0	3.1	79.8	2.8
A N B	—	—	2.8	2.3	2.7	1.9
FH N P	87.8	3.6	—	—	86.6	3.6
S N P	—	—	—	—	80.6	2.8
+ 1 + S N	—	—	103.5	5.0	103.6	6.0
+ 1 + FH	—	—	110.0	4.9	109.7	7.1
+ 1 + — 1 —	135.4	5.76	130.4	7.2	129.8	8.0
— 1 — Gn Go	91.4	3.78	93.5	5.8	94.9	5.4
Gn Go NS	—	—	32.2	4.7	31.2	4.5

SUMMARY

A study was made of the position of the jaws in relation to the cranial base in 31 subjects, 15 boys and 16 girls, with anatomically correct occlusion. The primary purpose was to obtain a Swedish standard for lateral x-ray analysis at the Royal School of Dentistry in Stockholm.

The base planes used were the sella — nasion (S — N) and the Frankfort horizontal (Fh) i.e. porion — orbitale. The results for the two sex groups were combined to give one mean.

Table 2 gives the values of the angles, the means, the dispersions and the standard errors. The calculation of the values was based on double determinations.

Comparison between the findings and those of other investigators e.g. *Downs* and *Riedel* show that the values obtained in the present study differ little from *Riedel's* but more from those of *Downs*.

There is a large range of variation within the limits of normality.

RÉSUMÉ

DÉTERMINATION DE L'ORIENTATION CÉPHALOMÉTRIQUE DE LA MÂCHOIRE SUPÉRIEURE ET INFÉRIEURE

Une investigation de la position des dents en relation à la base du crâne a été exécutée de 31 cas (15 fils, 16 filles) avec "occlusion anatomiquement correcte". Le but du travail a été principalement de trouver une règle pour les suédois à employer comme modèle de notre analyse radiographique de profil à l'école dentaire.

Comme plan de base l'auteur emploie le plan Sella Nasion (S — N) et l'horizontal Francfort (FH), Porion — Orbitale. Les résultats aussi bien de fils que de filles ont été groupés à une moyenne. Dans le tableau 2 les moyennes et les valeurs de dispersion des angles examinés sont retrouvées ainsi que l'erreur de méthode de l'auteur. (La calculation des valeurs différentes est basée sur des déterminations doubles.)

Enfin l'auteur a fait une comparaison entre sa propre investigation et des autres du même genre (entre autres Down et Riedel). Alors il a revelé que les valeurs de Riedel ainsi que celles de l'auteur s'accordent assez bien tandis que les valeurs de Down tendent à diverger un peu. La comparaison montre qu'il existe une grande possibilité de variation dans les limites du normal.

ZUSAMMENFASSUNG

DIE BESTIMMUNG DER CEPHALOMETRISCHEN ORIENTIERUNG DES OBER- UND UNTERKIEFERS

An Hand von 31 Fällen (15 Knaben, 16 Mädchen) mit "anatomisch korrekter Okklusion" wurde die Lage des Gebisses in Relation zur Schädelbasis untersucht. Zweck der Arbeit war in erster Linie einen schwedischen Standard zu bekommen, der als

Norm für unsere Profilröntgenanalyse an der Hochschule dienen konnte.

Als Basisebene benützte der Verfasser die Sella Nasion—Ebene (S — N) und die Frankfurter Horizontale (FH), Porion — Orbitale. Aus den Werten für sowohl Knaben als auch Mädchen wurde *ein* Mittelwert errechnet. In Tabelle 2 findet man die Mittelwerte der untersuchten Winkel, ihre Streuung und der mittleren Fehler der Methode des Verfassers. (Die Berechnung der verschiedenen Werte ist auf Doppelbestimmungen basiert.)

Schliesslich vergleicht der Verfasser seine Untersuchungen mit anderen ähnlicher Art (Downs und Riedels). Dabei zeigte sich, dass die Ergebnisse Riedels mit denen des Verfassers relativ gut übereinstimmen, während die Werte Downs etwas abweichen. Der Vergleich zeigt, dass eine grosse Variationsbreite innerhalb der Grenzen für das Normale vorhanden ist.

REFERENCES

Björk, A., 1947: The Face in Profile. Berlingska Boktr., Lund.

Broadbent, H., 1931: A new X-ray Technique and its Application to Orthodontia. Angle Orth. *1:* 45.

—»— 1937: Bolton standard and technique in orthodontic practice. Angle Orth. *7:* 209.

—»— 1948: Measurements of dentofacial changes in relation to the cranium. Cit. by Anderson, G. M.: Practical Orthodontia, 1 edit.

Brodie, A. G., 1938: Cephalometric Appraisal of Orthodontic Results. Angle Orth. *8:* 261.

—»— 1941: On the growth pattern of the human head from the third month to the eighth year of life. Am. Journ. Anat. *68:* 209.

—»— 1941: Behaviour of Normal and Abnormal facial growth Patterns. Am. Journ. Orth. and Oral Surg. *27:* 633.

Bushra, E., 1947: Variations in the human facial pattern in norma lateralis. Cit. by Downs 1948.

Camper, J., 1791: Dissertation physique sur les différences réeles que présentent les traits du visage chez les hommes de différents pays et de différents ages. Paris, Cit. by M. Graber 1954.

Downs, W. B., 1948: Variations in facial Relationships; Their significance in treatment and prognosis. Am. Journ. Orthod. *34:* 812.

Graber, T. M., 1954: A critical review of clinical cephalometric radiography. Am. Journ. Orthod. *40:* 1.

Hellman, Milo, 1922: Changes in the Human Face brought about by development, Cit. by Björk 1947.

Hofrath, H., 1931: Die Bedeutung der Röntgenfern- und Abstandsaufnahme für die Diagnostik der Kieferanomalien. Fortschr. d. Orthodontik *1.*

Lundborg, H. & F. J. Linders, 1926: The racial characters of the Swedish nation. Uppsala.

Lundström, A., 1950: Om betydelsen av kefalometriska registreringar för diagnosen vid bettanomalier. Festskrift utgiven av Sv. Tandl.- Sällsk. med anledning av dess 90-årsdag.

Lönberg, F., 1951: Changes in the size of the lower jaw on account of age and loss of teeth. Stockholm.

Margolis, H., 1940: Standardized X-Ray cephalometrics. Am. Journ. Orth. and Oral Surg. *33:* 631.

—»— 1947: A basic facial pattern and its application in clinical orthodontics. Am Journ. Orth. and Oral Surg. *33:* 631.

Mayne, W., 1946: A study of the skeletal Pattern of the human Face. Cit. by Downs 1948.

Paccini, A. J., 1922: Roentgen ray anthropometry of the skull, J. Radiol *3.*

Riedel, R. R., 1952: The relation of maxillary structures to cranium in malocclusion and in normal occlusion. Angle Orthod. *22:* 142.

Simon, P., 1922: Grundzüge einer systematischen Diagnostik der Gebissanomalien, Berlin.

Tompson, J. R., 1941: A cephalometric Study of the Movements of the Mandible. Journ. of Am. Dent. Ass. *28:* 750.

—»— 1946: The rest position of the Mandible and its significance to dental science. Journ. of Am. Dent. Ass. *33:* 151.

—»— 1949: Oral and environmental factors as etiological factors in malocclusion of the teeth. Am. Journ. Orthod. *35:* 33.

Thörne, H., 1951: Teleröntgencephalometrisk profilanalys: systemöversikt, diagram för Downs system samt mätmetod för "path of closure". Svensk Tandl. Tidskr. *44:* 1.

Tweed, C. W., 1946: Frankfort-mandibular plane angle in Orthodontic Diagnosis, Classification, Treatment Planning and Prognosis. Am. Journ. Orthod. and Oral Surg. *32:* 175.

Address: *Department of Orthodontics*
The Royal School of Dentistry
Stockholm, Sweden