A COMPUTER AIDED

LATERAL CEPHALOMETRIC RADIOGRAPHIC ANALYSIS

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# INTRODUCTION

The study of the form of the human face has been one which has fascinated man since the earliest artworks were scrawled on cave surfaces during prehistoric times. Until the twentieth century, man's visualization of the human head was limited to what could be perceived through his own eyes or those of another and was limited in scope to external dimensions. With the advent and refinement of cephalometric radiographic techniques in 1931 by Broadbent and Hoffrath, a new perspective was achieved; but yet this still provided only a two-dimensional view.[26]

Cephalometric radiography provided a quantum leap from anthropometric studies in that actual measurements could now be made on living individuals, albeit only in two dimensions. Yet this method gave researchers a tool in which to study individuals serially. However, many of the changes during growth that were described were often less than the errors associated with the technique. Because of this, the clinical usefulness of cephalometric data has been questioned.[16]

Many attempts at perfecting cephalometrics to give more accurate and utilizable data have been made. None were more noteworthy than the classical implant studies of Bjork in 1955.[6,3] Bjork used metallic implants to provide more stable reference points on which to make measurements and analyze growth. Previous attempts at landmark location had been fraught with error arising from anatomic location, distortion, etc. Bjork attempted to provide a base, via his implants, upon which successive cephalometric radiographs could be superimposed and thus provide some insight for longitudinal facial growth studies.[6]

Cephalometric tracing technique and the associated error have long been a factor to consider in evaluation. Many attempts have been made to try to reduce this as the ability to have valid and reliable results rests in part with the inherent error used to determine those measures. Baumrind and Frantz in 1971 felt that errors in computing linear and angular measures on lateral headfilms stem in part from antecedent errors in landmark identification.[18,19,20] They found that the magnitude of error varied widely among the measures and that the more sharply delineated the landmark, the less was the associated error.[18]

Evaluation of cephalometric results then relies on an adequate tracing ability and the ability to confine this to a fine-line drawing and then further properly measure and interpret these as angles or distances. To reduce human manipulation would seem a feasible way to rule out some of this measurement error.

The actual interpretation of cephalometric results has also been an area in which there are widespread feelings as to what is and is not adequate. Bjork in 1955 attempted to describe his data in a schematic manner, attempting to provide some form by which he could arrive at a quick appraisal of the individual being considered, but this approach still required much hand manipulation.[3] Moorrees, also at this time, presented schematic representations of cephalometric radiographs in the form of mesh diagrams[7] yet still failed to provide any further advances or reduce human manipulation time. Irie and Nakamura in 1977 devised a method of profile interpretation using a computer program to catalog patients and provide data outputs.[8]

This paper will present a method of programming an Apple II plus computer with sufficient data to produce a printout of various angular measurements and linear distances that considerably shortens the time needed to arrive at a cephalometric appraisal of an individual. This program in its end form will not require the use of tracing paper or additional measurement paraphenalia. The necessary landmark points will be read by the computer off the cephalometric radiograph and then print out the calculated angles and distances programmed into it.

# LITERATURE REVIEW

The invention of the cephalometric x-ray technique gave to orthodontics a tool with a usefulness that has often been questioned. Hixon describes it as "the oriented roentgenogram or cephalogram which is a two-dimensional shadow picture of the three-dimensional face."[24] Yet without this two-dimensional shadow, the study of facial growth would not be where it is today.

It was Broadbent in 1931 who introduced the cephalometric technique as we know it today.[26] This gave a tool to both anthropologists and orthodontists which enabled them to make actual measurements, albeit with certain limitations, on living subjects and to "register the craniometric landmarks of the face and cranial base of the living head which heretofore had only been measured on dead skulls with a craniostat."[26] Probably Broadbent's remark that is most apropo to this situation was that standards were compiled from skulls of dead children and that most dead children were defective ones.

Refinements have been made to the technique and machines utilized by these early cephalometric pioneers, but many of the underlying problems still persist. Problems such as enlargement, distortion, penumbra effect, graininess of the film, and secondary radiation have all been reduced by refinements of technique[13,16] yet the actual tracing mechanics still pose perhaps the biggest dilemma for the cephalometric operator.

In 1956 the American Association of Orthodontists appointed a special committee on roentgenographic cephalometrics and gave its approval for a workshop to be held in March of 1957 at Western Reserve University. Included in this committee were such notable people as Allan G. Brodie, L. Higley, W. M. Krogman, William Downs, T. M. Graber, B. Holly Broadbent, Herbert J. Margolis, Anders Lündstrom, Ernest Hixon and others. The purpose of this workshop was to find some common areas of agreement with regard to (1) sites of cranial-facial growth; (2) landmarks; (3) points of reference; (4) methods of locating the foregoing; (5) points, planes and angles of measurement; (6) the significance of the various measurements obtained in the interpretation of dentofacial growth and development changes; and (7) the validity of the norms in use.[27]

In a report on the first cephalometric workshop held on March 1, 1957, at Western Reserve University, J. A. Salzmann called attention to the need for a baseline in roentgenographic cephalometrics and for an objective appraisal of the parameters established by various workers in the field. Many of these parameters had been based on insufficient sampling but yet were being used as "standards" by clinical orthodontists.[27]

This first workshop pointed out the vast disagreements among the contributors with no unanimity of opinion. Even though many points, angles, planes and minimum requirements were discussed, no degree of clinical usefulness or reliability was ascertained. Even the old standby of point sella showed considerable variation among contributors as to what should be used as a definition. At the end, however, it was agreed by all that a definite need existed to further clarify and classify these areas with which we are concerned in cephalometric diagnosis. Thus the second cephalometric workshop was scheduled and took place on July 7, 1959, at Western Reserve University.

W. M. Krogman in the second cephalometric workshop stated that "to the best of our ability, the end points that we pile up are useful and in a certain sense functional osteologic landmarks consistent with our knowledge of growth and development and, therefore consistent with the interpretation of growth changes, should be used." He further felt that no particular landmark or point will be perfect for by their very nature they cannot be; but by adhering to concise and specific definitions, we can achieve some conformity among ourselves.[27]

Cephalometric landmarks and measurement points that are the easiest to see and of most uniformity should be used, the committee decided, and among these are:

In the cranium: Bolton point, basion, sphenoccipital sychondrosis, sella turcica, "R" point (Broadbent) and nasion.

In the middle face: porion, orbitale, pterygomaxillary fissure and articulare.

In the dental area: posterior nasal spine, anterior nasal spine, point A, point B, pogonion, gnathion, menton and gonion.

Based on the research of Dick, Koski, Virolanin, Bjork and Lundstrom, the more variable points found were Bolton point, basion porion, pterygo-maxillary fissure, orbitale, sphenoccipital synchondrosis, gonion, anterior and posterior nasal spines and point A. Even though these landmarks are in the variable category, individual uniformity could be found. Again this rested on the researcher's ability to follow criterion for landmark definition.[5,15,27]

No matter what the landmarks selected by an individual for a representative cephalometric analysis are, there should be three main components: a skeletal analysis, a profile analysis and a denture analysis. The skeletal analysis' main objective should be to provide a basic appreciation of facial type and an appraisal of anteroposterior apical base relationships. The committee felt that point A and point B (the corresponding angles being SNA and SNB) were the primary points of choice in a skeletal analysis.[27]

The profile analysis, as discussed by the committee, should be primarily of soft tissue origin and adapted to the bony profile, or lip posture, etc. Yet skeletal angular criteria would influence the profile and measurements such as SNA can take this into account.[27]

Describing the denture analysis should include those elements that appraise both tooth relationships with one another and with their respective bony bases. Axial inclinations of incisors should also be considered as well as respective relations to cranial and mandibular planes. The committee felt also that anteroposterior relationships should be described in some way.[27]

Baumrind and Frantz pointed out in 1971 that no matter how well we define our landmarks or what is chosen for inclusion in the cephalometric analysis, when we get to the actual measurement of the headfilms, there is some question as to the reliability of those measurements; and these errors in landmark identification are of too great a magnitude to be ignored even though one may be replicating his assessments of the same headfilm. Secondly, that the magnitude of error varies greatly from landmark to landmark; and, third, that the "distribution of errors for most landmarks is not random but is, rather, systematic in that each landmark has its own peculiar envelope of error."[18,19,14]

There was a suggestion made by these authors that the impact of the observed errors in landmark location on clinical decisions can be reduced through the routine use of replicated estimates for each landmark. However, this is totally impractical unless one has access to automatic data-reducing equipment (i.e. a computer). With a computer replicate measures become easy and commonplace rather than the exception.[18]

In a follow-up study on the reliability of headfilm measurements, Baumrind and Frantz further stated that errors in computing linear and angular measures on lateral headfilms stem in part from antecedent errors in landmark identification and that the magnitude of error varied widely among the measurers. Again emphasis was made to include the use of replicate measures and the need for some sort of computerized cephalometric analysis.[19,22]

With Baumrind and Frantz advocating the use of a computer to provide a more reliable cephalometric evaluation, there followed, in 1972, a series of articles on the use of computers in orthodontic analysis and diagnosis. It was W. M. Krogman who said that the application of the computer to orthodontic research and diagnosis was as inevitable as death and taxes.[12]

Krogman felt that there were two basic aims now in orthodontics as he saw it: quantification (dimensions, ratios, angles) and standardization (a method which guarantees comparability, age to age and child by child); and that if we are to achieve this with the minimum amount of error involved, then we must integrate the computer into our approach to cephalometric analysis.[12]

Savara, in 1972, felt that in the future there would be a need for the construction of more accurate and reliable norms unattainable without the aid of the computer.[10] The computer would become a vital piece of machinery to allow quick assessment of vast amounts of raw data.[11]

With the entry of the computer into the field of orthodontics and its ability to be connected to various types of plotting devices, many researchers saw the chance to develop their own types of cephalometric analyses with the computer possessing the ability to return this information in innumerable ways.[9,10,11] Irie and Nakamura[8] integrated the use of a computer into their diagnosis and treatment planning for Class III types of malocclusions. Using specified landmark points they were able to direct the computer (and associated plotter) to print out a format of calculated angles and distances on the patient (derived from a lateral cephalometric radiograph) as well as a profilogram or schematic representation of the patient.

Schematic representations of patients had been done by earlier workers (Bjork in 1953 and Moorrees, 1953) where interconnected landmark points were used or mesh diagrams created.[1,2,3] These schematic representations were used to assess certain facial tendencies and required a certain amount of work to construct. Irie and Nakamura, however, merely entered landmark points into the computer and out came the information. Suffice it to say that there was considerable time spent in the research and development of a program for the computer that enabled all of this to occur.

With the establishment of the need for reliable cephalometric data produced with a minimum amount of measurement error, it seems only logical to conclude that the use of some computerized analysis of cephalometric radiographs is needed. This will allow for quick replicate measures to be made with a reduction in the measurement error,[18,19] providing the proper program for the computer is constructed.

# MATERIALS AND METHODS

A preliminary sample was obtained of six individuals: two under the age of 12 (one male and one female), two under the age of 20 (one male and one female), and two over the age of 20 (one male and one female). From these patients' records cephalometric radiographs were obtained. Medium weight transparency film in 8½ x 10-inch size obtained from the National Education Corporation was next affixed to those cephalometric radiographs and landmark locations scratched onto the surface (delineated by a small x). This was accomplished with the use of a .3 mm pen equipped with a needle point. The transparencies were then placed over black paper (to better distinguish the landmark locations) and the centers of each point punched through with a .5 mm needle point pen (see Figure 1). The landmarks used in the establishment of the data in this study are found in Appendix A.

These landmark points will be used in the construction of a profilogram (see Figure 2) as well as input data for the computer in the computation of various angles and distances.

These acetate transparency films were then affixed to an Apple Graphics tablet and landmark points then entered into an Apple II plus computer with a two disk drive connected to an Epson MX-80 printer. The Apple II plus computer was then programmed to receive this data and then transfer it to a cassette recorder for storage. After a sufficient number of patients were cataloged in this way, the information was then retransferred back into the computer for the calculation of the following angles and distances (see Appendix B).

The printout produced by the Apple II plus computer (Table I) shows the name of the patient, their age at cephalometric evaluation, and the date at said evaluation as well as a display of the calculated angles and distances. The steps necessary to produce the cataloged display and utilize this computer program are listed in Table II.

# FINDINGS

This computer program produced an array of angles and distances as measured from a lateral cephalometric radiograph taken on each of six patients; two under 12, two under 20 and two over 20 with each age group consisting of one male and one female. The measurements on each individual were checked by conventional cephalometric tracing methods to insure the accuracy of the computer program. Some preliminary faults were found, but the final program has proven to be without error and quickly produces results that are consistent with conventional cephalometric measurement techniques.

The calculated angles were:

S-N-A

S-N-B

S-N-$MX_1$

$MX_1$-$MD_1$

$MD_1$-MP

AR-GO-PO

S-N-MP

AR-S-N

AR-GO-ME

The calculated distances were:

ANS-PNS

$MX_6$-ANS

$MD_6$-ANS

O.J.

O.B.

N-ANS

ANS-Me

% M.F. Ht.

M.D. Length

AR.-GO

GO-PO

AR-Me

# DISCUSSION

In the field of orthodontics, the ability to have clear, concise and accurate data to aid in diagnosis and treatment planning plays an integral role. To take a cephalometric radiograph, trace it out on acetate tracing paper, then measure all the necessary angles and distances and finally relate this to some set of norms takes an incredible amount of time, especially in a busy practice where any excess time spent will only cost money or patients lost. Hence, in many busy orthodontic practices, what usually ends up happening is that truly adequate data is not assembled but is instead given way to "window looks" at cephalometric radiographs and guesses made as to what is actually there. Granted that it has been said that sometimes too much is played by the numbers game[16] but having accurate measurements that are not time consuming would certainly be beneficial.

The method of arriving at cephalometric data proposed in this paper produces results which are subject to some operator error and inconsistencies but decreases the time taken to produce the same results via the conventional cephalometric tracing technique by a considerable amount. The computer is also programmed to produce a clear array of orderly arranged angles and linear distances as well as providing a profilogram of the patient that allows a better visualization of the patient than "window looks" at bony contours.[16,17]

The angular and linear distance measurements chosen for inclusion in this program were picked to provide as concise an evaluation as could be ascertained without becoming redundant. Yet this program contains sufficient data to produce an individual profile that can be compared to normative figures and thus arrive at an adequate appraisal of this individual. Realizing that no set of figures will provide sufficient data to please everyone, an attempt was made in this project to give an adequate appraisal of the maxilla and mandible as well as the teeth within these structures as they relate to each other and to the cranial base.

An attempt was made in this project to utilize angles which were related to the cranial base rather than to Frankfort Horizontal which was felt to provide a more stable reference point from which to measure.[27] The angle SNA was chosen to represent the relationship of the maxilla to the cranium because of its widespread usage and ease of determination. Likewise SNB was chosen to represent the mandibular relationship. To assess anterior tooth position the angle of the maxillary central incisor to the line S-N was chosen as well as the inter-incisal angle between the maxillary and mandibular central incisors and the angle of the mandibular central incisor to the mandibular plane. The mandibular plane, as determined by the angle formed by the intersection of the two lines Go-Me and S-Na, is found useful by many practitioners in assessing some malocclusions. To give a picture of the shape of the mandible, the gonial angle was also included. Other angles also included were the Ar-S-Na angle and Ar-Go-Po angle.[27]

Also included in this program were various distances that are helpful in assessing many malocclusions and in current usage by many practitioners. These include ANS to PNS, the overjet, the overbite, the midfacial height, the lower facial height, the percentage midfacial height and the mandibular length. Other measurements that were included are the relationship of the maxillary and mandibular first molars to the anterior nasal spine, the lengths of the ramus (Ar-Go), the length of the body of the mandible (Go-Po) and a mandibular length not including the chin button (Ar-Me).

The primary goal of this project was to provide a program that would give an adequate amount of data from a cephalometric radiograph and be printed out so that it was well organized and easily read. From this stored data the computer produced a printout which included the patient's name, age at which the radiograph was taken and patient's age as well as a listing of the computed angles and distances. It was felt that from this data an adequate appraisal could be made of the individual.

One minor problem encountered in this program was the need to transfer information from the computer into a cassette recorder and then again transfer it from the recorder back into the computer. This took some extra time but provided a check to the program. Future additions to this program will be able to circumvent this step. There was also the need to manually adjust the MX-80 printer each time a patient's data was printed out to prevent the dotted perforation line from appearing in the center of the printed data.

The total cost of this package will result in the capital outlay of approximately $4,000 but this amount fluctuates widely depending on special sales of individual components. Overall, though, the cost is still not so prohibitive so as to prevent its purchase, considering the time saved and the importance of the data presented.

There remains yet to be some additions to the program developed in this project. A future addition to the program could be made such that the first 16 landmark points would be connected to produce the profilogram that is included in the appendix. Later additions to this program could be made so that a table of means and standard deviations would be printed out with the results of the angular and linear measurements. There was sufficient space left on the data sheet for this and waits only for an adequate sample to be made and the program modified accordingly. Another addition to the program would allow for the computer to superimpose succeeding profilograms of the same patient to compare growth in particular areas as well as assessing the overall change in profile.

Lastly, the program remains to be finalized so that the use of the cassette recorder will be negated and allow entry directly onto the disk storage, thus further reducing the time required to obtain the results.

## SUMMARY AND CONCLUSION

In summary this project produced a computer program that makes use of 19 landmark points to produce a printout of nine angular measurements and 12 linear distances. This information is printed on conventional computer printout paper by an Epson MX-80 printer using information from an Apple II plus computer. The information is printed on the left-hand side of the paper with adequate space left for the incorporation of means and standard deviations to be done in a future project.

The time required to produce the end results of this data are considerably shorter than that required by conventional cephalometric tracing and measuring techniques. This should be of interest to any orthodontist who has a busy schedule where he wants clear, concise and relevant data produced in as short a time as possible. The cost factor at around $4,000 for the entire package is at a price that might encourage purchase by most orthodontic offices.[28]

Future additions to this program could be added to provide a graphic table of means and standard deviations to the right of each angle and distance on the printout. The computer could be further programmed to connect the first 16 landmarks to produce a profilogram printout of each patient and then later retain the ability to superimpose future evaluations. This could all be done without the use of an intermediary cassette recorder using instead the disk drive storage system, thus saving even more time.[28]

A final point to consider is the measurement error involved in producing these results. A further replicate study might also compare measurement error in this type of technique as contrasted to that obtained using conventional cephalometric tracing techniques and measurements.

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FIGURE 1

Acetate Paper with Landmark Points Delineated

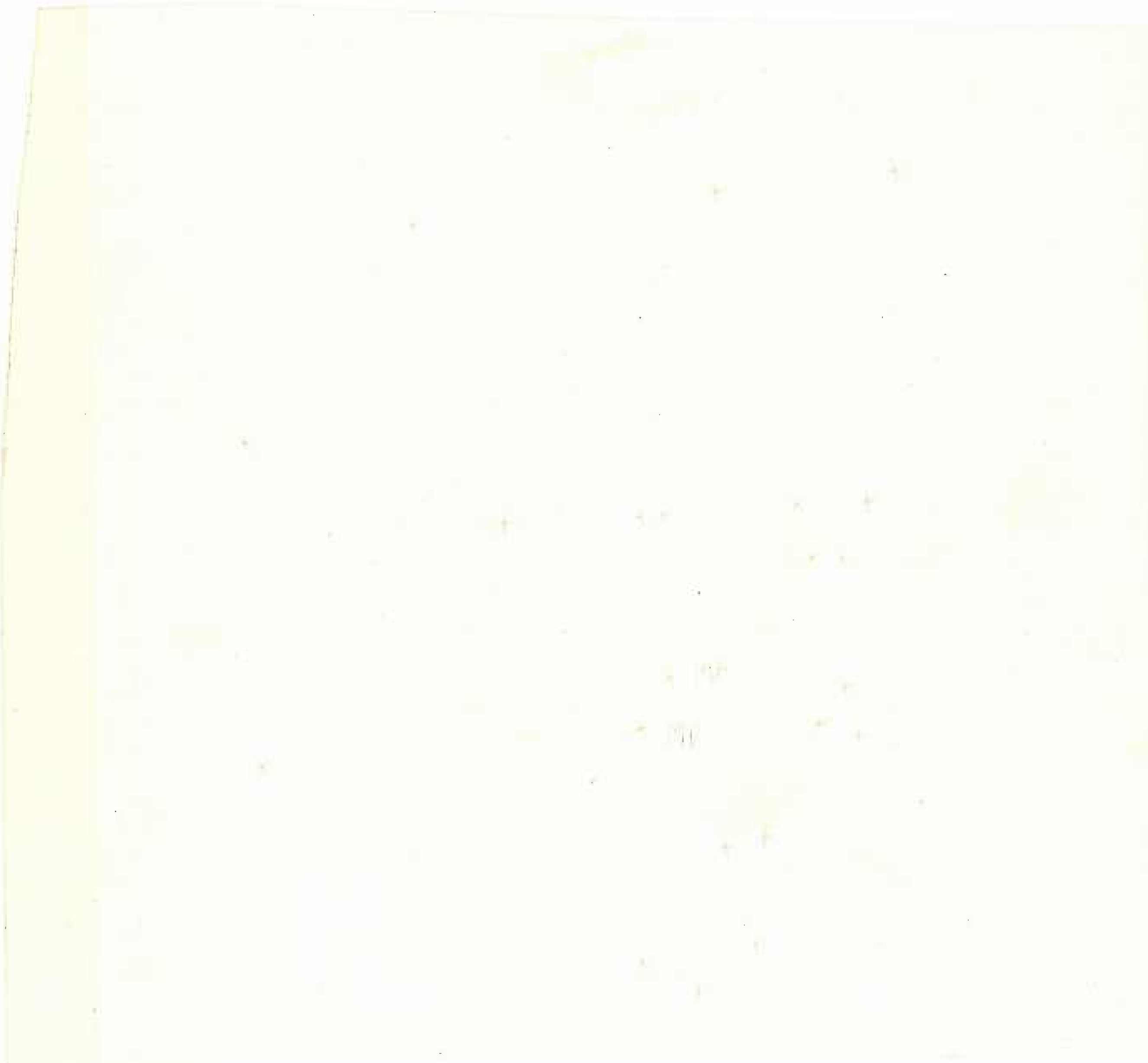

FIGURE 2

Profilogram Constructed By Connection of First 16 Landmark Points

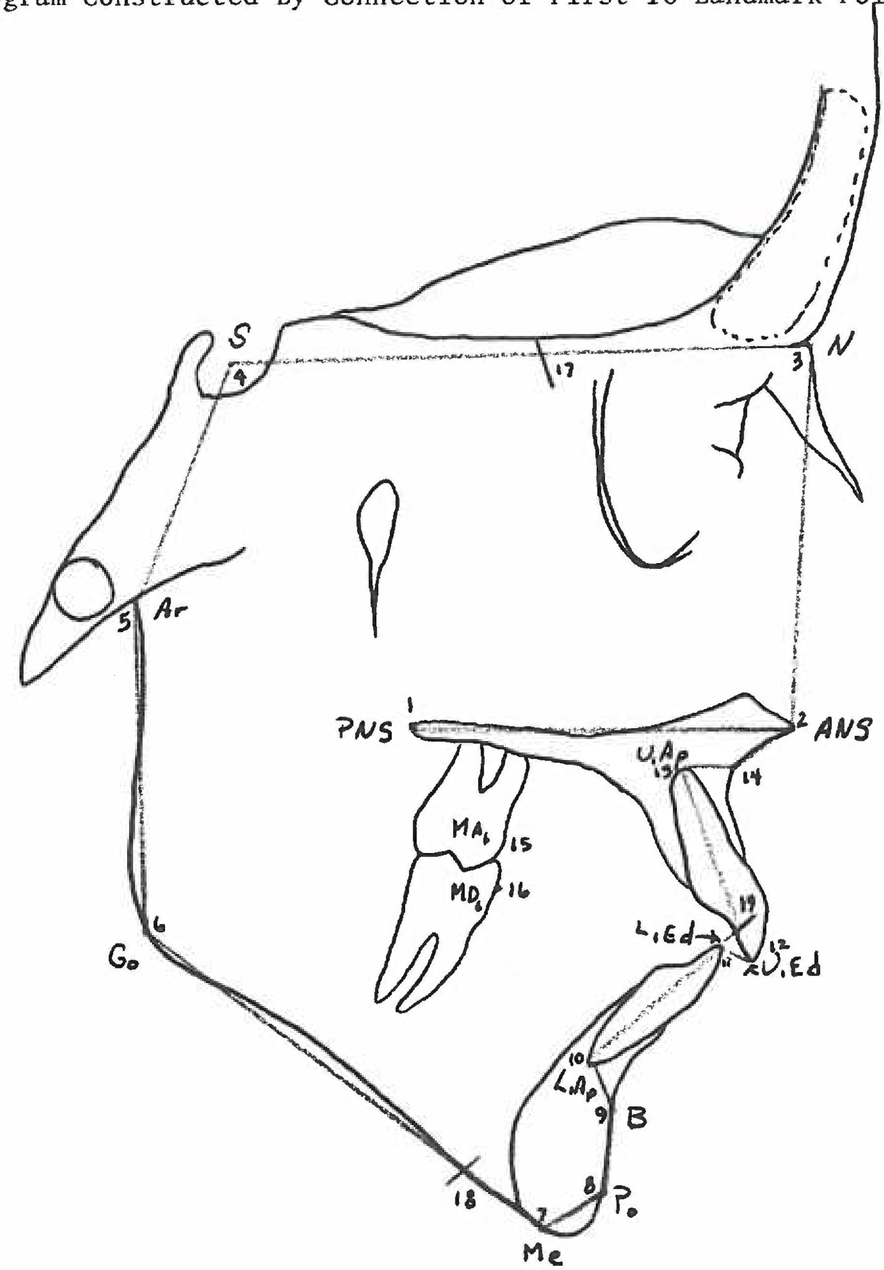

TABLE I

TABLE OF ANGLES AND DISTANCES PRINTED OUT BY THE APPLE II PLUS COMPUTER

PATIENT NAME: KEVIN HRYCIW

AGE: 10-10

DATE OF EVALUATION: 11-2-82

---

| ANGLES | DEGREES |
|---|---|
| S-N-A | 75.66 |
| S-N-B | 73.82 |
| SN-MXI | 103.16 |
| MXI-MDI | 119.34 |
| MP-MDI | 90.56 |
| AR-GO-PO | 128.92 |
| SN-MP | 44.45 |
| AR-S-N | 127.80 |
| AR-GO-ME | 136.64 |

| DISTANCES | MILLIMETERS |
|---|---|
| ANS->PNS | 50.10 |
| MX6->ANS | 34.79 |
| MD6->ANS | 30.75 |
| O.J. | 3 .0 |
| O.B. | 0.15 |
| N->ANS | 50.68 |
| ANS->ME | 72.68 |
| % M.F.HT. | 41.77 |
| MD.L. | 101.04 |
| AR->GO | 38.25 |
| GO->PO | 72.52 |
| AR->ME | 98.64 |

TABLE II

SEQUENCE OF STEPS NECESSARY TO RUN ORTHOPLOT-1 PROGRAM

1. Type (Load Orthoplot-1)

2. Type (run) set tablet pointer on first point, then--

3. Press (return)

4. Set pointer to next point. Press to engage switch, then--

5. Press letter (c)

Repeat #4. & 5. until all data points have been entered for the case, then:
(a) note reading on tape counter; (b) Start the tape machine in record mode--

6. Press letter (E) & wait until speaker has "beeped" 4 times. Stop the recorder & note tape counter reading.

Repeat #s 2. through 6. until all desired cases have been entered; then-

7. Type (PR#6)--When the disk drive quits running--

8. Type (load orthocalc)

9. Turn printer on and align paper

10. Type (run) then press (return)

11. Enter data as requested by the computer. After each data set has been entered from the tape, computer will calculate and print out the angles & distances for that patient. To enter next patient data, repeat lines 9., 10, & 11.

# APPENDIX A

The following is a list of definitions of the landmark points used in the calculations on this profilogram:

1. ANS - Anterior Nasal Spine - This point is the tip of the anterior nasal spine and prosthion (Downs).
2. PNS - Posterior Nasal Spine - The tip of the posterior spine of the palatine bone in the hard palate.
3. N - Nasion - The intersection of the internasal suture with the nasofrontal suture in the midsagittal plane.
4. S - Sella turcica - The midpoint of sella turcica, determined by inspection.
5. Ar - Articulare - The point of intersection of the dorsal surface of processus articularis mandible and os temperale. The midpoint $A_1$ is used where double projection gives rise to two images, $A_1$ and $A_2$.
6. Go - Gonion - The lowest, posterior and most outward point of bisection formed by tangents to the lower and the posterior borders of the mandible. When both angles appear on the same film, then the midpoint between the two is used.
7. Me - Menton - The lowest point of the median plane in the lower border of the chin. It is the midpoint between the most anterior and inferior point on the bony chin.

8. Po - Pogonion - The most anterior, prominent point on the chin on the anterior border.

9. B - B Point - That point of intersection on the anterior shadow of the border of the mandible arising from a perpendicular bisection line between Infradentale and Pogonion.

10. $L_1$Ap - Lower Central Incisor Apex - The root apex of the most anterior mandibular central incisor.

11. $L_1$Ed - The incisal edge of the most anteriorly located mandibular central incisor.

12. $U_1$Ed - The incisal edge of the most anteriorly located maxillary central incisor.

13. $U_1$Ap - Upper central incisor apex - The root apex of the most anteriorly located maxillary central incisor.

14. A - A Point - That point of intersection on the anterior shadow of the maxilla arising from a perpendicular bisection line between ANS and Prosthion.

15. $MA_6$ - The most anterior point on the contour of the crown of the maxillary first molar. If there are two images present, then a bisection point between these two images shall be used.

16. $MD_6$ - The most anterior point on the contour of the crown of the mandibular first molar. If there are two images present, then a bisection point between these two images shall be used.

17. $P_1$ - The point of intersection between the line S-N and the long axis of the most anteriorly located maxillary central incisor.

18. $P_2$ - The point of intersection between the line Go-Me and the long axis of the most anteriorly located mandibular central incisor.

19. $P_3$ - The point of intersection on the line between $U_1$Ed-$U_1$Ap and the long axis of the most anteriorly located mandibular central incisor.[3,27,8]

# APPENDIX B

In the construction of this computer program, the following angles and distances were used:

| ANGLES: | DISTANCES: |
|---|---|
| S-N-A | ANS-PNS |
| S-N-B | $MX_6$-ANS |
| $SN-MX_1$ | $MD_6$-ANS |
| $MX_1-MD_1$ | O.J. |
| $MP-MD_1$ | O.B. |
| Ar-Go-Po | N-ANS |
| SN-MP | ANS-ME |
| Ar-S-N | % M.F. Ht. |
| Ar-Go-Me | MD. L. |
| | Ar-Go |
| | GO-Po |
| | Ar-Me |

The above angles and distances may be defined as follows:

1. S-N-A - That angle formed by connecting the three points Sella, Nasion and A point and lying within the profilogram.
2. S-N-B - That angle formed by connecting the three points Sella, Nasion and B point and lying within the profilogram.

3. SN-$MX_1$ - That angle formed by connecting the line Sella-Nasion with the long axis of the most anteriorly located maxillary central incisor and lying within the profilogram.

4. $MX_1$-$MD_1$ - That angle formed by the intersection of the long axis of the most anteriorly located maxillary and mandibular central incisors and lying within the profilogram.

5. MP-$MD_1$ - That angle formed by the intersection of the mandibular plane and the long axis of the most prominent mandibular central incisor and lying within the profilogram.

6. Ar-Go-Po - That angle formed by connection of the three points articulare, gonion and pogonion with gonion being the apex of the angle and lying within the profilogram.

7. S-N-Mp - That angle formed by the intersection of the line Sella-Nasion with the line gonion-menton.

8. Ar-S-N - That angle formed by the intersection of the three points sella, nasion and articulare with sella being at the apex and lying within the profilogram.

9. Ar-Go-Me - That angle formed by the intersection of the three points articulare, gonion and menton with gonion being at the apex and lying within the profilogram.

10. ANS-PNS - The linear distance between the points ANS and PNS.

11. $MX_6$-ANS - The linear distance from a point on the ANS-PNS line to the point ANS as determined by the X coordinate of $MX_6$.

12. $MD_6$-ANS - The linear distance from a point on the ANS-PNS line to the point ANS as determined by the X coordinate of $MD_6$.

13. O.J. - The horizontal distance between the incisal edges of the most anteriorly located maxillary and mandibular central incisors.

14. O.B. - The vertical distance between the incisal edges of the most anteriorly located maxillary and mandibular central incisors.

15. N-ANS - The linear distance between the points nasion and anterior nasal spine, a measure of the midfacial height.

16. ANS-Me - The linear distance between the points anterior nasal spine and menton, a measure of the lower face height.

17. % M.F. Ht. - That percentage determined by dividing the distance N-Me by the distance N-ANS and multiplying by 100. This percentage represents a proportion of the midfacial height to the total facial height.

18. Md. L. - The linear distance between the points articulare and pogonion. This represents the total mandibular length and takes into account the bony chin button.

19. Ar-Go - The linear distance between the points articulare and gonion. This distance represents a measurement of the mandibular height.

20. Go-Po - The linear distance between the points gonion and pogonion. This distance gives a representation of the length of the body of the mandible.

21. Ar-Me - The linear distance between the points articulare and menton. This distance gives a representation of the length of the mandible (including the ramus) but not including the bony chin button.[3,27,8]