Lateral Facial Asymmetry - Methods of Assessment

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The subject of the symmetry or lack of symmetry of the human face is of considerable interest, particularly in the field of orthodontics. In 1907 Angle[2] said, "The study of orthodontia is indissolubly connected with that of art as related to the human face" and Berendt[4] considered that "Aesthetic problems are . . . of decisive importance in orthodontics". In spite of this, Cheney[10] stated, "With few exceptions, no attention has been given to the influence of asymmetries in the production of malocclusion or to the significance of these variations upon treatment procedures". This neglect may be due to the assumption that "malocclusion affects the face in the sagittal plane more than it does in the transverse plane".[12] However, active measures are taken to correct those cases which show the "centre line disharmony" between the maxillary and the mandibular central incisors.[25]

Stanton[50] considered that the adoption, more generally, of the mathematical approach for the study of malocclusion may reveal the true deforming forces at work on the human denture.

The present study concerns factors which play a part in the development of "normal" lateral facial asymmetry; its aim is to contribute to the understanding of the mechanisms of facial growth which are of fundamental importance in the theory and practice of orthodontics. It is based on data relating to lateral facial asymmetry obtained from 1029 subjects—772 Australians (of European stock) and 257 Polynesians.

The first paper[52] reported an association between the lateral position of the nose and handedness. The present one outlines some aspects of this subject, discusses methods which have been used to assess this condition, and describes a concept of lateral facial asymmetry and a method of assessment both of which are thought to be new. In addition, changes and fluctuations in asymmetry associated with increase in age are reported.

CONCEPTS OF LATERAL FACIAL ASYMMETRY

The classical concept of symmetry of the human face is that depicted by Leonardo da Vinci[41] and by Albrecht Durer's drawings of 1507-8.[42] These depict the face as bisected by a vertical line running through the center of the nose, the lips and the chin; the pupils of the eyes are equidistant from this line, and a line drawn through them is at right angles to the vertical line. This concept is still illustrated in most, but not all,[56] anatomical illustrations.

From a survey of the medical and dental literature on this subject it would appear that some authors regarded such absolute symmetry as the normal condition[35,47] so that "One side mirrors the other".[27] Simon[48] considered that "bilateral symmetry is a most manifest morphological characteristic of the body and especially of the head". The majority of the contributors to this subject recognized that minor degrees of facial asymmetry are common; others felt that they are universally present. Liebreich[34] considered that asymmetry of the skull and face is a constant and characteristic feature of the human species. Mills[38] said that "asymmetry of structure and of function is a basic con-

dition of the human body in its present stage of evolution". Schwarz[45] also regarded asymmetry as normal, as did Thompson[54] who stated that this "normal asymmetry is not very evident, whereas the abnormal asymmetry is quite obvious". According to Ward and Lerner[59] "Marked asymmetry is probably much more common than a review of the literature would indicate" and Fischer[17] said that "Facial asymmetry is a natural phenomenon and there is nothing abnormal about it". Asymmetry of the face is no new phenomenon, and where rigid symmetry is seen in the portraits of primitive peoples it is due to convention.[58]

In studies of asymmetry of the facial structures the main emphasis has been on asymmetry of the maxillary bones themselves and particularly on the shape of the dental arch and palate.[18,22,39,50,57] Facial asymmetry is possible in all three planes of the body;[45] it may be muscular, skeletal, or functional, perhaps disclosed only on movement.[9,10]

The present investigation is limited to study of lateral asymmetry of the face observed from the frontal aspect. In this case the face is asymmetrical if, when it is in the condition of repose, one or more of the facial features which occur bilaterally are farther from the median line of the face than is the corresponding feature on the other side, or if the center of each unpaired facial feature does not lie on that line. Therefore it is of fundamental importance to define the median line.

The Median Line of the Face

Hemley[24] said that "The median *plane* divides the body into halves, a right and a left half. The median *line* is the periphery of the median plane". It would appear that the median line of the face is considered, by the authors of most papers on this subject, to be the periphery of that part of the median plane which may be visualized as emerging through the "central" facial features and which is an extension of the median plane of the skull.

Owing to the lack of comment on the median plane as it is related to the face, mention will be made of observations made regarding a closely related matter—the median plane of the skull. Tildesley,[55] Buxton and Morant,[8] Sollas,[49] and Ray[43] have pointed out difficulties which arise in investigations involving the use of this plane, and Jackson[30] considered that to determine the median sagittal plane of the skull "is not easy, if at all possible."

Most papers mentioning the median plane ignore the difficulty of establishing its position. Buxton and Morant said that the median sagittal plane has generally been presumed without being defined. Cheney[11] said that it passes through nasion and the anterior nasal spine. It would appear that this plane is usually considered to bisect all the central anatomical features. However, investigation will readily show that such a plane, probably without exception, cannot be described through these "central" features. Therefore the term "plane" is merely an approximation which is convenient for descriptive purposes, in fact Simon[48] termed the sagittal plane a "more or less bent surface."

Even the three central anatomical landmarks which are being used in this study rarely lie on a straight line when viewed from in front of the subject. These landmarks are *subnasale* defined by Howells[28] as: "The apex of the angle formed by the lower border of the nasal septum and the surface of the upper lip, or the junction between these two" and *prosthion* defined by Gosman[21] as "the lowest point of the intermaxillary suture, upon the alveolar margin, between the two first incisors". In the living, prosthion is the lowest point of the soft gum between the upper

central incisors in the median plane and is therefore a slight distance below the bony prosthion. The third landmark used is *pogonion* which Wood-Jones[62] defined as "The most prominent point in the middle line of the anterior surface of the chin".

Ferris[15] said that the median line of the face was determined by using a French curve. It is clear, therefore, that the median line, based on this almost universally-used concept, is merely an approximately straight line drawn through the centers of those anatomical features which are situated in the vicinity of the center of the face. It can be seen that Adler's[1] criticism of Grunberg's work applies to this concept also: "that the symmetry axis itself is determined by relying upon formations of the symmetrical position which is to be examined". As a line drawn in this manner would be unsatisfactory for the study which is in progress, another and, it is thought, a new method of defining the median line of the face has been adopted and will be discussed later in this paper.

The Recognition and Assessment of Lateral Facial Asymmetry

Campbell[9] said this subject can be studied by the use of the eye of the observer, the roentgenograph, or mechanical methods. To these three may be added a fourth method—the use of photographic techniques.

Direct observation

Herzberg[26] said that "Probably the best means for developing the ability to appraise faces is to look at them critically and repeatedly". Direct observation was used by Moore and Hughes [39] who observed their patients in the dental chair. Vassal[58] placed his subjects in the recumbent position and made use of a mirror to increase the acuracy of his observations. Campbell[9] asserted that "It is not popularly appreciated how accurate is the eye when it is used as a measuring instrument" and Sved[53] was of the opinion that "an ocular examination may often be more accurate than an apparently accurate scientific method".

Radiographic techniques

According to Krogman[33] "Roentgenographic cephalometry is the natural heritor of craniometry, and it has gone far ahead, as it should." Such studies are based on the methods of Broadbent[6] although the cephalostatic apparatus has varied.[37,61] With few exceptions[13,40] these investigations have been confined to the aspects portrayed in the lateral films.

Mechanical methods

Mechanical devices which have been used to assess the dimensions of the mouth and face may be divided into three groups: those which have been used to measure the maxillary arch and the palate,[18,22,23] those which are suitable for the study of skulls,[31,57] and those which have been designed for use on the living subject. Gnathostatic casts prepared with the aid of the "gnathostat" demonstrate the relationship between the head and jaws and the teeth[47] but are of little interest in the present connection; nor are the "Maxillator" of Salzmann[44] and the "Facial Orthometer" of Elsasser,[12] as both were designed to measure the lateral aspects of the face. One instrument which can be used to measure the face is the "Prosopometer".[3] Fischer[16] used a cubical steel framework called a "Cephalophore", which is fitted with ear rods which are "guided into the ears until an equal reading is obtained on the graduated right and left scale. The head is automatically positioned in the center of the front face of the cephalophore, and any slight deviation of the median line can be corrected by means of the

vertical wire of the cephalophore," presumably by adjusting the position of the head so that this wire bisects, as closely as can be judged, the central anatomical features.

Photographic techniques

The use of orientated photographs for the study of the face was advocated by Herzberg.[26] Gavan, Washburn and Lewis[19] stated that "If selected anatomical points are marked on the individual, many measurements can be taken as accurately on the photograph as on the individual himself". Ferris,[15] Jackson,[30] Weinberger[60] and Felisati[14] are among those who have used a method of making, from each negative, two positives, one the mirror image of the other. "Both positives were cut in the median line and both right or left halves reunited by photomontage".[14] This is a striking way of demonstrating the presence of asymmetry.

Comments on methods

Each of the methods that have just been mentioned incorporates undesirable features. From what has been said previously it will be seen that the process of cutting photographs in the median line is a subjective procedure and can be, at best, only approximately correct. A slight degree of rotation of the head round its vertical axis is very difficult to detect in a view-finder or even in a photograph. Such a movement will produce little change in outline in those parts of the photograph which record the lateral aspects of the face, but it will produce a considerable alteration in the position on the photograph of such features as the nose and chin.

The "Prosopometer" has been criticised on mechanical grounds; Friel[18] considered that its accuracy is very doubtful. In addition, it shares with the cephalometer and with devices used to produce orientated photographs the errors which occur when ear rods are inserted into the external meati with the aim of establishing fixed points from which to determine the transverse axis of the skull.

The use of the meati for this purpose may be criticised because of their structure, because they may not lie at the same vertical level, and because one may be more anterior than is the other. The process of using the axes of the ear rods to designate the positions of the centers of the meati is of doubtful accuracy because there may be differences in the thickness of the two meati and in the compressibility of the soft tissue lining them.[18] Also, because the ends of the rods may not fill the meati, it is possible for the subject to produce a slight rotation or tilting of the head. With apparatus incorporating ear rods, the standard method is to adjust these so that an equal reading is obtained on the graduated scales of both rods. It is then assumed that the head is situated centrally in the apparatus. This will be so if the observer has decided to consider that the bisection of the line joining the tips of the ear rods will determine one point on the median plane of the skull. If this is not the case, the head will be centrally placed only if those parts of the wall of each meati which prevent the end of each rod from penetrating more deeply, when under the compression produced by the ear rods, are equidistant from the median plane of the skull (as defined by the observer). If this condition is not fulfilled, even if the meati are symmetrically placed in regard to their anteroposterior positions, the median plane of the apparatus will not coincide with that median plane of the skull, and those anatomical features which lie on it will not be recorded in the center of the photographic or radiographic negative as judged by the positions of the ear rods. In the case of bilateral bony features, in addition to this error, the displace-

ment of the image on the film due to the divergent course of the rays from the radiographic apparatus will not be the same on each side. A similar effect is seen when two bilateral features are not the same distance from the film.

Rotation of the head around its vertical axis, as in those asymmetrical conditions of the skull in which one of the meati is situated more anteriorly than the other, will cause the images on the film to be displaced laterally. The magnitude of this error will increase the more "central" are the anatomical features, the farther they are from the intermeatal line in an anterior or a posterior direction, and the greater the angular rotation of the head.

Tilting the head to one side, as would occur in the condition, which is frequently seen, in which the meati are at different vertical levels, will produce little change in the distance from the median line of those anatomical features which are situated approximately at the level of the meati; but the deviation from this line will become greater the farther upwards or downwards the anatomical point is from the intermeatal line. Vertical or horizontal rotations, such as these, are of little importance when the lateral aspects of the skull are considered; however, errors of considerable magnitude may be produced by them when assessing lateral facial asymmetry.

Radiographs may show differential distortion and magnification due to divergence of the rays and aberrations of the image due to techniques used. These points need no comment. Frontal cephalometry, used in assessing lateral asymmetries, produces a more confused image than does profile cephalometry as there is much more superimposition of bones.[9]

Attempts to develop an objective method for measuring lateral facial asymmetry must depend on establishing fixed bases from which measurements can be taken. Goldstein[20] pointed out that, when making anthropometric observations in the living, and especially on the face, the overlying tissues make precise location of landmarks a more or less uncertain procedure. Kherumian[32] said that it is necessary to prescribe a system of exact landmarks which will permit searching analysis of human morphological characters, as much for the skeleton as for the soft parts. Such a system of "morphologic points" does not exist. Hrdlicka[29] stated that "Whatever point for prospective measurements may be chosen by orthodontists or any other research workers will surely differ, and that often materially, in different individuals, at different ages, and even on the two sides of the head or face of the same individual. Here is a natural limitation to our efforts, with which it is well to be acquainted fully, and for which a discount must be made in our procedures".

A New Concept and Method of Measurement of Lateral Facial Asymmetry

In this study use is made of a concept of lateral facial asymmetry and a method of assessment, both of which are thought to be new.

Concept

In all the methods which have been mentioned the median line of the face is estimated either by bisecting the intermeatal dimension on the assumption that the meati are symmetrically placed, or by a process of judgment from the position of the central anatomical features. However, it is felt that the lateral extremities of the face should be used, for the middle is equidistant from the extremities.

When the lateral asymmetry of the facial skeleton is being studied, measurements must be read from its lateral ex-

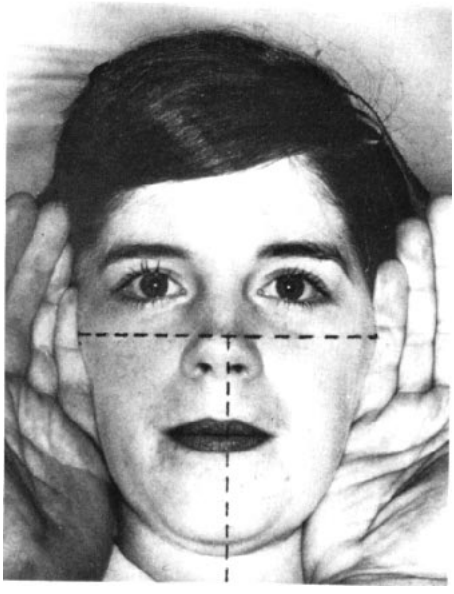

Fig. 1

tremities. These are the zygions, as the zygion is "the most lateral point upon the zygomatic arch as determined by measurement".[62] Growth in the bizygomatic dimension of the skull is slow and takes place at a steady rate.[5,63]

The concept that the medial line is equidistant from the zygions may be applied to measurements from cephalometric radiographs, but when either directly viewing the subject, as in this study, or when studying photographs, appraisals must be made by observing the positions of the skin areas over the zygions. In this study the method of direct observation was used; the Polynesian observations were made in localities where electric power was not available.

Method

The subject is seated, the head being steadied by means of a headrest. The observer stands in front of the subject and places the ulnar borders of his hands on the face, one just behind each of the zygions, screening the ears. The hands are pressed inwards and backwards, drawing taut the tissues over the zygions. The observer moves his head, several times, slightly to the left and then to the right so that the position of the skin surface over each zygion can be appraised. The following construction (Fig. 1) is visualized—a straight median line bisecting, and perpendicular to the straight line joining the centers of the skin areas over the zygions. The anatomical points subnasale and pogonion are considered to indicate, respectively, the position of the nose and the chin. The relation of each of these points to this median line is assessed and given one of the following arbitrary values: 0 when no asymmetry is detected, 1 when the deviation is considered to be slight, 2 when moderate, and 3 when it is marked.

Objections to this method are that it produces only a ranking assessment (this is sufficient for the present purpose) and that it is subjective. However, as has been seen, the usual methods of assessing lateral asymmetry have serious, though often unrecognised, limitations. As Krogman[33] said, in research "Perfection may be the goal, but adequacy is the most useful standard." An essential requirement for an adequate method is that appraisals made at different times on the same subject should be sufficiently consistent.

Consistency of results

To test this matter two observations were made, between three and six months apart, of the position of the nose and of the chin in each of 182 Australians and 101 Polynesians and each pair of initial and subsequent results was compared. In the former group, in 103 cases the result obtained for the position of the subnasale was the same on both occasions, the difference between the mean values of the first and second sets of observations being 0.04. .Similar results were obtained for other readings; the numbers of identical results and the

TABLE I

RELATIVE LATERAL ASYMMETRY OF THE NOSE AT DIFFERENT AGES IN EUROPEANS AND POLYNESIANS

Age in Years		N. Relative Deviation 0	1	2	3	Sum of Relative Deviation Value × No. Subjects	Means
				Europeans			
3-5	71	41	18	12	0	42	0.59
6-8	135	62	37	32	4	113	0.84
9-11	132	43	45	38	6	139	1.05
12-14	120	36	40	33	11	139	1.16
15-17	71	18	25	22	6	87	1.23
18-20	37	11	14	5	7	45	1.22
21-23	27	7	8	8	4	36	1.33
24-26	21	5	7	6	3	28	1.33
27-29	17	3	6	5	3	25	1.47
30-	141	31	53	26	31	198	1.40
				Polynesians			
3-5	18	8	8	2	0	12	0.67
6-8	66	25	20	19	2	64	0.97
9-11	45	7	19	11	8	65	1.44
12-14	42	6	13	16	7	66	1.57
15-17	52	8	17	19	8	79	1.52
18-20	14	1	7	3	3	22	1.57
21-29	7	1	2	2	2	12	1.71
30-	13	2	3	5	3	22	1.69

differences between the means of the first and second readings were: pogonion, 119, 0.01; prosthion, 129, 0.12. In the 101 Polynesians, subnasale, 57, 0.06; pogonion, 63, 0.06; prosthion, 70, 0.11. In none of these six comparisons was the difference between the mean values statistically significant, so that lack of consistency in these observations was not demonstrated.

It is clear that the observer could have shown a consistent bias. However, even if a gross bias existed so that those positions which were only slightly to the right were recorded as markedly to the right, and so on, as the statistical method used is that of regression, the conclusions drawn from these observations would not be affected.

Changes and Fluctuations with Increase in Age

Material

All the 1029 subjects examined had some natural teeth and were without a history of fracture of facial bones. The 772 Australians (330 males and 442 females) were consecutive patients presenting for routine dental examination in a private practice in Melbourne. The 257 Polynesians (128 males and 129 females) lived on the island of Rarotonga, South Pacific, and comprised all the children attending a primary school, all the secondary school pupils aged 15 years or more, and consecutive adults who attended for dental examination.

Results

The results are set out in Tables 1

TABLE II
RELATIVE LATERAL ASYMMETRY OF THE CHIN AT DIFFERENT AGES IN EUROPEANS AND POLYNESIANS

Age in Years	N.	Relative Deviation 0	1	2	3	Sum of Relative Deviation Value × No. Subjects	Means
			Europeans				
3-5	71	20	20	31	0	82	1.15
6-8	135	24	40	71	0	182	1.35
9-11	132	13	32	85	2	208	1.58
12-14	120	16	39	61	4	173	1.44
15-17	71	15	17	36	3	98	1.38
18-20	37	4	7	20	6	65	1.76
21-23	27	3	5	15	4	47	1.74
24-26	21	4	4	8	5	35	1.67
27-29	17	4	2	7	4	28	1.65
30-	141	20	25	90	6	223	1.58
			Polynesians				
3-5	18	11	4	3	0	10	0.56
6-8	66	24	31	11	0	53	0.80
9-11	45	11	13	18	3	58	1.29
12-14	42	10	16	13	3	51	1.21
15-17	52	17	20	14	1	51	0.98
18-20	14	2	5	5	2	21	1.50
21-29	7	2	2	2	1	9	1.29
30-	13	5	1	7	0	15	1.15

and 2 and depicted in Figures 2 and 3. At each age in each racial group, the male and the female results were combined as they were not significantly different. The data are grouped in three-year age groups, except that only one mean value is given for the small sample of seven Polynesians aged 21-29 years. The mean asymmetry of the subjects who were 30 years of age or more (whose ages were known only approximately) are plotted at their mean ages, estimated to be 40 years in both racial groups.

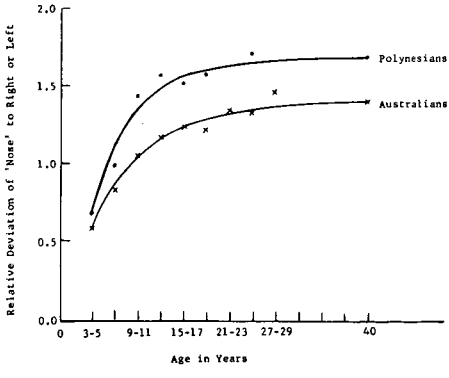

Fig. 2 Association between age and the mean degree of lateral asymmetry of the nose in Australians and Polynesians.

Discussion

The increase in the mean lateral position of the nose with increase in age is shown in Figure 2. The curves of the two racial groups are of similar form but the method is not considered to be sufficiently precise to justify a comparison between the levels of the curves. The difference in the colour of the skin of the two races may have modified the assessments of the observer. In both racial groups the mean values for the adults, aged 30 years or more, are not significantly lower than those of the preceding age group. The increase in

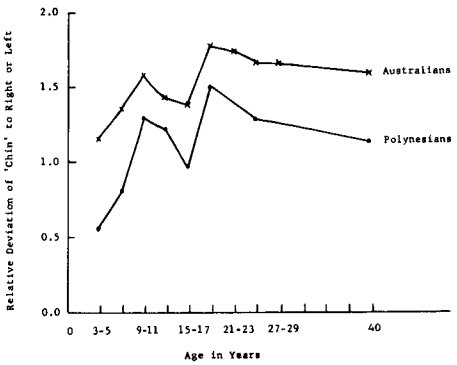

Fig. 3 Association between age and the mean degree of lateral asymmetry of the chin in Australians and Polynesians.

the degree of lateral asymmetry of the nose with age supports the contention that normal facial asymmetry is produced mainly by postnatal factors. If any pathological conditions which produce lateral asymmetry occurred in these subjects, it is unlikely that they were sufficiently prevalent to distort the mean values more than slightly. As lateral asymmetry of the nose is uncommon in young children, even a moderate degree of asymmetry in a child should be investigated.

Figure 3 depicts the mean lateral position of the chin at each age. The bimodal shapes of the curves of the two racial groups were unexpected and are in marked contrast to the form of those in Figure 2. The fluctuations could not have been due to the observer developing a bias during some examination periods for the subjects were not examined in age groups. These curves are considered to indicate the correct form as most of the points are based on substantial numbers of observations and as this bimodal shape is found in both sexes in each racial group.

Many observers have emphasized the plasticity of the craniofacial structures, that the form of the bone is controlled by the magnitude and direction of the forces it has to bear and that the full development of the ramus of the mandible appears to depend on adequate function.[36,46] Some contend that the length and width of the body of the mandible are not increased by functional stress.[51] Cases of marked mandibular asymmetry have been attributed to muscle imbalance, a recent one to a very slight weakness of the facial muscles on the left side and apparent complete absence of the sternomastoid.[7] Preliminary data suggest that, in some subjects, there is a change in laterality of biting force between early and late childhood. If such a change occurs it may, in part, explain the fluctuations in the mean degree of asymmetry of the chin (Fig. 3), but the etiology of these changes and fluctuations requires further investigation.

Summary

Published views regarding lateral facial asymmetry, its normality, occurrence, and assessment are considered and the term "median line of the face" is discussed. A new concept and method of assessing lateral facial asymmetry is described. Observations made of three anatomical points, in each of two racial groups, showed that consistent results are obtainable by this new method.

Using this technique the position of the nose and of the chin has been investigated in 1029 subjects, 772 Australians of European stock, and 257 Polynesians.

In both racial groups similar results were obtained: the mean lateral position of the nose increased with age, but the curves showing the mean position of the chin are of a bimodal shape with marked fluctuations at certain ages.

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REFERENCES

1. Adler, P.: A critical account of Grunberg's method of symmetroscopy. *Dent. Items* 70:433-41, 1948.
2. Angle, E. H.: Treatment of Malocclusion of the Teeth. 7th ed. Philadelphia, *S. S. White*, 1907. p. 60.
3. Apostolakis, G., Petridis, P. and Lourdis, O. R.: Biometric research on the face and ears of Greek adults. *Arch. Orthodont.* 1:66-7, 1952.
4. Berendt, N. C.: Orthodontics and the study of art. Malformations in art history. *Int. Dent. J.* 3:216-19, 1952.
5. Berger, H.: Twenty-five years' experience with the zygomatic method. *Amer. J. Orthodont.* 38:369-81, 1952.
6. Broadbent, B. H.: A new x-ray technique and its application to orthodontia. *Angle Orthodont.* 1:45-66, 1931.
7. Broadway, E. S.: Two unusual cases of facial asymmetry. *Dent. Practit.* 15:145-148, 1964.
8. Buxton, L. H. D. and Morant, G. M.: The essential craniological technique. Part I. Definition of points and planes. *J. Roy. Anthrop. Inst.* 63:19-47, 1933.
9. Campbell, J.: The mylohyoid line in the assessment of facial asymmetry. *Dent. Rec.* 70:204-8, 1950.
10. Cheney, E. A.: The influence of dentofacial asymmetries upon treatment procedures. *Amer. J. Orthodont.* 38: 934-45, 1952.
11. ———: Dentofacial asymmetries and their clinical significance. *Amer. J. Orthodont.* 47:814-29, 1961.
12. Elsasser, W. A.: Studies of dentofacial morphology. *Angle Orthodont.* 21:163-71, 1951.
13. Engel, M. B. and Brodie, A. G.: Condylar growth and mandibular deformities. *Surgery* 22:976-92, 1947.
14. Felisati, D.: Rapporti fra asimmetrie sinusali e disrafismo facciale. *Revista di Clinica Medica, Florence,* 1949. 6/2 suppl. 3. (192-200). Quoted from Excerpta Medica 4: Sect. 1, p. 404, 1950.
15. Ferris, H. C.: Original photographic studies of orthodontic cases. *Int. J. Orthodont.* 13:627-32, 1927.
16. Fischer, B.: *Orthodontics.* Philadelphia, Saunders, 1952. pp. 305-7.
17. ———: Asymmetries of the dentofacial complex. *Angle Orthodont.* 24: 179-192, 1954.
18. Friel, S.: The diagnosis of malocclusion of the teeth. *Dent. Cosmos* 56:825-33, 1914.
19. Gavan, J. A. Washburn, S. L. and Lewis, P. H.: Photography: an anthropometric tool. *Amer. J. Phys. Anthrop.* N.S. 10:331-53, 1952.
20. Goldstein, M. S.: Changes in dimensions and form of the face and head with age. *Amer. J. Phys. Anthrop.* 22:37-89, 1936.
21. Gosman, S. D.: Anthropometric method of facial analysis in orthodontics. *Amer. J. Orthodont.* 36: 749-62, 1950.
22. Gruenberg, J.: The symmetroscope: An apparatus for measuring the symmetry or asymmetry of the dental arches. *Dent. Cosmos* 54:490-1, 1912.
23. Halperin, G.: Normal asymmetry and unilateral hypertrophy. *Arch. Int. Med.* 48:676-82, 1931.
24. Hemley, S.: *Fundamentals of Occlusion.* Philadelphia, Saunders, 1944. p. 26, 173.
25. Henry, R. G.: The Australian Society of Orthodontists' case of the year. *Aust. J. Dent.* 58:361-64, 1954.
26. Herzberg, B. L.: Facial esthetics in relation to orthodontic treatment. *Angle Orthodont.* 22:3-22, 1952.
27. Hildreth, Gertrude: The development and training of hand dominance: I. Characteristics of handedness. *J. Genet. Psychol.* 75:197-220, 1949.
28. Howells, W. W.: The designation of the principal anthropometric landmarks on the head and skull. *Amer. J. Phys. Anthrop.* 22:477-94, 1937.
29. Hrdlicka, A.: Normal variation of teeth and jaws, and orthodonty. *Int. J. Orthodont.* 21:1099-1114, 1935.
30. Jackson, A. F.: Facts, fictions and fallacies in orthodontia. *Amer. J. Orthodont.* 23:1073-95, 1937.
31. Keith, A.: Description of a new craniometer and of certain age changes in the anthropoid skull. *J. Anat. Physiol.* 44:251-70, 1910.
32. Kherumian, R.: Repertoire des points cranometriques anthropometrique. *Rev. Morpho-Phelpiologie Humaine* No. 2, p. 22, 1949. Quoted from Salzmann, J. A. Editorial. *Amer. J. Orthodont.* 41: 709-11, 1955.
33. Krogman, W. M.: Craniometry and cephalometry as research tools in growth of head and face. *Amer. J. Orthodont.* 37:406-14, 1951.

34. Liebreich, R.: *Die Asymmetrie des Gesichtes und ihre Entstehung.* Munich, Bergmann, 1908. Quoted from Halperin, G. (Reference 23)
35. McCoy, J. D.: *Applied Orthodontia.* 3rd ed. London, Kimpton, 1931. p. 49.
36. McKeag, H. T. A. and Scott, J. H.: *In* Brash, J. C., McKeag, H. T. A. and Scott, J. H.: *Aetiology of Irregularity and Malocclusion of the Teeth.* 2nd ed. London, The Dental Board of the United Kingdom, 1956, p. 441.
37. Margolis, H. I.: Standardized X-ray cephalographics. *Amer. J. Orthodont.* 26:725-40, 1940.
38. Mills, L.: Eyedness and handedness. *Amer. J. Opthal.* 8:933-41, 1925.
39. Moore, G. R. and Hughes, B. O.: Familial factors in diagnosis, treatment, and prognosis of dento-facial disturbances. *Amer. J. Orthodont.* 28:603-39, 1942.
40. Mulick, J. F.: An investigation of craniofacial asymmetry using the serial twin-study method. *Amer. J. Orthodont.* 51:112-129, 1965.
41. Panofsky, E.: *The Codex Huygens and Leonardo da Vinci's art theory.* London, Warburg Institute, 1940.
42. ———: *Albrecht Durer.* Volume I. London, Oxford University Press 1945.
43. Ray, L. J.: Cranial contours in the Australian aboriginal. *Amer. J. Phys. Anthrop.* n.s. 18:313-320, 1960.
44. Salzmann, J. A.: *Principles of Orthodontics.* 2nd ed. Philadelphia, Lippincott, 1950. pp. 106, 597.
45. Schwarz, R.: New cephalometric method and apparatus and its application to orthodontia. *Int. J. Orthodont.* 11:989-1017, 1925.
46. Seward, T.: Dentistry—A study in anatomical design. *Aust. J. Dent.* 51: 223-234, 1947.
47. Simon, P. W.: On gnathostatic diagnosis in orthodontics. *Int. J. Orthodont.* 10:755-777, 1924.
48. ———: *A Systematic Diagnosis of Dental Anomalies.* Boston, Stratford, p. 54. Quoted from Sved, A. (Reference 53).
49. Sollas, W. J.: The sagittal section of the human skull. *J. Roy. Anthrop. Inst.* 63:389-431, 1933.
50. Stanton, F. L.: A consideration of normal and abnormal dentures as a problem of three dimensional spaces and its bearing on orthodontic classification and terminology. *Int. J. Orthodont.* 8:185-204, 1922.
51. Strang, R. H. W. and Thompson, W. M.: *A Text-Book of Orthodontia.* 4th ed. Philadelphia, Lea and Febiger, 1958, p. 290.
52. Sutton, P. R. N.: Handedness and facial asymmetry: lateral position of the nose in two racial groups. *Nature* 198:909, 1963.
53. Sved, A.: An analysis of the most important diagnostic methods used in orthodontia. *Angle Orthodont.* 1: 139-60, 1931.
54. Thompson, J. R.: Asymmetry of the face. *J. A. D. A.* 30:1859-71, 1943.
55. Tildesley, M. L.: A first study of the Burmese skull. *Biometrika* 13:176-262, 1921.
56. Truex, R. C. and Kellner, C. E.: *Detailed atlas of the head and neck.* New York, Oxford University Press, 1948.
57. Van Loon, J. A. W.: A new method for indicating normal and abnormal relations of the teeth to the facial lines. *Dent. Cosmos* 57: 973-83, 1093-1101, 1229-35, 1915.
58. Vassal, P. A.: Les asymétries faciales. *Rev. Path. Comp.* 53:1540-68, 1953.
59. Ward, J. and Lerner, H. H.: A review of the subject of congenital hemihypertrophy and a complete case report. *J. Pediatrics* 31:403-14, 1947.
60. Weinberger, B. W.: *An Introduction to the History of Dentistry in America.* Volume II. St. Louis, C. V. Mosby Company, 1948. p. 349.
61. Wild, N.: A mobile craniostat. *Brit. Dent. J.* 96:137-40, 1954.
62. Wood-Jones, F.: *Measurements and Landmarks in Physical Anthropology.* Honolulu, Bernice P. Bishop Museum, Bulletin 63, 1929. pp. 8, 9.
63. Woods, G. A. Jr.: Changes in width dimensions between certain teeth and facial points during human growth. *Amer. J. Orthodont.* 36:676-700, 1950.