Boston University

OpenBU **http://open.bu.edu**

Boston University Theses & Dissertations GSDM: Historical Theses and Dissertations (Open Access)

1970

The determination of an extra-skeletal reference line and its reliability

https://hdl.handle.net/2144/31716

Downloaded from OpenBU. Boston University's institutional repository.

BOSTON UNIVERSITY

SCHOOL OF GRADUATE DENTISTRY

8807-1

THESIS

THE DETERMINATION OF AN EXTRA-SKELETAL REFERENCE LINE AND ITS RELIABILITY

by

David M. Albert, D.D.S.

Case-Western Reserve University

Cleveland, Ohio

Submitted in partial fulfillment of

the requirements for the

degree of Master of Science in Orthodontics

1970

Boston University

Copyright and Digitization Notice

Copyright of this work is held by the author.

This work is protected against unauthorized copying under Title 17, United States code.

This reproduction is made available for personal use, and is not for distribution.

The image quality of this digital reproduction depends on the quality of the print original. Signatures and personal information, if present, have been redacted.

WU 440
A335d
1970
c.2

LIBRARY
BOSTON UNIVERSITY
SCHOOL OF MEDICINE

Approved by:

First reader [redacted] DMD PhD 3/23/70
Professor of Orthodontics Date

Second reader [redacted] DMD 3/23/70
Assistant Professor of Orthodontics Date

DEDICATION

To my parents
with deepest gratitude

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr. Anthony Gianelly, Professor and Chairman of the Department of Orthodontics at Boston University School of Graduate Dentistry, for his guidance throughout this investigation.* His expert clinical and didactic teaching is also deeply appreciated. The knowledge that I have gained through his ceaseless efforts to help me in any way, will never be forgotten.

My thanks go to Dr. Steven Gamm, Assistant Professor at Boston University School of Graduate Dentistry, for his counsel and assistance in the preparation of this project. His excellent clinical instruction is sincerely appreciated.

*I would like to thank my wife Eileen for her diligent support and help during the months of this investigation.

ABSTRACT

The present investigation was undertaken to determine an extra-skeletal reference plane and its reliability.

The results of this study revealed that it seems possible for an orthodontist to establish an extra-skeletal reference plane, if a specially designed analyzer is used. It has been shown that by using this devise in his determination of a base landmark, an orthodontist can have a high degree of reliability within himself. It also appears likely that the reference plane obtained in this manner by one orthodontist is reproducible, to a high degree of reliability by other orthodontists. A remarkably high reproducibility was obtained if a group determination of a reference base was done. To the orthodontist, it means that there may be a way of accurately producing a reliable reference plane for static cephalometric analysis. This could be used to standardize communication among orthodontists.

TABLE OF CONTENTS

	Page
READERS' APPROVAL	i
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
LIST OF TABLES	vi
LIST OF ILLUSTRATIONS	vii
INTRODUCTION:	1
CHAPTER I: Literature Review	4
CHAPTER II: Material and Method	15
CHAPTER III: Results	18
CHAPTER IV: Discussion	20
REFERENCES	25
TABLES	30
ILLUSTRATIONS	43

LIST OF TABLES

TABLE		PAGE
I	Measurements recorded from the angle formed at the intersection of the sella-nasion plane to a vertical landmark established by the observer	
II	Mean and standard deviation from the combined mean values of all examiners for each head	
III	Two methods of reliability	
IV	Accuracy of measuring method	

LIST OF ILLUSTRATIONS

Figure 1: Diagram of analyzer developed to determine an extra-skeletal reference plane

Figure 2: Method of measuring the angle formed by the sella-nasion plane intersecting the vertical reference landmarks established by the observers

INTRODUCTION

Static cephalometric analysis has become an important part of the orthodontist's diagnostic tools. This type of analysis is done by taking a standardized lateral and/or frontal cephalogram of the patient. Certain landmarks such as orbitale, porion, sella, nasion, etc., may be traced to establish a base reference plane. Once it is established, various linear, angular, and/or positional measurements can be made and compared with a set of previously determined "reference norms." Some analyses use only linear calculations,[1] others use angular[2,3] or positional measurements.[4,5] Many analyses are made up of a combination of one, two, or all three of the basic measures.[6,7,8] In any case, the reliability of the analyses is dependent on the landmarks chosen for a reference plane, and the tracing error inherent in cephalometrics.

It has been shown that accuracy in cephalometric tracing is most difficult to achieve.[9] Comparison of the same cephalogram, traced by reliable examiners, who knew beforehand that their work would be judged for accuracy, revealed marked discrepancies.

The base reference planes' reliability is a combination of two factors: biologic variation and mechanical tracing error. An ideal reference plane would be one that has landmarks that do not vary and are easily reproducible from the cephalogram. If this plane existed, a more uniform standardized system of communication among orthodontists could be established.

LIBRARY
BOSTON UNIVERSITY
SCHOOL OF MEDICINE

Unfortunately, evidence seems to show that no such plane exists in the living head. Research indicates that the reliability of the reference planes is dependant upon differential growth of the areas containing the points composing the planes.[10-16]

Many reference bases have been used in cephalometrics and are still employed today by various clinicians and researchers. Some of the more common ones are: sella-nasion, spheno-occipital synchondrosis-nasion, Bolton line, Frankfort-horizontal, His line, and the pterygomaxillary fissure axis intersecting the Frankfort-horizontal.

Garn, in 1961, said that there were no "fixed points" in the skull of the living person.[17] Others state that basion, porion, opisthion, orbitale, pterygomaxillary fissure, speno-occipital synchondrosis, anterior nasal spine and posterior nasal spine are the most variable of all cephalometric landmarks.[18-20]

One of the most common base lines, sella-nasion, contains an endocranial structure (sella) and an ectocranial structure (nasion).[10] Each one may grow at a different rate and direction.[10-16] Apparently, the "stable" reference planes used today may contain variable reference points.

Krogman and Sassouni submitted the same case history to forty-four different analyses. Depending on which one was used, the patient could exhibit any combination of such factors as: normal, prognathic, or retrognathic maxilla; normal, prognathic, or retrognathic mandible; steep, normal, or flat mandibular plane; etc.

Researchers have shown that natural head position is a remarkably constant position, at least over a short period of time. Intra-cranial reference lines, when compared to the natural head position horizontal, were shown to have much variation.[21,22]

It is apparent that all of the current reference planes used in static cephalometric evaluation are based on degrees of error. It follows that any analysis besed on these inaccurate landmarks can have little value to the orthodontist. At best, they provide no more than a quasi scientific approach to the patient evaluation. They are used because we have nothing better.

The present investigation was undertaken in an attempt to find a more reliable base line for static cephalometric evaluation. Since previous investigations have shown the variability of intra-skeletal reference points, this paper will deal with the determination of an extra-skeletal reference line and its reliability.

CHAPTER I

Literature Review

During the period before roentgenographic cephalometry, orthodontic diagnosis depended largely upon soft tissue appearance, dental casts, direct measurements, and photography. Various planes of orientation were being used in orthodontic diagnosis. They were borrowed from Anthropometry, which had its beginning in the eighteenth century. Camper measured the relationship of the face to the head on dry skulls. He charted the angle formed by the following: a plane passing through the external auditory meatus and the anterior nasal spine, and a plane tangent to the forehead and face.[23] His work was recognized as the start of modern anthropometry.[24] In 1884, the next important advancement came with the substitution of the Frankfort horizontal for Camper's base plane.[25] Camper's tangent was changed to a plane passing from nasion to prosthion.

Early orthodontists needed to use a reference line that was accesible on the living head because they had no roentgenograms. Since it was also felt that a plane of orientation should be one that was meaningful to natural postural position, it seemed logical that the Frankfort horizontal would be accepted by orthodontists as a possible base line.

Simon was most likely the first orthodontist that attempted to orient the dental casts on an articulator in such a way that they simulated the relationships observed in the living patient.

Once so mounted, he could then do a static analysis based on certain criteria he deemed important. He felt that the canine could be related in such a way that it would determine the location of the denture of man relative to his cranium. He related the canine to a coordinate system of three intersecting planes. They were as follows: the median saggital plane, the Frankfort horizontal, and the orbital plane. The construction of these planes was based on rather ambiguous landmarks; nevertheless, his entire treatment plan and diagnosis depended on the "law of the canine."[4] Stanton, and others, criticized this method of diagnosis as being frought with error and variation.[26]

A new realm of orthodontic diagnosis and treatment planning came into being in 1931 as Broadbent standardized the radiographic technique which is employed in cephalometry today. It was felt that no longer would the field need to rely on ambiguous soft tissue points of reference but could employ hard tissue landmarks seen on a cephalogram.[27]

Based on Broadbent's standardized technique of cephalometrics, orthodontists began to search for some means of static analysis that could be employed as a basis for treatment and diagnosis. Tweed was one of the first to justify treatment based on cephalometric analysis.[28] He noted that Margolis,[29] and Speidel and Stoner[30] had studied the average inclination of the lower incisor to the mandibular plane. They found it to be 90° plus or minus 5°. Based on clinical observation, it

was Tweed's contention that the lower incisor in well-balanced faces and ideal dental occlusions was upright over basal bone and at 90° to the mandibular plane. He indicated that treatment goals should be geared to obtain this ideal in every case. He further stated that the Frankfort horizontal-mandibular plane angle was a measure of the patient's facial growth. He concluded that a mandibular plane of 16°-28° was ideal, 28°-35° had some chance of successful treatment; the latter always required extraction of teeth. Any angle above 35° meant that the mandible was growing most unfavorably with a great component of downward and backward growth. Tweed's statements were most dogmatic. He was basing treatment on the lower incisor position with little regard for individual variation;[31,32] moreover, many class three mal-occlusions may exhibit a steep mandibular plane with an excessive forward growth component.[33]

In 1954, Tweed changed his philosophy somewhat by orienting the lower incisor more towards the Frankfort plane than the mandibular plane. He constructed a triangle. The sides were composed of the Frankfort horizontal, the mandibular plane, and a line drawn through the lower incisor intersecting the aforementioned planes. The inside angles of the triangle were measure. The Frankfort-mandibular incisal-angle was the most critical one, and was found to be 65° in well balanced faces. Of course, these harmonious faces were picked according to Tweed's bias of facial and dental beauty; thus, his treatment became orientated largely toward the FMIA, with a modifing factor, the mandibular plane.

The steeper the mandibular plane, the more upright would be the IMPA and the larger would be the FMIA.[3] Much criticism of this static technique of cephalometric evaluation is present.[31,32,34,35] It is generally geared towards the treatment of an individual based on a number with little regard to his facial pattern. i.e. large nose, or chin.

Other popular diagnostic and treatment orientated static cephalometric analyses have been proposed through the years. A few of the more popular ones will briefly be discussed because their findings are generally dependent on the base reference line employed in the analysis.

Reidel studied the position of the maxilla and mandible relative to the cranial base plane sella-nasion. He also noted that the degree of discrepancy in point A and point B were fairly reliable indicators of apical base disharmony between maxilla and mandible. He determined the inclination of the upper incisor to sella-nasion, Frankfort horizontal, and nasion-opisthion.[36]

Downs, in 1948, organized the first static analysis based on statistical measurements covering a wide range of cranial, facial, and dental components. His reference norms were documented with a mean and standard deviation. The analysis was set up using the Vorhies polygon.[37] Downs used the Frankfort horizontal as his plane of orientation. He studied the facial angle (nasion-pogonion) of twenty living persons, ages twelve to seventeen, all having ideal dento-facial harmony.

He compared the readings using the sella-nasion plane, the Bolton line, and the Frankfort plane. His range and standard deviations were about the same, regardless of which base was used. When he compared the facial type exhibited clinically with the facial angle cephalometrically, differences were noted. He found that the Frankfort horizontal was the only plane that indicated the same facial type observed clinically when the patient was in his "natural head position." Downs suggested that the lack of correlation of the sella-nasion and Bolton lines with the facial type was due to the fact that these planes were located in the cranium, while the Frankfort plane was in the face and so could more readily correlate with the facial pattern.[38] With the Down's analysis, any patient could be diagnosed and a treatment plan set up accordingly. Although Down's analysis remains popular today, many investigators question its validity because of the base line employed.

The Steiner analysis was introduced in 1953. It was based on the sella-nasion plane. Steiner and others felt that the Frankfort plane was not easily identified cephalometrically. He varified this conclusion by means of an interesting experiment. Several films of the same patient were taken within minutes of each other. In between the films, the patient was not removed from the cephalostat. Superimpositions were done over sella-nasion. Porion was found to move up, down, anteriorly, or posteriorly.

He also stated that true porion could not be observed in a cephalogram. Others also supported this contention. Steiner also felt that an added advantage of the sella-nasion line, composed of midline structures, was that it would less likely be affected by head position that the Frankfort horizontal. The analysis currently used, is basically a conglomeration of Steiner's ideas coupled with those of Reidel and Holdaway. This analysis can be intimately associated with the diagnosis and treatment planning of a case.[6]

One of the simplest static cephalometric analysis was introduced by Margolis. The base reference plane used was the spheno-occipital synchondrosis. A triangle was constructed using the nasion-spheno-occipital plane, mandibular plane, and facial plane as its borders. The inside angles were read. Reference norms using means and standard deviations were employed. The analysis was designed to indicate various facial, skeletal, or dental disharmonies.[8]

It is evident that many cephalometric analyses have been formulated since Tweed's initial attempt to relate treatment in terms of the lower incisor position and mandibular plane angle. In fact, over forty-four different static analyses are present in the field of orthodontics today. With so many, it would seem to indicate that no one analysis provides a meaningful method of communication among orthodontists. An orthodontist's diagnosis and treatment plan is dependent upon the way in which he evaluates the patient.

In 1937, Broadbent stated that after age six, the cranial base did not change with growth. Based on this assumption, he discussed the possibility of using the sella-nasion plane, the Bolton line, and the Frankfort horizontal in cephalometrics. He compared the average dimensions of fifty males and females. Statistical analysis was done on the reference planes. Standard deviations and co-efficients of variation were shown. The Bolton line had the lowest co-efficient of variability; therefore, judged on the statistical evidence, he felt that it should be used as the cranial reference line of choice. He further stated that the cephalograms provided a means of making a "precise" and permanent record of the patient's facial type at the initiation of treatment, and could be compared with future cephalograms to determine progress.[39]

Bjork, in a study of the reference planes sella-nasion, porion-orbitale, and the Bolton line, found evidence that contradicted Broadbent's conclusion. It was noted that the landmarks porion and Bolton point could not be seen radiographically and were therefore subject to gross tracing error. On the basis of his study, he felt that the sella-nasion line offered the best combination of relative stability and ease of reproducibility on the lateral cephalogram.[40]

A study of prognathism comparing the adult Bantus to the adult Swede concluded that the intra-cranial reference lines, sella-nasion, nasion-articulare, and nasion-basion were influenced by individual variations in anatomic detail. Two of those examined, representing the maximun and minimum prognatism

in adult Bantus, appeared to be of near identical facial profile. When measured by a deflected cranial base, they gave opposite results.[41]

Koski and Virolanen tested several reference bases in terms of variability. Those planes analyzed were the Frankfort horizontal, sella-nasion, Bolton line, nasion-basion line, nasion-opisthion, and the His line (acanthion-opisthion). One hundred dental students were examined. Porion was taken as the highest point of the ear rod. Double shadows were bisected to form one point. The measurements were taken directly on the films. To check the reliability of tracings, double determinations were done. Two linear measurements, nasion-Bolton point, and porion-orbitale, showed considerable systematic error when compared in the double determinant method. All other reference planes tested showed a similar amount of variation. It was concluded that since no base line was really outstanding, the His line should be used because it was nearly parallel to the Frankfort plane but exhibited less variation.[42]

It is questionable as to why porion is still included in any static cephalometric analysis. Downs, a proponent of the Frankfort plane, has reported that "porion was not distinguishable on a lateral cephalogram of the living patient." He felt that the earpost, commonly used as porion, did not accurately represent its true location. In his opinion, anatomic porion was three millimeters above the ear rod.[43] Research seems to indicate that this landmark should be discarded from cephalometric analysis due to its variability.

An interesting method of comparing anatomic reference plane was demonstrated by Bjering and Moorrees.[21,22] They found that natural head position was a remarkably stable position. Bjerin's determination of the natural head position seemed to be somewhat inaccurate; however, he found a standard deviation of only $\pm 2.7^{\circ}$ for the true vertical. He then compared the Frankfort horizontal and the sella-nasion line to the natural head horizontal. The Frankfort plane was found to be $+1.8^{\circ}$ with a standard deviation of $\pm 4.6^{\circ}$; sella-nasion was found to be -4.3° with a standard deviation of $\pm 4.0^{\circ}$. Similar observations for the Frankfort plane, relative to the natural head position, were reported by Downs in 1953. Thus, Bjerin's data seemed to indicate that the intra-skeletal reference planes had greater dispersion about their means than the extra-skeletal base line.

Moorrees work showed an even smaller standard deviation for the true vertical than Bjerin's work. It is possible that his methodology was more reliable than Bjerin's. Moorrees used a modified Broadbent cephalostat. It had a plumb line perpendicular to the cassette and in such a way that it would be recorded on the x-ray film. There were no ear supports. To maintain a constant distance between the midsaggital plane of the patient to the film, two vertical bars were centered and built into the headholder. One bar was in the front of the cephalostat, the other was in the rear. Two groups of dental students were participants in the experiment.

Each student was instructed to orient his head so that his midsaggital plane was on the vertical bar in the middle of the head holder. A mirror was set up in front of the student. He was instructed to look directly into the mirror at an image of his own eyes. The first group consisted of sixty-six students. Two cephalograms were taken one week apart. The standard deviation of the head position in this group was $\pm 2.05^{\circ}$. The second group was composed of sixty-one members. They were given the same instruction as group one; however, observers were allowed to adjust the "natural head position" if they felt that the test subject was in variant position. Two cephalograms were again taken one week apart. The results indicated a reduction in the standard deviation of head position variation to $\pm 1.54^{\circ}$. This was significant at the 5% level. With a small dispersion, it seemed possible to compare the variability of intra-skeletal base lines. Such a test was done with the following reference planes: sella-nasion, Frankfort horizontal, His plane, and the Bolton plane. The results indicated that the intra-skeletal reference planes showed from two to four times as much variation as the natural head position. Moorrees also found that a deflection of one intra-skeletal reference plane was usually associated with a deflection of the other reference planes; thus, contradicting the idea that increased reliability in cephalometric evaluation could be achieved by using multiple reference lines.

The growth data available corroborates cephalometric studies showing the inherent variability of anatomic landmarks as reference points for static cephalometric evaluation. Biologic reference points such as sella, nasion, porion, Bolton point, etc., are located in different areas of the skull. It has been shown that these areas grow at a differential rate; thus, nasion may be growing upward and forward while sella moves downward.[10-16] It is apparent that the landmarks composing a reference plane may change their position during growth. Enlow has stated, "There are no stable reference points in the skull."[13] Bjork has demonstrated that the cranial base may alter its shape up to adult age.[16] The idea of a stable cranial base during orthodontic treatment is open to question.

Cephalometric evaluation has become an integral part of many orthodontic practices. Yet the static cephalometric analyses use reference norms based on variable landmarks. It follows that a patient having a deflected base line may have an inaccurate diagnosis and treatment plan. The search for a more reliable plane of reference must go on.

CHAPTER II

Materials

Using a Margolis cephalostat and G.E. x-ray head at a a film distance of 5', lateral cephalograms were taken of fifteen orthodontic patients before treatment was initiated. The soft tissue profile, sella, nasion, palate, upper and lower incisor, upper and lower molar, and the mandible were traced. The centers of sella and nasion were marked with a small dot. An ink drawing of each head was made. Using legal sized paper, ten copies of each drawing were made with a Xerox duplicating machine.

An analyzer was designed for the experiment. It consisted of a masonite $\frac{1}{4}$" board cut twenty inches in length and eighteen inches width. At one end, the width was twenty inches because of two 1" by 2" projections. They gave the appearance of making that end of the board look as if it had a vertical bar. This was called the sighting bar and represented the front of the analyzer. A $3\frac{1}{2}$" radius circle was centered vertically and cut $\frac{1}{4}$" from the sighting bar. Five pairs of marking holes were drilled into the board. Each set of holes was parallel to the vertical bar. These marking holes started one inch behind the circle and were spaced horizontally every $\frac{1}{2}$" and vertically every two inches. A picture of the analyzer is shown in figure one.

Method

Ten observers consisting of seven second year orthodontic students and three orthodontic instructors were used in the experiment. Each man was given a brief instruction period in how to use the analyzer. He was told that each observer would receive a packet containing fifteen sheets of paper, each having a tracing of a different patient. One picture at a time was to be placed under the analyzer so that the face appeared in the circle; the soft tissue profile was then to be oriented as if the patient were looking directly at the vertical bar. When this position was determined, the experimenter was to mark a dot with a sharp pencil in each of the first set of holes. He was then instructed to slide the paper from beneath the analyzer and write a small number, one over each of the two dots. After going through the entire series, the observer was told to shuffle the drawings and repeat the observations marking the dots in the second row of holes with the number two. This procedure was to be done five times on every drawing. This meant that every observer recorded 75 measurements at the end of his part of the experiment.

When the drawings were returned for evaluation, each one had five sets of dots. The two dots marked with the number one were connected; the dots marked two were connected, etc. Next, a horizontal line was constructed passing through the points denoting sella and nasion. These dots were marked before the ink tracings were duplicated; therefore, each copy of the same head contained identical markings for the horizontal baseline.

The angle formed by the intersection of the baseline with the verticals was recorded. (Figure 2)

Statistics

A mean, standard deviation, and a range for each examiner's readings for each head were calculated. This was followed by a mean, standard deviation, and range for each head. The standard deviation was computed according to the formula S. D. $= \sqrt{\frac{NEX^2 - (EX)^2}{N^2}}$.

Reliability tests were figured according to two formulae: Hoyt's reliability $= \frac{Vr-Ve}{Vr}$; and intra-class reliability $= \frac{Vr-Ve}{Vr+(K-1)Ve}$.

To determine the accuracy of the measuring method, six replications were made of each five angles. Mean and standard deviations were calculated for each.

CHAPTER III

Results

The standard deviations of the angle formed at the intersection of the sella-nasion plane to a vertical landmark established by each observer on an individual head were quite small. The readings had a range of $\pm .4^{\circ}$ as a low, to $\pm 3.7^{\circ}$ as a high. Sixty percent of those measurements were $\pm 1.5^{\circ}$ or less; over twenty-five percent were below $\pm 1.0^{\circ}$. (table 1).

When a standard deviation computed from combined mean values of all examiners for each head was compared to the standard deviations derived from the observations of each examiner for each head, the results were somewhat comparable, although there were fewer low values. This range of standard deviation was from a low of ± 1.7 to a high of ± 3.4. Over 50% of the standard deviations of this group were below $\pm 2.0^{\circ}$. (table 2).

Reliability tests were performed to determine the measure of reproducibility of the obtained readings, if the examiner or group were to repeat the analysis. Hoyt's formula was used to calculate the reliability of the findings recorded by an individual when more than one observation was done, as well as the reliability of the combined results of multiple observations determined by the group. Intraclass reliability was employed to determine a measure of one rater's ability to reproduce a given reading at any particular time. It was also used to evaluate the reproducibility of the raters within the group to each other.

The reliability tests yielded the following results:

1. When one examiner recorded a series of five readings for each head, it was determined that they could be reliably reproduced. Depending on the observer, the range was from .964 to .990. (table 3)

2. If an observer made a single rating on each head, he could reproduce this reading on any other evaluation reasonably accurately. The intraclass r ranged from .861 to .964 (table 3)

3. When ten examiners (the group) evaluated the same head five times, the degree of reliability was .988. If a member of the group rated each head five times, and was compared to the results any other member of the group would achieve looking at the same heads, an intraclass r of .890 would be obtained. It is an indication of a high degree of reliability within the group. (table 3)

The accuracy of the measuring method, as determined by the standard deviations calculated from six replications of the same five angles, was high. The range of standard deviations was $\pm.186^{\circ}$ to $\pm.250^{\circ}$. (table 4)

CHAPTER IV

Discussion

Since the advent of the standardized technique for cephalometrics, much study has gone into finding a stable reference plane for static cephalometric evaluation. Many planes of the skull have been proposed, but none has proven their reliability. There is no reference line today that cannot be associated with some degree of variation.[21,22,39,42-45,48] Some have more than others. Orthodontists may base their diagnosis and treatment plan mainly on a static cephalometric evaluation. The validity of the analysis must be questioned, particularly when an error in the reference plane may yield misleading angular or linear measurements that may be directly related to diagnosis and treatment planning.

A popular concept in orthodontic diagnosis and treatment planning is the control of the vertical dimension of the patient by measurement of various angles.[46,47] The angles are made up of the mandibular plane intersecting the base line; and the occlusal plane intersecting the mandibular plane. Proponents of this theory claim that the greater the angle, the more likely will mandibular counter-clockwise rotation occur if any extrusive forces are placed in the molar area. These planes diverge from each other, giving the facial pattern the picture of a large wedge. It is thought that a small extrusion in the posterior is magnified in the anterior, the result is a counter-clockwise mandibular rotation. The idea seems logical; however, no study done by these men has

shown any significant clinical correlation between mandibular rotation and the measured angles. The highest statistical correlation they found using this method of diagnosis was r=.36, which is nearly meaningless clinically.[47]

One possible reason for the lack of clinical correlation between vertical dimension changes and angular measurements of the mandibular plane, occlusal plane, and palatal plane, is that the base line variability may mask the true facial pattern of the individual. It has been shown that reference planes, excluding natural head position, can be associated with variations approximating $\pm 5.0^{\circ}$ for one standard deviation. Let us suppose that a three standard deviation exists for a cranial reference line within an individual; the deflection would then be $\pm 15^{\circ}$. The person could possess a "normal" mandibular plane, occlusal plane, and palatal plane; but the deflected base-line could give the appearance of highly divergent facial pattern. An analysis in such a situation would indicate an inaccurate diagnosis and treatment plan.

An illustration of this concept was demonstrated by Mills.[48] He conducted a static cephalometric analysis on the same patient using the sella-nasion line, the Frankfort horizontal, and the natural head position horizontal. The diagnosis and treatment plan was appreciably affected by the plane of reference. Based on the sella-nasion line, an extremely divergent facial pattern was noted with a markedly retrognathic mandible and normal maxilla. The Frankfort plane showed less

of a hyper-divergent facial pattern plus a combination of a prognathic maxilla and retrognathic mandible. The natural head position indicated a normal facial pattern with the exception of an extremely prognathic maxilla. Based on the sella-nasion and Frankfort horizontal, it would seem to be very dangerous to employ any treatment mechanics causing molar extrusion. Mills treated this patient according to a natural head position analysis. It apparently showed that vertical forces were not contra-indicated. Cervical traction was used for two years; class two mechanics was employed for six months. There was no counter-clockwise mandibular rotation. It would seem that the subject did not have the hyper-divergence indicated by the angular measurements based on the intra-skeletal reference lines.

Natural head position has been associated with perhaps the least amount of variation as a reference plane for static cephalometric analysis.[21,22] Moorrees demonstrated that two patients having nearly identical profiles could exhibit marked differences within analyses using intra-skeletal reference planes. This difference was found to be related to the inclination of the base lines. Yet natural head position analysis has never gained significant popularity. One of its faults may be that it does not provide a clear means of communication among orthodontists. It must be remembered that the least variation associated with the natural head position occured when an observer corrected the individual's head position into what he felt was the true natural head position.

Suppose that someone in New York established a diagnosis and treatment plan based on the corrected head posture. Could someone in California duplicate these results if he received only the original cephalogram? No, he would need the living patient to perform the same type of analysis done by the orthodontist in New York. If natural head position is used for a reference plane, how can a diagnosis and treatment plan arrived at by one orthodontist be validated by another?

The search for a reliable reference plane has been going on for centuries. One may ask what is reliability? It is a measure of reproducibility. A perfect reliability would be expressed mathamatically as 1.0, indicating that the same results would always be obtained given the same object to analyze.[49] In orthodontics, we are looking for a reference plane that ideally is exactly reproducible by the same observer if he looked at a particular cephalograph today, tomorrow, or next year. The reference plane would also need to be reproducible by any other orthodontist at any time. If these criteria could be met, a standardized means of communication would be established among orthodontists. No such reproducibility is present in any current reference base used in static cephalometric analysis. Perhaps that is a possible reason why we have over forty different static analyses currently used by orthodontics.

This investigation has revealed that it would seem possible for an orthodontist to establish an extra-skeletal reference plane, if a specially designed analyzer is used.

It has been shown that by using this devise in his determination of a base landmark, he can have a high degree of reliability within himself (Hoyt's r=.969-990) providing he takes a sum or average of 5 readings. It also appears possible that the reference plane obtained in this manner by one orthodontist is reproducible, to a high degree of reliability by other orthodontists (Intraclass r=.89) if a group determination of a reference base was done. It means that there was apparently almost no variation present in a determination of a base plane by a group observation. To the orthodontist, it means that there may be a way of accurately producing a reliable reference plane that could be used to standardize communication among orthodontists in regards to static cephalometric analysis.

There is a possibility that the extra-skeletal reference lines proposed in this paper may approach the criteria necessary for a standardized, reliable reference plane. It is easily reproducible from a cephalogram, as the soft tissue profile is the landmark used for orientation of the tracing in the analyzer. It can be highly reliable. Communication among orthodontists using this technique seems possible. It would also provide another means to study the biologic variation of the cranial configuration of man.

REFERENCES

1. Elasser, W.A.: A Cephalometric Method for Linear Analysis of Human Profile. American Journal of Orthodontics, 43: 192-209, 1957.

2. Downs, W.B.: Analysis of the Dentofacial Profile. Angle Orthodontist, 26: 191-212, 1956.

3. Tweed, C.H.: Frankfort Mandibular Incisor Angle (FMIA) in Diagnosis, Treatment Planning and Prognosis. Angle Orthodontist, 24: 121-169, 1954.

4. Simon, P.W.: On Gnathostatic Diagnosis in Orthodontics. International Journal of Orthodontia, 10: 755-785, 1924.

5. Moorrees, C.F.: Normal Variation and Its Bearing on the use of the Cephalometric Radiographs in Orthodontic Diagnosis. American Journal of Orthodontics 12, 39: 942-950, 1953.

6. Steiner, C.C.: Cephalometrics for You and Me. American Journal of Orthodontics, 39: 729-754, 1953.

7. Thompson, J., Graeber, T., Reidel, R.: Northwestern University Analysis in Syllabus of Roentgenographic Cephalometry, Ed. by Krogman, W., and Sassouni, V. Center for Research in Child Growth, Philadelphia, 1957.

8. Margolis, H.I.: A basic Facial Pattern and Its Application in Clinical Orthodontics. American Journal of Orthodontics, 33: 631-641, 1947.

9. McGonagle, R.R.: An evaluation of the Accuracy of Cephalometric Tracings. Angle Orthodontist, 30: 134-140, 1960.

10. Moss, M.L., and Greenberg, S.N.: Post Natal Growth of the Human Skull Base. Angle Orthodontist, 25: 77-84, 1955.

11. Moss, M.L.,: The Functional Matrix in Vistas in Orthodontics. Ed. by Kraus, B.S., and Reidel, R., Lea & Febiger, 1962.

12. Salzman, J.A.: Limitations of Roentgenographic Cephalometrics. American Journal of Orthodontics, 52: 283-299, 1966.

13. Enlow, D.H.: A Morphogenetic Analysis of Facial Growth. American Journal of Orthodontics, 50: 169-188, 1964.

14. Scott, H.H.: The Cranial Base. American Journal of Physical Anthropology, 16: 319-348, 1958.

15. Ford, E.H.R.: Growth of the Human Cranial Base. American Journal of Orthodontics, 44: 498-506, 1958.

16. Bjork, A.: Cranial Base Development. American Journal of Orthodontics, 41: 198-225, 1955.

17. Garn, S.M.: In Roentgenographic Cephalometrics. J.B. Lippincott and Co., Philadelphia, 1961.

18. Graeber, T.M.: Current Concepts and Techniques. W.B. Saunders Company, Philadelphia, pgs. 16-31, 1939.

19. Krogman, W. and Sassouni, V.: Syllabus in Roentgenographic Cephalometry, Center for Research in Child Growth, Philadelphia, 1957.

20. Salzman, J.A.: Resume of the Workshop and Limitations of the Technique. American Journal of Orthodontics, 44: 901-905, 1958.

21. Bjerin, R.A.: Comparison Between the Frankfort Horizontal and the Sella Nasion as Reference Planes in Cephalometric Analysis. Acta Odontologica Scand., 15: 1-12, 1957.

22. Moorrees, C.F.A., and Kean, K.M.: Natural Head Position, A Basic Consideration in the Interpretation of Cephalometric Radiographs. American Journal of Physical Anthropology, 16: 213-233, 1958.

23. Camper, P.: Dissertation sur les Varietes Naturelles qui Caracterisent la Physionomie des hommes des divers climats et des different ages, 1792.

24. Wilder, H.H.: Laboratory Manual of Anthropometry, Blakiston's Sons & Company, Philadelphia, pages 4-5, 1920.

25. Craniometrishe Kongerenz zu Frankfurt 1884 Verstandigung uber ein gemeinsames craniometrisches Vergahren (Frankfurter Versttandigung). Archiv. f. Anthropologie, 15: 1-8.

26. Stanton, F.I.: A critique of Simon's Diagnostic Methods. International Journal of Orthodontia, 14: 26-55, 1928.

27. Broadbent, B.H.: A New X-Ray Technique and Its Application to Orthodontia. Angle Orthodontist, 1: 45-66, 1931.

28. Tweed, C.H.: The Frankfort Mandibular Plane Angle in Orthodontic Diagnosis, Classification, Treatment Planning and Prognosis. American Journal of Orthodontics and Oral Surgery, 32: 175-221, 1946.

29. Margolis, H.I.: The Axial Inclination of the Mandibular Incisor Axis in Adult "Normal" Occlusion. American Journal of Orthodontics and Oral Surgery, 29: 571-594, 1943.

30. Speidel, T.D., and Stoner, M.M.: Variation of Mandibular Incisor Axis in Adult "Normal" Occlusion. American Journal of Orthodontics and Oral Surgery, 30: 536-542, 1944.

31. Wylie, W.L.: Mandibular Incisor-Its Role in Facial Esthetics. Angle Orthodontist, 25: 32-41, 1955.

32. Lindquist, J.T.: The Lower Incisor-Its Influence on Treatment and Esthetics. American Journal of Orthodontics, 44: 112-140, 1958.

33. Sassouni, V.: A classification of Skeletal Facial Types. American Journal of Orthodontics, 55: 109-123, 1969.

34. Graeber, T.M.: Orthodontics, Principles and Practice, W.B. Saunders Company, Philadelphia, pg. 436, 1966.

35. Salzman, J.A.: Practice of Orthodontics, J.B. Lippincott Company, Philadelphia, pgs. 502-552, 1966.

36. Reidel, R.: The Relation of Maxillary Structures to the Cranium in Malocclusion and in Normal Occlusion. Angle Orthodontist, 3, 22: 142-145, 1952.

37. Vorhies, J.M., and Adams, J.W.: Polygonic Interpretation of Cephalometric Findings. Angle Orthodontist, 21: 194-197, 1951.

38. Downs, W.: Variations in Facial Relationships: Their Significance in Treatment and Prognosis. American Journal of Orthodontics, 10, 34: 812-840, 1948.

39. Broadbent, B.H.: The Face of the Normal Child. Angle Orthodontist, 4, 7:183-207,1937.

40. Bjork, A.: The Face in Profile, Svensk Tandlakare-Tiddskrift, Vol. 40, No. 5B.

41. Bjork, A.: Some Biological Aspects of Prognathism and Occlusion of the Teeth. Acta Odontologica Scand., 9:1-40, 1950.

42. Koski, K. and Virolainen, K.: On the Relationships Between Roentgenographic Cephalometric Lines of Reference. Acta Odontologica Scand., 11, 14: 23-32, 1956.

43. Graeber, T.M.: Implementation of the Roentgenographic Cephalometric Technique. American Journal of Orthodontics, 44: 906-932, 1958.

44. Nanda, S., and Sassouni, V.: Planes of Reference in Roentgenographic Cephalometry. Angle Orthodontist, 35:311-319, 1965.

45. Wei, S.H., The Variability of Roentgenographic Cephalometric Technique. Angle Orthodontist, 38:74-78, 1968.

46. Schudy, F.F.: The Rotation of the Mandible Resulting From Growth: Its Implications in Orthodontic Treatment, 35:36-50, 1965.

47. Schudy, F.F.: The Control of Vertical Overbite in Clinical Orthodontics. Angle Orthodontist, 38: 19-39, 1968.

48. Mills, P.B.: A Grid and Visual Head Positioning as Adjuncts to Cephalometric Analysis. American Journal of Orthodontics, 54: 521-531, 1968.

49. Guilford, J.P.: Fundamental Statistics in Psychology and Education, McGraw-Hill Book Company, Inc., pgs. 145, 280-281, 455, 1966.

50. Baume, L.J.: Principles of Craniofacial Development Revealed by Experimental Biology. American Journal of Orthodontics, 47: 881-901, 1961.

51. Broadbent, B.H.: Investigations on the Orbital Plane. Dental Cosmos, 69: 797-805, 1927.

52. Broadbent, B.H.: Ontogenic Development of Occlusion. Angle Orthodontist, 11:223, 1941.

53. Brodie, A.G.: Behavior of Normal and Abnormal Facial Growth Patterns. American Journal of Orthodontics, 27: 633-647, 1941.

54. Brodie, Late Growth Changes in the Human Head from the Third Month to the Eighth Year of Life. Angle Orthodontist, 23: 143-157, 1953.

55. Downs, W.A.: Cephalometrics in Orthodontic Case Analysis and Diagnosis. American Journal of Orthodontics, 38: 162-182, 1952.

56. Fleish, Slyvia, Boston University Computer Center, personal communication, January 8, 1970, and March 6, 1970.

57. Holdway, R.H.: Changes in Relationship of Points A & B. American Journal of Orthodontics, 42:176-193, 1956.

58. Krogman, W.W.: Validity of the Roentgenographic Cephalometric Technique. American Journal of Orthodontics, 44: 933-939, 1958.

59. MacEwan, C.C.: Some Illusory Phenomena of Importance in Orthodontia. American Journal of Orthodontics, 44: 46-58, 1958.

60. Salzmen, J.A.: The Maxillator: A New Instrument for Measuring the Frankfort Mandibular Base Angle, The Incisor Mandibular Base Angle, and Other Component Parts of the Face and Jaws. American Journal of Orthodontics and Oral Surgery, 31: 608-617, 1945.

61. Salzman, J.A.: In Roentgenographic Cephalometrics, Research Workshop conducted by the Special Committee of the American Association of Orthodontics, J.B. Lippincott and Company, Philadelphia, 1961.

62. Sassouni, V.: Roentgenographic Cephalometric Analysis of Cephalofacial-Dental Relationships. American Journal of Orthodontics, 41: 735-764, 1955.

63. Sassouni, V. The Face in Five Dimensions, School of Dentistry Publication, West Virginia University, Morgantown, West Virginia, second edition, 1962.

64. Scott, J.H.: Growth at Facial Sutures. American Journal of Orthodontics, 42: 381-387, 1956.

TABLE I

Measurements recorded from the angle formed at the intersection of the sella-nasion plane to a vertical landmark established by each observer

OBSERVER 1

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
	1. 88.0	1. 98.0	1. 101.5	1. 95.0
	2. 89.0	2. 98.0	2. 101.0	2. 95.0
	3. 90.0	3. 95.0	3. 103.0	3. 91.5
	4. 90.0	4. 95.5	4. 102.0	4. 92.0
	5. 89.0	5. 92.0	5. 96.0	5. 91.0
mean	89.2	95.7	100.7	92.9
s. d.	±0.7	±2.2	±2.41	±1.7
range	88.0-90.0	92.0-98.0	96.0-103.0	91.0-95.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
	1. 94.0	1. 101.0	1. 103.0	1. 98.0
	2. 91.0	2. 103.5	2. 103.0	2. 98.0
	3. 95.0	3. 104.0	3. 103.0	3. 108.0
	4. 94.0	4. 101.5	4. 103.5	4. 102.0
	5. 91.0	5. 100.0	5. 104.5	5. 104.0
mean	93.0	102.0	103.4	102.0
s. d.	±1.6	±1.5	±0.5	±3.7
range	91.0-95.0	100.0-104.0	103.0-104.5	98.0-108.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
	1. 97.5	1. 104.0	1. 95.0	1. 97.0
	2. 97.5	2. 104.5	2. 94.0	2. 98.0
	3. 96.5	3. 101.0	3. 93.5	3. 97.0
	4. 96.0	4. 102.5	4. 93.0	4. 97.0
	5. 95.0	5. 100.0	5. 91.5	5. 96.0
mean	96.5	102.4	93.4	97.0
s. d.	±0.9	±1.7	±1.1	±0.6
range	95.0-97.5	100.0-104.0	91.5-95.0	96.0-98.0

	HEAD 13	HEAD 14	HEAD 15
	1. 97.0	1. 93.0	1. 91.5
	2. 97.0	2. 95.0	2. 93.0
	3. 93.0	3. 95.0	3. 92.5
	4. 95.5	4. 93.5	4. 91.0
	5. 93.0	5. 91.0	5. 90.0
mean	95.1	93.5	91.6
s. d.	±1.8	±1.4	±1.0
range	93.0-97.0	91.0-95.0	90.0-93.0

TABLE I CONTINUED

OBSERVER 2

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
	1. 93.5	1. 98.0	1. 101.0	1. 99.0
	2. 97.0	2. 97.0	2. 101.0	2. 98.0
	3. 94.0	3. 95.5	3. 104.0	3. 91.0
	4. 97.0	4. 98.0	4. 104.0	4. 94.5
	5. 97.0	5. 99.0	5. 104.0	5. 98.0
mean	95.7	97.5	102.8	96.1
s. d.	±1.6	±1.1	±1.4	±2.9
range	93.5-97.0	95.5-99.0	101.0-104.0	91.0-99.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
	1. 99.0	1. 104.0	1. 99.5	1. 100.0
	2. 97.0	2. 105.5	2. 102.5	2. 105.0
	3. 96.0	3. 103.0	3. 102.0	3. 101.0
	4. 96.0	4. 104.0	4. 100.0	4. 105.0
	5. 96.0	5. 103.5	5. 105.0	5. 106.0
mean	96.8	104.0	101.8	103.4
s. d.	±1.1	±0.8	±1.9	±2.4
range	96.0-99.0	103.0-105.0	99.5-105.0	100.0-106.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
	1. 97.5	1. 104.0	1. 95.0	1. 97.0
	2. 97.5	2. 104.5	2. 94.0	2. 98.0
	3. 96.5	3. 101.0	3. 93.5	3. 97.0
	4. 96.0	4. 102.5	4. 93.0	4. 97.0
	5. 95.0	5. 100.0	5. 91.5	5. 96.0
mean	97.7	109.0	93.6	99.3
s. d.	±1.3	±2.3	±1.6	±2.4
range	95.0-97.5	100.0-104.0	91.5-95.0	96.0-98.0

	HEAD 13	HEAD 14	HEAD 15
	1. 97.0	1. 93.0	1. 91.5
	2. 97.0	2. 95.0	2. 93.0
	3. 93.0	3. 95.0	3. 92.5
	4. 95.5	4. 93.5	4. 91.0
	5. 93.0	5. 91.0	5. 90.0
mean	97.4	94.6	97.4
s. d.	±2.3	±0.8	±1.5
range	93.0-97.0	91.0-95.0	90.0-93.0

TABLE I CONTINUED

OBSERVER 3

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
1.	93.0	97.0	102.0	91.0
2.	91.5	97.0	104.0	96.0
3.	93.0	97.5	104.0	94.0
4.	93.0	95.0	103.0	94.5
5.	93.0	94.0	104.0	95.0
mean	92.7	96.1	103.4	94.1
s. d.	±0.6	±0.3	±0.8	±1.6
range	91.5-93.0	94.0-97.0	102.0-104.0	91.0-96.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
1.	91.0	102.0	99.5	97.5
2.	90.0	101.0	98.0	99.5
3.	94.5	103.0	97.5	101.0
4.	91.0	102.0	97.0	98.0
5.	91.0	104.0	100.0	100.0
mean	91.5	102.4	98.4	99.2
s. d.	±1.5	±1.0	±1.1	±1.2
range	90.0-94.5	101.0-104.0	97.0-100.0	97.5-101.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
1.	97.0	104.0	89.0	101.0
2.	97.0	101.0	89.0	102.0
3.	99.0	102.0	88.5	95.0
4.	100.0	102.0	90.0	96.0
5.	99.0	101.0	92.0	98.0
mean	98.4	102.0	89.7	98.4
s. d.	±1.2	±1.1	±1.2	±2.7
range	97.0-100.0	101.0-104.0	89.0-92.0	95.0-101.0

	HEAD 13	HEAD 14	HEAD 15
1.	93.0	92.0	95.0
2.	92.0	95.0	95.0
3.	90.0	91.0	93.0
4.	93.5	90.0	94.0
5.	90.0	91.0	94.0
mean	91.7	91.8	94.2
s. d.	±1.4	±1.7	±0.7
range	90.0-93.5	90.0-95.0	93.0-95.0

TABLE I CONTINUED

OBSERVER 4

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
	1. 95.0	1. 96.0	1. 102.0	1. 93.5
	2. 95.0	2. 96.5	2. 102.0	2. 91.0
	3. 94.5	3. 97.0	3. 102.0	3. 94.0
	4. 93.0	4. 96.0	4. 102.0	4. 94.0
	5. 94.0	5. 96.0	5. 99.0	5. 92.0
mean	94.3	96.3	101.4	92.9
s. d.	±0.7	±0.4	±1.2	±1.2
range	93.0-95.0	96.0-97.0	99.0-102.0	91.0-94.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
	1. 93.5	1. 103.0	1. 101.0	1. 101.5
	2. 94.5	2. 107.0	2. 102.0	2. 102.0
	3. 94.0	3. 103.0	3. 103.0	3. 103.0
	4. 92.5	4. 103.0	4. 99.0	4. 102.0
	5. 92.5	5. 102.0	5. 99.0	5. 104.0
mean	93.4	103.6	100.8	102.5
s. d.	±0.8	±1.7	±1.6	±0.8
range	92.5-94.5	102.0-107.0	99.0-103.0	101.5-104.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
	1. 95.0	1. 103.5	1. 90.0	1. 97.0
	2. 95.0	2. 104.0	2. 91.0	2. 97.0
	3. 94.0	3. 101.5	3. 90.0	3. 95.0
	4. 92.0	4. 101.0	4. 88.0	4. 96.5
	5. 94.0	5. 97.0	5. 88.0	5. 94.5
mean	94.0	101.4	89.4	96.0
s. d.	±1.1	±2.4	±1.2	±1.0
range	92.0-95.0	97.0-104.0	88.0-91.0	94.5-97.0

	HEAD 13	HEAD 14	HEAD 15
	1. 97.5	1. 91.5	1. 90.0
	2. 99.0	2. 87.0	2. 89.0
	3. 96.0	3. 93.0	3. 88.0
	4. 96.0	4. 88.0	4. 86.0
	5. 91.5	5. 91.0	5. 89.0
mean	96.0	90.1	88.4
s. d.	±2.5	±2.2	±1.3
range	91.5-99.0	87.0-93.0	86.0-90.0

TABLE I CONTINUED

OBSERVER 5

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
1.	94.0	97.0	104.0	93.0
2.	95.0	99.0	105.0	96.0
3.	96.0	104.0	104.5	98.5
4.	96.0	104.0	105.0	96.0
5.	97.0	106.0	105.0	99.0
mean	95.6	102.0	104.7	96.5
s. d.	±1.0	±3.4	±0.4	±2.1
range	94.0-97.0	97.0-106.0	104.0-105.0	93.0-99.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
1.	94.0	103.0	104.0	107.0
2.	95.5	110.0	104.5	107.0
3.	98.0	108.0	107.0	106.0
4.	98.0	105.0	106.0	107.0
5.	99.0	105.0	105.0	106.0
mean	96.9	106.2	105.3	106.6
s. d.	±1.8	±2.4	±1.0	±0.4
range	94.0-99.0	103.0-110.0	104.0-107.0	106.0-107.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
1.	96.5	108.0	92.0	97.0
2.	99.0	108.0	94.0	97.0
3.	99.0	105.0	92.0	97.0
4.	99.0	110.0	96.5	102.0
5.	97.0	110.0	98.0	101.0
mean	98.1	108.2	94.5	99.2
s. d.	±1.1	±1.8	±2.4	±2.0
range	96.5-99.0	105.0-110.0	92.0-98.0	97.0-102.0

	HEAD 13	HEAD 14	HEAD 15
1.	98.5	94.0	91.0
2.	99.5	96.0	90.5
3.	98.5	92.0	92.0
4.	99.5	96.5	95.0
5.	96.0	94.5	94.0
mean	98.4	94.6	92.5
s. d.	±1.2	±1.5	±1.7
range	96.0-99.5	92.0-96.5	90.0-95.0

TABLE I CONTINUED

OBSERVER 6

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
1.	93.5	94.0	102.5	93.5
2.	93.0	97.0	104.5	95.0
3.	94.0	96.0	104.5	95.5
4.	92.5	97.0	105.0	99.0
5.	94.0	99.5	106.5	98.0
mean	93.4	96.7	104.6	96.2
s. d.	±0.5	±1.7	±1.2	±2.0
range	92.5-94.0	94.0-99.5	102.5-106.5	93.5-99.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
1.	94.0	103.0	101.0	99.0
2.	92.0	103.0	98.0	99.0
3.	89.0	102.0	99.0	100.0
4.	90.0	105.5	98.0	101.0
5.	92.0	104.0	101.0	101.0
mean	91.4	103.5	99.4	100.0
s. d.	±1.7	±1.1	±1.3	±0.8
range	89.0-94.0	102.0-105.5	98.0-101.0	99.0-101.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
1.	97.0	104.0	88.0	95.0
2.	95.5	105.0	91.0	97.0
3.	97.0	100.0	88.0	95.0
4.	96.0	103.0	87.0	89.5
5.	98.0	102.0	86.0	93.0
mean	96.7	102.8	88.0	93.9
s. d.	±0.8	±1.7	±1.6	±2.5
range	95.8-98.0	100.0-105.0	86.0-91.0	89.5-97.0

	HEAD 13	HEAD 14	HEAD 15
1.	92.0	90.0	93.0
2.	95.0	94.0	95.0
3.	94.5	91.5	90.5
4.	91.0	91.5	94.0
5.	92.0	87.0	90.0
mean	92.9	90.8	92.5
s. d.	±1.5	±2.2	±1.9
range	91.0-95.0	87.0-94.0	90.0-95.0

TABLE I CONTINUED

OBSERVER 7

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
1.	89.0	95.0	96.5	95.0
2.	91.0	98.0	99.0	95.0
3.	91.0	98.5	100.0	97.0
4.	89.0	96.5	98.0	93.0
5.	89.0	98.0	96.0	95.0
mean	89.8	97.2	97.9	95.0
s. d.	±0.9	±1.2	±1.5	±1.2
range	89.0-91.0	95.0-98.5	96.0-100.0	93.0-97.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
1.	91.0	101.0	102.0	103.0
2.	91.0	103.5	105.0	106.5
3.	93.0	103.0	100.0	100.0
4.	93.0	103.0	99.5	103.0
5.	92.5	104.0	99.0	102.0
mean	92.1	102.9	101.1	101.9
s. d.	±0.9	±1.0	±2.2	±1.1
range	91.0-93.0	101.0-104.0	99.0-105.0	100.0-103.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
1.	95.0	103.5	90.0	94.0
2.	97.0	105.0	92.5	96.5
3.	95.0	104.0	92.0	95.0
4.	95.0	102.0	91.0	95.0
5.	96.0	105.0	93.0	94.0
mean	95.6	103.9	91.7	94.9
s. d.	±0.8	±1.1	±1.0	±0.9
range	95.0-97.0	102.0-105.0	90.0-93.0	94.0-96.5

	HEAD 13	HEAD 14	HEAD 15
1.	93.0	92.0	91.0
2.	93.5	91.0	94.0
3.	92.5	92.0	93.5
4.	92.0	92.0	92.0
5.	93.0	90.0	94.0
mean	92.8	91.4	92.9
s. d.	±0.5	±0.8	±1.2
range	92.0-93.0	90.0-92.0	91.0-94.0

TABLE I CONTINUED

OBSERVER 8

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
	1. 96.0	1. 100.0	1. 104.0	1. 97.0
	2. 93.0	2. 103.0	2. 103.0	2. 97.0
	3. 94.0	3. 97.0	3. 101.0	3. 97.0
	4. 91.0	4. 99.0	4. 100.0	4. 94.0
	5. 92.0	5. 99.0	5. 102.0	5. 93.0
mean	93.2	99.6	102.0	95.6
s. d.	±1.7	±1.9	±1.4	±1.7
range	91.0-96.0	99.0-103.0	100.0-104.0	93.0-97.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
	1. 99.0	1. 105.0	1. 102.0	1. 101.0
	2. 97.0	2. 103.0	2. 103.5	2. 104.0
	3. 93.0	3. 104.0	3. 104.0	3. 103.0
	4. 96.0	4. 105.0	4. 101.0	4. 103.0
	5. 95.0	5. 101.0	5. 100.5	5. 100.0
mean	96.0	103.6	102.2	102.2
s. d.	±2.0	±1.5	±1.3	±1.4
range	93.0-99.0	101.0-105.0	100.5-104.0	100.0-104.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
	1. 93.0	1. 105.0	1. 95.0	1. 92.0
	2. 97.0	2. 103.0	2. 92.0	2. 97.0
	3. 97.0	3. 104.0	3. 90.0	3. 96.0
	4. 95.0	4. 103.0	4. 89.0	4. 93.0
	5. 93.0	5. 100.0	5. 88.0	5. 93.0
mean	95.0	103.0	90.8	94.2
s. d.	±1.7	±1.6	±2.4	±1.9
range	93.0-97.0	100.0-105.0	88.0-95.0	93.0-97.0

	HEAD 13	HEAD 14	HEAD 15
	1. 99.0	1. 93.0	1. 96.0
	2. 94.0	2. 92.0	2. 95.5
	3. 94.0	3. 92.0	3. 96.0
	4. 92.0	4. 93.0	4. 93.0
	5. 94.0	5. 91.0	5. 94.0
mean	94.6	92.2	94.9
s. d.	±2.3	±0.7	±1.2
range	92.0-99.0	91.0-93.0	93.0-96.0

TABLE I CONTINUED

OBSERVER 9

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
1.	88.0	97.0	101.0	96.0
2.	93.0	97.0	104.0	96.0
3.	91.0	96.5	103.0	95.0
4.	92.0	96.0	103.0	96.0
5.	93.0	95.0	99.0	97.0
mean	91.4	96.3	102.0	96.0
s. d.	±1.8	±0.7	±1.7	±0.6
range	88.0-93.0	95.0-97.0	99.0-104.0	95.0-97.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
1.	94.0	105.0	98.0	106.0
2.	92.5	103.0	99.0	103.0
3.	90.0	102.0	106.0	102.0
4.	93.0	102.5	107.0	101.0
5.	91.0	100.0	105.0	98.0
mean	92.1	102.5	103.0	102.0
s. d.	±1.4	±1.6	±3.7	±2.6
range	90.0-94.0	100.0-105.0	98.0-107.0	98.0-106.0

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
1.	96.0	105.0	91.0	94.0
2.	95.0	104.0	91.0	99.0
3.	94.5	102.0	91.0	97.0
4.	96.0	101.0	90.0	97.5
5.	95.0	101.0	90.0	94.0
mean	95.3	102.6	90.8	96.3
s. d.	±0.6	±1.6	±0.4	±1.9
range	94.0-96.0	101.0-105.0	90.0-91.0	94.0-97.5

	HEAD 13	HEAD 14	HEAD 15
1.	95.0	91.5	95.0
2.	97.0	90.0	95.0
3.	96.0	88.0	94.0
4.	95.0	88.0	92.5
5.	95.0	87.0	94.0
mean	95.6	88.9	94.1
s. d.	±0.8	±1.6	±0.9
range	95.0-97.0	87.0-91.5	92.5-95.0

TABLE I CONTINUED

OBSERVER 10

	HEAD 1	HEAD 2	HEAD 3	HEAD 4
	1. 95.0	1. 101.0	1. 104.0	1. 100.0
	2. 97.0	2. 96.5	2. 103.0	2. 96.0
	3. 97.5	3. 99.0	3. 103.0	3. 97.0
	4. 95.0	4. 100.0	4. 104.0	4. 95.0
	5. 95.0	5. 96.5	5. 104.0	5. 97.0
mean	95.9	96.0	103.6	97.0
s. d.	±1.1	±1.9	±0.4	±1.6
range	95.0-97.5	96.0-101.0	103.0-104.0	95.0-100.0

	HEAD 5	HEAD 6	HEAD 7	HEAD 8
	1. 95.0	1. 106.0	1. 105.0	1. 107.0
	2. 96.0	2. 107.0	2. 108.0	2. 105.0
	3. 95.0	3. 106.0	3. 108.0	3. 106.0
	4. 97.0	4. 106.0	4. 109.0	4. 104.0
	5. 95.0	5. 106.0	5. 110.0	5. 106.0
mean	95.6	106.2	108.0	105.6
s. d.	±0.8	±0.4	±1.6	±1.0
range	95.0-97.0	106.0-107.0	105.0-110.0	104.0-107.5

	HEAD 9	HEAD 10	HEAD 11	HEAD 12
	1. 96.0	1. 110.5	1. 92.5	1. 99.0
	2. 98.5	2. 109.5	2. 90.0	2. 99.0
	3. 97.0	3. 110.0	3. 91.0	3. 97.5
	4. 98.0	4. 109.0	4. 92.0	4. 99.0
	5. 97.0	5. 109.5	5. 93.0	5. 98.0
mean	97.3	109.7	91.7	98.5
s. d.	±0.8	±0.5	±1.0	±0.6
range	96.0-98.5	109.0-110.5	91.0-93.0	97.5-99.0

	HEAD 13	HEAD 14	HEAD 15
	1. 101.5	1. 96.0	1. 99.0
	2. 100.0	2. 95.0	2. 95.0
	3. 101.0	3. 93.5	3. 95.0
	4. 101.5	4. 94.0	4. 94.0
	5. 101.0	5. 94.5	5. 94.0
mean	101.0	94.6	95.4
s. d.	±0.5	±0.8	±1.8
range	100.0-101.5	93.5-94.5	94.0-99.0

TABLE II

Mean and Standard Deviation computed from the combined mean values of all examiners for each head

HEADS	MEAN (OBSERVERS 1-10)	STANDARD D.
1	93.1	±2.2
2	97.5	±1.8
3	102.3	±1.9
4	95.2	±1.3
5	93.8	±2.1
6	103.6	±1.3
7	102.3	±2.6
8	102.5	±2.1
9	96.4	±1.3
10	104.5	±3.0
11	91.3	±1.9
12	96.7	±1.9
13	95.5	±2.6
14	92.2	±1.9
15	93.3	±2.3

TABLE III

Two Methods of Reliability

OBSERVERS	Hoyt's Reliability	Intra-class r
1	.969	.861
2	.964	.840
3	.974	.880
4	.983	.917
5	.977	.913
6	.973	.902
7	.987	.948
8	.974	.903
9	.969	.889
10	.990	.964
Observers combined	.988	.890

TABLE IV

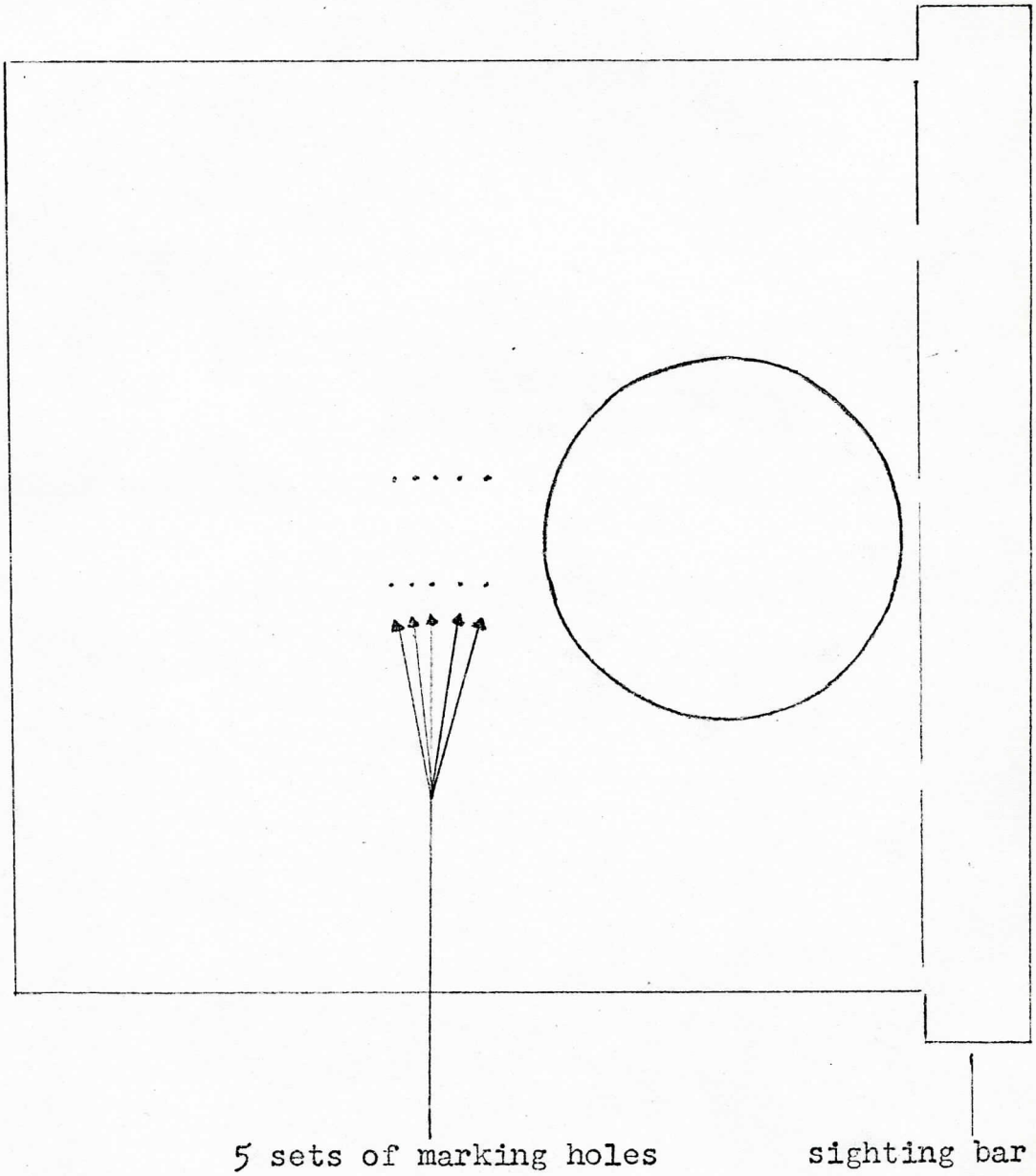
Accuracy of Measuring Method

Angles

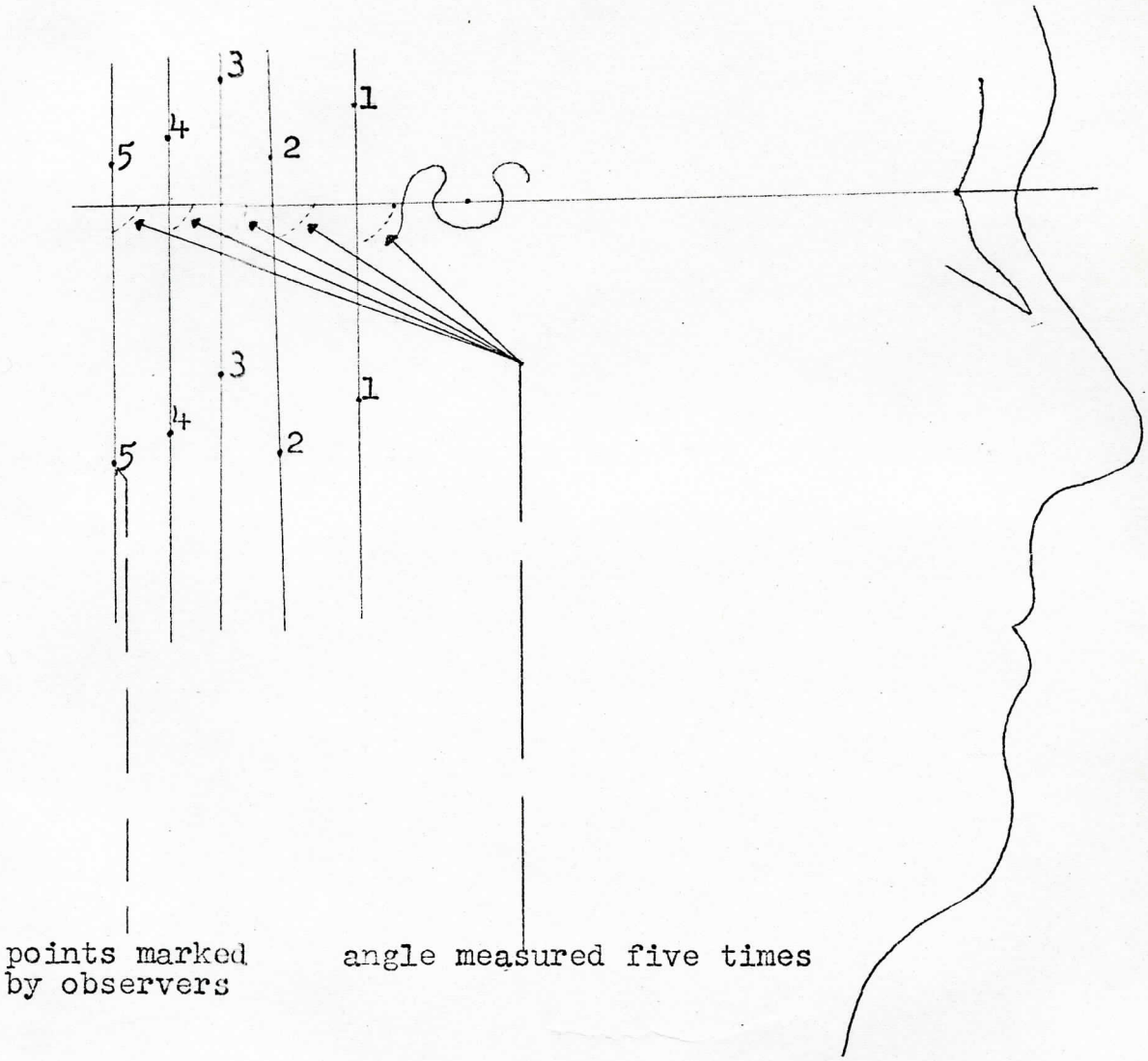
Observations	1	2	3	4	5
1	91.0	91.5	91.0	91.0	92.0
2	91.0	92.0	91.0	91.5	92.0
3	91.5	91.5	91.5	91.5	92.5
4	91.5	91.5	91.0	91.0	92.5
5	91.0	91.5	91.0	91.5	92.0
6	91.0	92.0	91.0	91.0	92.0
mean	91.166	91.666	91.083	91.250	92.166
s. d.	±0.235	±0.235	±0.186	±0.250	±0.235

FIGURE I

Diagram of analyzer developed to determine an extra-skeletal reference plane



scale: 1 inch = 7 mm.

FIGURE II

Methods of measuring the angle formed by the sella-nasion plane intersecting the vertical reference landmarks established by the observers