NORMATIVE CEPHALOMETRIC DATA FOR OREGON CHILDREN AGED 12 TO 16

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INTRODUCTION

Radiographic cephalometrics has been an integral part of the orthodontic profession since its inception. Introduced independently in 1931 by Hoffrath in Europe and Broadbent in the United States, the primary professional objective was the development of a craniofacial analysis which would accurately describe the normal range of individual variation. This development allowed for the recognition of those cases that did not fit into the so-called normal range or that were considered to be skeletal dysplasias. A few of these recognized analyses were done by Downs in 1948, Riedel in 1952, Wylie in 1952, and Steiner in 1953.[6,16,19,21] Many other such analyses have been developed to date.

It was not long before early orthodontic researchers recognized that additional information could be gathered from the radiographic cephalogram. Biometric longitudinal studies of large numbers of children, using the cephalogram, were undertaken in hopes of gaining some insight into the growth and development of the normal human face and jaws. In addition, studies using the cephalogram were undertaken in order to accurately describe changes that were occurring due to orthodontic treatment. Lastly and probably the least emphasized, although many consider it to be the most important aspect of radiographic cephalometry, is the use of the cephalogram for the purpose of screening for craniodentofacial pathology, such as the cleft palate and congenitally deformed patient.

Since the age of the computer has come upon us, several computer-aided analyses have been developed to add to the large number of existing conventional analyses. These various programs do not purport to more accurately assess the cephalograms; however, they do offer a more rapid means of cephalometric data presentation if there is immediate access to a computer.

The purpose of this investigation is to develop cephalometric statistical data (means, standard deviations and standard error of the mean) for the in-office Apple II E orthoplot program[18a] for 12 to 16-year-old males and females possessing Angle Class I molar occlusion. The development of such an in-office program with accompanying standards enables the orthodontist to more rapidly and efficiently analyze a cephalogram using standards developed exclusively for this particular program not relying on standards developed for previous investigations.

LITERATURE REVIEW

Numerous orthodontic cephalometric analyses have been developed over the past 50 years. Accompanying the development of such analyses has been the development of cephalometric standards (i.e. mean, standard deviation, standard error of the mean, etc.) for various select groups. These standards have been used in many different ways ranging from diagnosis and treatment planning to the so-called "science" of growth prediction. The decisions for the manner in which these standards are used should be based on several factors: 1) the orthodontist's understanding of the norm concept, 2) the sample and statistical methods used in the development of the standards, 3) the reliability of cephalometric analyses and 4) growth and development changes of the dentofacial complex.

The norm concept has been an integral part of orthodontics since the first appliance was introduced into the stomatognathic system for the purpose of correcting an abnormality of tooth position or malocclusion. One of the earliest, if not the first investigator of the norm concept with respect to orthodontics was none other than E. H. Angle. In 1899 Angle[1] published his classification scheme for malocclusions of the dentition. The classification system he proposed was based on his concept of normal (i.e. ideal) occlusion. Development of this concept did not appear to be statistically supported; rather, Angle simply defined the occlusal relationships of an ideal occlusion according to his interpretation. He then proceeded to classify variances from this "normal occlusion" thus establishing the well-known Class I, Class II and Class III, Angle's classification scheme.

Although Angle's discussion on normal occlusion cannot be considered a classic example of the use of norm concept, it did establish a starting point for patient description and communication among the profession. Additionally, he established the groundwork for future studies concerning the norm concept with respect to the orthodontic patient. Even though many articles were published in the early orthodontic literature concerning the shortcomings of the Angle's classification system, it is probably the most widely accepted system in use today. This system or variations there of have been used in numerous studies dealing with the development of standards for the purpose of sample selection.

By 1920 there was some confusion as to the meaning of normal. Previous authors had used normal in referring to ideal while others had used normal as an expression of a characteristic common to a majority of the patients in the population. During this same year Johnson[9] published an article dealing with the importance of clarifying the meaning of normal. He stated, "the concept of the normal, what it means, what it signifies, is at the very foundation of dentistry, and its careful analysis is a practical necessity to the progress of the science."

Johnson's[9] definition of normal was that condition which comes within the range of variation characteristic of the majority of the members of the group to which the individual belongs. This article was of particular importance in that it not only discussed the concept of normal as being a range of acceptable variation, but also emphasized the importance of the norm concept to the field of orthodontics.

Controversy continued over the various uses and definitions of normal. In 1947 Smith[18] published an article which questioned the use of a mean or average value to describe normal. Using a satyrical style, Smith stated that no matter how far you look, it is unlikely you will ever find anyone that is exactly normal with respect to mean values of the numerous parameters. It may be assumed from this writing that Smith was an avid supporter of the expression of normal as a range rather than a single value of central tendency.

In this same year Bjork[5] submitted a study for the purpose of analyzing the nature of prognathism, to determine the normal range of variation in the facial skeleton in the Swedish population and to determine the growth changes that occur in that population. In the study, Bjork's first sample included 322 Swedish boys passed the age of 12 but not yet 13. His second sample included 281 Swedish conscripts passed the age of 21 but not 23. The only requirements for selection to the sample were:

1) must be males of appropriate age.
2) cannot be missing more than single teeth.
3) cannot be wearing any prosthetic device.

Oriented cephalograms were taken on all subjects. Twenty-four points were located on the cephalograms and numerous angular and linear measurements were made using these reference points. Using standard statistical methodology, Bjork determined the mean, standard deviation, standard error of the mean, standard error of the measurement, and coefficient of variation for each measurement of each sample.

This particular study by Bjork[5] was an excellent example of establishing the normal range of variation of the facial skeleton. He did not try to evaluate growth; rather, he just described the range of normal using statistical methods. The primary problem with the study is that the values determined are only applicable to Swedish boys, 12 to 13, or Swedish men, older than 21 years.

Just a year later in 1948, Downs[6] presented his well-known paper which was "undertaken to determine the range of facial and dental pattern within which one might expect to find the normal." In his study Downs used the cephalometric radiographs of 20 individuals (10 males and 10 females), ages 12 to 17 years, to determine the mean, standard deviation, and range for several linear and angular measurements. The individuals were selected on the basis of age, sex and the possession of excellent occlusion and facial harmony. The values determined have come to be known as the Downs analysis and are used as standards by many orthodontists for the evaluation of an orthodontic patient.

The standards developed by Downs[6] appear to have two major flaws: 1) sample selection was so subjectively colored that the values would not be considered completely valid, and 2) the number of cases included in the sample was too small to give a valid evaluation of the normal range of variation.

A few years later, in 1951, Baum[2] felt there was a need for the development of age-specific standards for patients of an ethnic background in his specific location of practice. In order to do this he selected 62 white children (boys and girls) of the Seattle area, ages 11 through 13. All subjects had "clinically excellent occlusion." No other selection criterion were stated. Baum constructed statistical standards for linear and angular measurements of previously outlined cephalometric analyses. Since his sample selection was sufficiently large and based only on age, sex, ethnic origin and occlusion, the standards developed would appear to be applicable, however, only to a limited population of patients.

In 1952 Riedel[16] developed his cephalometric analysis and accompanying standards to describe the relationship of the maxillary structures to craniofacial structures. His sample was divided into three groups: 1) 52 adults ages 18 to 36, with excellent occlusion; 2) 24 children ages 7 to 11, with excellent occlusion; 3) 38 adult individuals with Angle Class II division 1 malocclusion. Riedel found there was a significantly different anteroposterior relationship of the mandible to the cranial base between the adults with excellent occlusion and the adults with the Angle Class II division 1 malocclusion. He also corroberated the findings of others that there are significant changes in numerous linear and angular measurements when comparing children to adults. These findings point out the limitations sample selection places on the standards developed for the various analyses.

In 1953 Steiner[19] presented a paper entitled "Cephalometrics for You and Me." In the paper he introduced a cephalometric analysis and accompanying standards which were intended as treatment goals or objectives. His sample selection for the development of the standards was not completely apparent; however, it does appear that he may have used what he considered to be well-treated cases. With this type of completely subjective sample selection, the accompanying standards would only be useful to Steiner himself for analyzing how a particular finished case compared to his definition of a well-treated orthodontic case. However, if a practitioner is comfortable with Steiner's assessment of a well-treated case, he may use Steiner's standards for comparison as well.

That same year Harold Schwartz[17] presented an excellent paper that investigated the development of the norm concept as it relates to orthodontics. From examination of many of the writings previously mentioned, Schwartz concluded the following: "failure to achieve the ideal norm has forced investigators to recognize limitations in treatment imposed by the resistance of the individual dentofacial or morphogenetic pattern to extensive change."[17] Based on Schwartz's conclusions it could be stated that he was no longer an advocate of the use of norms for the purpose of establishing treatment goals. However, the use of norms for descriptive or diagnostic purposes could be considered a very important aspect of orthodontic therapy.

Just two years later another excellent contribution to the understanding of the norm concept was presented. In his paper Koski[11] discussed the general acceptability and applicability of norms and standards with respect to the methodology in which they were computed. He outlined two basic ways in which these norms are developed:

1) on the basis of a clinical concept of normal
2) on the basis of statistical research.

The norms established using clinical concepts of normal are blatantly subjective while those established using statistical methodology are objective, provided proper methodology is employed. However, Koski also pointed out that clinical norms can be divided into two categories depending on whether they were developed exclusively on the basis of clinical vision or whether they were based on statistical analysis of data selected using clinical vision. With this in mind, Koski then completely rejected the general applicability of norms based on clinical vision alone. He did however feel there may be some value in norms based on statistical analysis of data selected by using a clinical concept of normal. The "clinical normal" used in the sample had to be easily established and universally accepted. An example of one such "clinical normal" is Angle Class I molar occlusion. If the sample selection is based on such things as esthetic harmony, perfection or beauty contest winners, the general applicability of the norm should be considered nil.

Koski[11] considered norms based on statistical analysis alone as being generally applicable if limitations of such are known. The limitations are primarily that the norms established in this manner are only useful if the material compared to the norms are from the same population as that of the sample.

A year later in 1956 Hixon[7] examined the use of the norm concept with respect to cephalometrics. He defined norm as a yardstick which includes the entire range of the sample from the smallest to the largest value. Great emphasis was placed on the definition of mean values or average values as mathematical representations of central tendency rather than as norms. The range of normal variation is what should concern the orthodontic community.

Hixon[7] stated that statistical methodology deals with the range of normal variation primarily in two ways: 1) percentiles or 2) standard deviation. Percentile ranking provides the more accurate ranking when dealing with asymmetrical distribution. In addition if someone is unfamiliar with statistical procedure, the percentile ranking is easier to comprehend.

Whether one chooses to describe normal variation using percentile or standard deviation, the biometric norms are only as good as the sample used to construct them. Hixon[7] felt the sample must be sufficiently large enough (approximately 50) to include the total range of normal variation. The samples must also be stratified samples (i.e. random samples of a given sex, age and ethnic group). Subjectively selected or inappropriately small samples should not be considered completely valid.

Even though biometric norms have many shortcomings, Hixon[7] still felt there were four basic uses for such norms:

1) to describe a trait of an individual with respect to the normal variation of that trait in the sample.

2) to call attention to a trait that deviates markedly from typical.

3) to facilitate communication.

4) to describe age changes in a trait of a given population.

The reproducibility of cephalometric landmarks, planes, distances and angles have also been presented in the orthodontic literature.

In 1966 Richardson[15] examined the reproducibility of points, planes and lines on a lateral cephalometric headfilm. In his study landmarks were located on 10 lateral cephalometric radiographs. One week later the same procedure was repeated. He found that some cephalometric landmarks could be located with a greater degree of accuracy than others. Additionally, it was determined that the direction of error (i.e. horizontal or vertical) was dependent upon the landmark in question.

Again in 1971 the reproducibility of cephalometric analyses was examined. During this year Baumrind and Frantz[3,4] published two articles that discussed this topic. In their studies five independent examiners located and "traced" landmarks on 20 different cephalometric headfilms. The data gathered was analyzed using a computer program designed specifically for this purpose. They found that each landmark, line, plane or angle had a range of error individually unique. Some landmarks, lines, planes or angles were reproduced with a great deal of accuracy while others had a range of error that was considerably large.

Lastly, the applicability of normative data is significantly influenced by growth and developmental changes of the dentofacial complex. Several studies, including those by Bjork in 1947, Baum in 1951, Riedel in 1952, and others have established that numerous angular and linear measurements for children are significantly different than those of adults.[2,5,16] These findings would tend to substantiate the suggestion that age specific standards are essential for accurate comparisons.

An understanding of the norm concept, statistical methodology, cephalometric analysis reproducibility, and growth and development changes establishes the usage for the standards developed. From the literature reviewed it is apparent that normative data is an expression of normal variation and should be used as a yardstick by which to compare patients. It should not be used as treatment goals or predictive data for orthodontic patients.

MATERIALS AND METHODS

In the study design a decision upon sample size which represents that portion of the population in question can be made with statistical methodology. The precision of this estimation should be attempted. While one would like to include every individual of the population, this is clearly impossible. The precision of the estimate also should take into consideration the ability of the examiner to accurately measure the object of interest. There is no need for precision which is greater than the accuracy of the measurement.

To determine the accuracy of measurements, in 1940 Dahlberg proposed the formula $SE^2 = \frac{\Sigma d^2}{2N}$ (SE = Standard error of the estimate, N = number of cases in the sample, d = difference between duplicate measurements) as a measure of error variance. This particular error analysis has been used in orthodontic investigations by Bjork[5] in 1947, Lundstrom[12] in 1955, and Wieslander and Buck[20] in 1974, as well as many others. If the error variance determined using $SE = \sqrt{\frac{\Sigma d^2}{2N}}$ exceeds 10% of the total variance in question, the method of measurement was inappropriate as stated by Mitguard, Bjork, and Hinder-Aronson[14] in 1974. However, increasing the number of cases studied by the percentage that exceeded the stated 10% will be an effective means of reducing the standard error.

The standard error of the estimate (SE) determined indicates the confidence interval which should be set for the population estimate. In 95% of the cases measured, the true value will lie within ± 2 x SE.

The population mean (μ) can be estimated as being between

$$\bar{x} + t_{\frac{1}{2}\alpha}(df)\frac{SD}{\sqrt{N}} \text{ and } \bar{x} + t_{1-\frac{1}{2}\alpha}(df)\frac{SD}{\sqrt{N}}$$

(Massey and Dixon 1969).

Since it has already been stated that the confidence interval is

$$\pm 2SE \text{ then } 2SE = t_{1-\frac{1}{2}\alpha}(df)\frac{SD}{\sqrt{N}}$$

$$t_{1-\frac{1}{2}\alpha}(df)\frac{SD}{\sqrt{N}} = t_{\frac{1}{2}\alpha}(df)\frac{SD}{\sqrt{N}}$$

Therefore the required sample size which will fulfill our particular precision requirements is found to satisfy the equation

$$N = \left(\frac{t_{(1-\frac{1}{2}\alpha)}(df)SD}{2SE}\right)^2$$

All that remains in determining the required sample size is the selection of SD (standard deviations) for the specified measures from previous studies by Bjork[5] in 1947, Downs[6] in 1948, Riedel[16] in 1952, and Wylie[21] in 1952.

The SE used in determining sample size was taken from studies by Bjork[5] in 1947 who used 20 duplicate measures on 12-year-old Swedish boys' lateral head radiographs and by Baumrind and Franz[3,4] in 1971 who used 20 lateral head radiographs, had tracings made by five examiners, then determined standard deviation of the error exhibited. Baumrind and Franz's data were converted to SE using the formula $SE = \sqrt{\frac{SD^2}{2}}$ described in Houston's[8] article in 1983.

From the information collected it was determined that approximately 45 individuals for each group would be samples of adequate size. Refer to Appendix A for determination of exact numbers required in the sample for each particular angle or distance.

This sample includes patients from OHSU Orthodontic Department between the ages of 12 and 16 years (mean ages: 13 years 5 months for males, 13 years 10 months for females) who possess Angle Class I molar occlusion and are primarily of northern European ancestry. Forty-nine females and 30 males were collected. Routine beginning orthodontic records were collected on all subjects. From these patients' records lateral cephalometric radiographs were obtained. Twenty-one landmarks were located on each headfilm as outlined in the following procedure by Johnson[10] in 1983:

> An 8½ x 10" transparency was affixed to the cephalometric radiograph. Each point was marked by placing a small hole in the transparency corresponding to the landmarks used in the study. These landmarks are found in Appendix B.
>
> The data was then digitized by orienting the transparency films such that the Frankfort Horizontal Plane was registered at porion on a predetermined point and horizontal line on the Apple Graphics Tablet. Once the orientation was established the landmarks were sequentially located and entered into the computer. Refer to Appendix C for sequence of landmark location.[10]

Using the data entered, calculations for the following angles and distances (see Appendix D) were computed for each individual. In addition a lateral facial polygon was constructed for each individual using the same data (see Figure 1).

The angles and distances collected were statistically analyzed creating mean, standard deviation, variance, standard error of the mean, coefficient of variation, histograms, and third moment about the mean for each angle and distance of each group. The mean of each measurement for the male and female groups were students t-tested to determine which angles or distances showed statistically significant different means. In addition, the normative data collected in this study were compared, using students' t-tests, to studies by Bjork,[5] Downs,[6] and Riedel.[16]

A reference catalog was constructed containing the individual's measurements and lateral facial polygons along with the normative data that were established.

FINDINGS

Five tables have been constructed from the data accumulated in this study:

Table I, II, and III are comparisons, by means of students' t-tests, of the measurements from Riedel's,[16] Downs',[6] and Bjork's[5] cephalometric studies to those measurements from the male and female groups of this study.

The comparison of measurements from Riedel's[16] study to those of this study reveals that the interincisal angle is signficantly larger for the male sample of this study at 0.05 probability level. The angle S-N-B is significantly smaller for the female sample of this study at 0.05 probability level. All remaining measurements common to both studies were not significantly different.

The comparison of measurements from Downs'[6] study to those of this study reveals that the interincisal angle is significantly larger for Downs' sample at 0.05 probability level. The remaining measurement common to both studies was not significantly different.

The comparison of measurements from Bjork's[5] study to those of the male sample of this study shows that all linear measurements are significantly larger for the male sample of this study at 0.05 probability level. The angle AR-S-N is also significantly larger for the male sample of this study. All other angular measurements were not significantly different.

Table IV is a comparison, by means of students' t-tests, of the angular measurements observed in the males to those observed in the females. The angles included in the table have been constructed from skeletal points, skeletal and denture points or denture points. The comparison of the data of the males to that of the females revealed that the angle AR-S-N is significantly larger for the female group at 0.05 probability level. No other significant differences were shown for the angles examined regardless of whether they were constructed using skeletal, skeletal and denture, or denture points.

Table V is a comparison, by means of students' t-tests, of the linear measurements observed in the males to those observed in the females. The linear measurements included in the table are either skeletal or denture appraisals.

The comparison of linear measurements associated with skeletal pattern of the males to those of the females reveals that the males have significantly longer faces and larger mandibles at 0.05 probability level. The distance from nasion to anterior nasal spine (a function of middle anterior vertical face height) is significantly longer for males. The distance from anterior nasal spine to menton (a function of lower anterior vertical face height) is significantly longer for males as well. All linear measurements related to mandibular size (i.e. mandibular length, distance from articulari to gonion, distance from articulare to menton, and distance from gonion to pogonion) were significantly larger for the male group. The remaining linear measurement related to skeletal pattern (i.e. distance from anterior nasal spine to posterior nasal spine) was not significantly different for the male and female groups.

The comparison of linear measurements associated with denture pattern of the males to those of the females reveals no significant differences between groups.

An accompanying reference catalog contains data for each individual included in the sample along with the normative data outlined in the tables presented.

DISCUSSION

Discussions of the norm concept have been a part of the orthodontic literature for many years. This concept has evolved from the single average or mean value to the present day expressions of normal variation. These expressions of normal variation are of a statistical nature and are as important to development of standards as the sample selection.

If a practitioner wishes to describe where his patient is in relation to the range of normal variation, he must first define his limits of this range. Many researchers have elected to define range of normal as ±2 standard deviations which would include approximately 95% of a normally distributed sample. However, even if a practitioner should determine that a patient has one or more cephalometric values outside the defined range of normal variation, he must temper his final judgment on patient evaluation with his "good clinical judgment." A true descriptive evaluation of a patient is not an examination of cephalometric measurements separately; rather, it includes a composite of all values along with subjective clinical judgments.

The selection of samples is probably the single most controversial aspect concerning the validity and applicability of the current standards that have been developed for the various cephalometric analyses. There are two basic questions one should ask regarding proposed standards:

1) What is the total number of individuals included in the sample?

2) Exactly what criteria is used for inclusion in the sample?

The total number of individuals required for a sample may not be the old statistical standard of 30. Rather, as discussed in the Materials and Methods, there is a specific number required for each angle or distance which can be determined using standard statistical methodology. When analyzing norms for specific measures, it would be wise to determine if the total number included in the sample to develop the norm was large enough to represent the normal variation of the population examined.

The question of what criteria are used for inclusion in the sample involves several different questions:

1) What population does the investigator want to examine?
    a) What age group is to be examined?
    b) What sex is to be examined?
    c) What race is to be examined?
2) Is the sample to be randomly selected?
3) Is the sample to be subjectively selected?
4) If there is subjective clinical selection, is it considered a universally accepted clinical decision?

The population the investigator wishes to examine is primarily dependent upon study design or the ethnic background of the individuals that inhabit the region of sample selection. Studies that examined the differences in cephalometric analyses between sexes selected their samples accordingly. Likewise, studies designed to investigate the cephalometric differences between children of specific age groups and adults select their samples accordingly. One aspect of sample selection that is difficult to control is the ethnic background of the patients in the region of the country from which the sample was selected.

Completely random selection of a sample is extremely difficult, many times impossible, and may not be as applicable as stratified samples (i.e. random sampling of specific age, sex, and race).

Many of the studies involving cephalometric norms have used samples that have been selected on the basis of clinical interpretation (i.e. ideal occlusion and facial harmony, etc.). Since every practitioner has his own interpretation of ideal occlusion and facial harmony, this type of sample selection is looked upon with disfavor.

The primary objective of this paper is the development of normative data for males and females ages 12 to 16 years for the computerized cephalometric analysis previously outlined by Johnson[10] in 1983. Selection of this particular age group was based on the assumption that the majority of the patients beginning treatment in the orthodontist's office fall into this age group.

Realizing the importance of the sample selection regarding validity and applicability of the standards developed, meticulous care was taken in selection of the sample. Using statistical methodology it was determined that approximately 45 individuals would be a sufficiently large enough sample to approximate the actual population for most measurements. As discussed previously, 49 girls were collected for the sample; however, only 30 boys were available. This number of boys did not appear to create a problem since a comparison of the boys' and girls' groups showed results that were consistent with the expected results of samples of 45 or more. Additions to the male sample as they became available would help to substantiate the results already established.

The only criterion used in sample selection other than age, sex and race of the individual was the requirement for an Angle Class I molar relationship. Although this requires a clinical judgment, it can be assumed that Angle Class I molar relationship is a universally accepted clinical observation.

There may be some question as to the selection of patients with Class I molar occlusion from the OHSU orthodontic files. Some may feel this is a severely skewed sample since patients selected for treatment may have more severe Class I molar malocclusions than the average orthodontic practice. This may in fact be somewhat true for the denture points; however, cranial base and basal bone landmarks and measurements should be no different for Class I acceptable occlusion group versus Class I malocclusion group.

An alternative selection procedure would be to randomly select Class I molar occlusion patients from the general dental clinic, take lateral cephalometric radiographs and develop standards from the data collected. This method, however, would probably be impossible in this country today. Therefore, the previously outlined method would be the one of choice.

The primary findings of this study are the normative data that have been developed from the specific population previously described. These data may be compared to normative data of other studies to establish how this particular sample compares to the samples of a few of the classic cephalometric studies. A finding of no significant difference between given measurements of the various samples may simply mean that individual variation is so great in the samples that the difference established may not be of statistical significance. However, a finding of no significant difference may also mean that the particular measurement in question may in fact be similar for the two populations. A finding of statistical significance implies that the measurement in question is different for the sample populations compared or it may be stated that the samples are drawn from entirely different populations.

Many of the normative data established by Riedel[16] are statistically similar to the corresponding normative data of this study. The majority of the angular measurements common to both the 1952 Riedel study and this study are statistically similar. The only measurements common to both studies that are significantly different statistically are the interincisal angle and angle S-N-B (for the female sample only). The interincisal angle was significantly larger for Riedel's sample. This difference can be attributed to Riedel's criteria for sample selection (i.e. excellent occlusion). The S-N-B angle for the female sample of this study was significantly smaller than Riedel's sample. This difference may be attributed to the difference in age of the two samples. The angle S-N-B for the male sample of this study showed no significant difference from the angle S-N-B of either Riedel's sample or the female sample of this study. The probable reason for this finding is that the male sample had such a high degree of variability that statistically there appeared to be no difference.

A comparison with standards established in Downs'[6] study revealed that the interincisal angle was significantly larger for Downs' sample as compared to this study's sample. Again this difference may be associated with sample selection since Downs used excellent occlusion and facial harmony as criteria for selection.

Similar comparison with Bjork's[5] study revealed numerous differences. These differences can be attributed to sample selection as well. All absolute linear measurements that are significantly different are probably due to the mean age of Bjork's sample. The one angular measurement that is significantly different between the two groups is the angle AR-S-N. Bjork's sample has a significantly smaller AR-S-N. This difference may be attributed to the ethnic background of the sample.

A comparison of the findings for the sexes revealed results consistent with many of those of previous studies. Only one of the angles measured in this study was significantly different statistically for boys and girls. The angle AR-S-N was significantly larger for girls as compared to boys. A preliminary search of the literature was unable to establish any studies dealing with sex differences for angle AR-S-N. Studies concerned with cranial base development only established that the angle AR-S-N for boys changed only slightly with growth.[5a] The remaining angular measurements showed no significant difference between boys and girls; this is consistent with many of Baum's[2] findings in his 1951 study.

The findings related to the difference between sexes for the linear measurements examined were also consistent with those of previous studies.

In 1947[22] and 1952[21] Wylie determined that there were several statistically, significantly different absolute linear measurements when comparing boys (mean age 11.5 years) to girls (mean age 11.5 years). In his studies he found that the mandibular length was significantly longer for boys compared to girls. The anterior upper vertical face height and the anterior lower vertical face height were significantly larger for boys as well. All other absolute linear measurements examined were not significantly different for boys and girls. Although the absolute measurements may differ when comparing findings of this study with previous studies, the consistency of statistical significance between the studies tends to substantiate the present findings.

The primary conclusion that can be drawn from these findings is that boys ages 12 to 16 are generally larger than girls of comparable ages. However, individual variation is so great that certain girls will be larger than many of the boys. Therefore, some of the absolute linear means developed in this study may show only small differences between sexes. Any measurement of proportion and most angular measurements should show no statistical difference between sexes since absolute size does not effect these values.

Several uses have been suggested for the normative data developed in this study. They may be used as a control sample for comparison in future studies. They may also be used as a data base for future studies in regard to correlations of the various angular and linear measurements. However, the normative data developed are primarily used as a guideline or yardstick by which to compare patients from similar populations.

Many different computer-aided analyses have been developed to date. Most have eliminated or reduced error attributed to tracing and compass measurements. All still exhibit landmark location error. The main advantage this analysis has over all the others is that an in-office Apple II E computer with accompanying equipment (approximately $4,000) and appropriate software is all that is needed. In addition usable normative data are now available for this cephalometric analysis program. One final advantage this analysis has over many of the others is that the interpretation of the data is left up to the orthodontist's "good clinical judgment." For in-depth discussion of the analysis for which these normative values were developed, please refer to Johnson's 1983 certificate paper.

Future studies could include the development of statistical data for Angle Class II molar occlusion patients of specific age, sex and race or Angle Class III molar occlusion patients of specific age, sex and race. These data may then be used for control groups in other studies or as a sample by which to compare a patient drawn from an equivalent population.

SUMMARY AND CONCLUSIONS

This study established normative data for 12 to 16-year-old children from the Portland area with Angle Class I molar occlusion for the computer-aided cephalometric analysis outlined by Johnson[10] in 1983. The usage of the normative data was discussed with reference to norm concept, statistical methodology, cephalometric analysis reliability, and growth and development changes.

These data were compared to normative data from other cephalometric studies. The comparisons revealed that many of the measurements from this study differed from those of previous studies. However, these differences could be attributed to the types of samples compared. Additionally, the male and female samples of this study were compared. From this comparison it can be concluded that males 12 to 16 years old are larger than females of a similar age range. One finding of interest and deserving of future investigation is the significantly different angle AR-S-N established for the male compared to the female sample.

Suggestions for the uses of these data are:

1) as standards for patients from an equivalent population
2) as a control group for future studies
3) as a data base for future studies

Future studies could include the development of specific standards for age, sex, ethnic origin and various molar occlusions for the computer-aided analysis outlined by Johnson[10] in 1983. Another could be an investigation into the difference between the angle AR-S-N for male compared to female samples.

With the storage capabilities of modern computers, data could be continually added to these samples thus allowing for a tremendous compilation of orthodontic information.

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Figure 1: Lateral Facial Polygon Constructed Using the First 16 Landmark Points

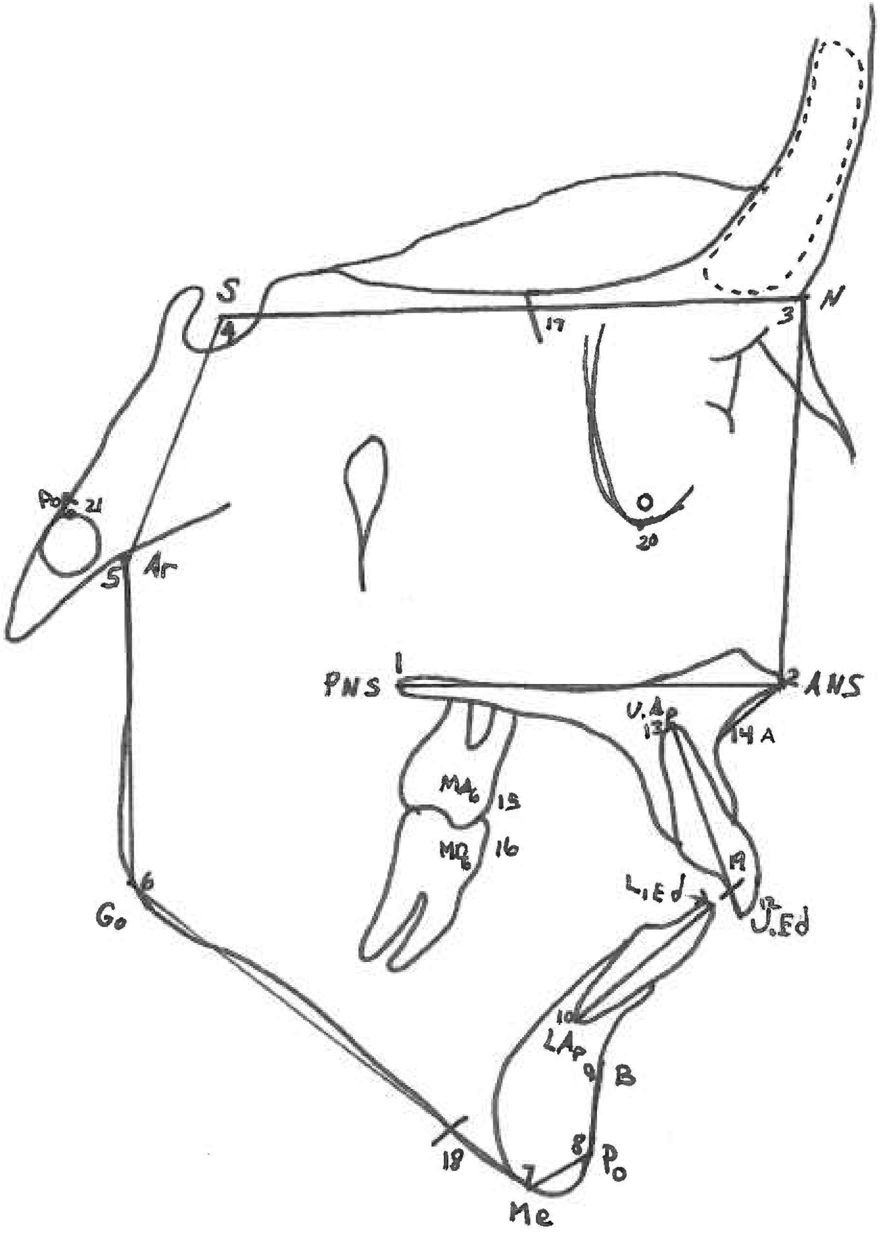

TABLE I

	Riedel[16]		Males N=30			Females N=49		
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	t-value	$\bar{X}$	S.D.	t-value
S-N-A	82.01	3.89	81.6	4.44	0.43	81.4	3.04	0.87
S-N-B	79.97	3.6	78.3	4.40	1.86	78.5	3.09	*2.19
SN-MP	31.71	5.19	33.8	5.47	1.73	33.5	4.10	1.92
SN-MXI	103.97	5.75	104.9	7.04	0.63	104.8	7.19	0.64
MXI-MDI	130.98	9.24	126.8	7.73	*2.09	127.6	11.54	1.63
MP-MDI	93.09	6.78	92.8	5.87	0.20	91.9	6.42	0.90

$\bar{X}$ = Mean
S.D. = Standard Deviation
N = Number included in sample
* = Statistically significant at 0.05 probability level

TABLE II

	Downs[6]		Males N=30			Females N=49		
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	t-value	$\overline{X}$	S.D.	t-value
MXI-MDI	135.4	5.76	126.8	7.73	*4.25	127.6	11.54	*2.88
MP-MDI	91.4	3.78	92.8	5.87	0.94	91.9	6.42	0.33

$\overline{X}$ = Mean
S.D. = Standard Deviation
N = Number included in sample
* = Statistically significant at 0.05 probability level

TABLE III

	Bjork[5]		Males N=30		
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	t-value
AR-S-N	122.9	4.85	133.1	4.42	*11.09
AR-GO-ME	131.1	6.11	130.7	5.59	0.34
ANS-PNS	51.7	2.83	52.5	4.18	1.42
O.J.	4.2	2.18	3.5	2.04	* 2.89
O.B.	2.7	1.75	3.9	1.99	* 3.63
N-ANS	50.1	2.65	54.9	3.56	* 9.12
ANS-ME	64.5	4.72	68.8	5.32	* 4.71
AR-GO	42.1	3.6	46.3	5.11	* 5.82
GO-PO	72.8	4.12	76.0	5.60	* 3.90

$\bar{X}$ = Mean
S.D. = Standard Deviation
N = Number included in sample
* = Statistically significant at 0.05 probability level

TABLE IV

(measurements in degrees)

	Females N=49				Males N=30				
	$\overline{X}$	S.D.	S.E.M.	Range	$\overline{X}$	S.D.	S.E.M.	Range	t-value
SNA	81.4	3.04	0.44	72.2- 87.3	81.6	4.44	0.82	73.4- 90.7	0.24
SNB	78.5	3.09	0.45	72.2- 83.9	78.3	4.40	0.82	70.3- 89.0	0.24
SN-MXI	104.8	7.19	1.04	84.7-124.1	104.9	7.04	1.31	86.4-122.7	0.07
MXI-MDI	127.6	11.54	1.67	94.5-155.8	126.8	7.73	1.43	113.4-142.5	0.30
MP-MDI	91.9	6.42	0.93	79.1-114.1	92.8	5.87	1.09	80.2-101.8	0.61
AR-GO-PO	122.4	4.28	0.62	114.4-131.6	122.8	6.22	1.15	109.0-134.5	0.34
SN-MP	33.5	4.10	0.59	23.7- 42.0	33.8	5.47	1.02	20.1- 42.2	0.28
AR-S-N	136.7	4.05	0.58	129.4-145.5	133.1	4.42	0.82	124.5-143.9	*3.73
AR-GO-ME	130.5	4.10	0.59	122.2-140.6	130.7	5.59	1.04	119.6-141.8	0.21

$\overline{X}$ = Mean
S.D. = Standard Deviation
S.E.M. = Standard Error of the Mean
N = Number included in sample
* = Significant at 0.05 probability level

TABLE V

(measurements in millimeters)

	Female N=49				Male N=30				
	$\bar{X}$	S.D.	S.E.M.	Range	$\bar{X}$	S.D.	S.E.M.	Range	t-value
ANS-PNS	51.4	3.18	0.46	44.4- 57.8	52.5	4.18	0.78	45.5- 62.6	1.30
MXG-ANS	31.2	2.54	0.37	25.9- 35.8	32.0	2.33	0.43	27.5- 36.7	1.37
MDG-ANS	30.5	2.81	0.41	24.7- 36.3	31.5	2.85	0.53	25.6- 36.4	1.44
O.J.	3.6	1.66	0.24	.7- 10.6	3.5	2.04	0.38	- 2.3- 9.1	0.18
O.B.	4.1	1.69	0.24	.6- 7.9	3.9	1.99	0.37	- 1.4- 8.6	0.52
N-ANS	51.5	2.56	0.37	44.4- 56.5	54.9	3.56	0.66	48.0- 63.1	*4.85
ANS-ME	65.8	4.87	0.70	54.3- 77.2	68.8	5.32	0.99	57.9- 79.3	*2.48
%M.F.Ht	44.5	1.97	0.28	39.4- 48.8	45.0	2.42	0.45	40.4- 50.5	0.99
MD.L.	103.4	4.47	0.64	94.7-111.2	108.0	7.64	1.42	91.7-124.2	*3.32
AR-GO	43.6	4.03	0.58	35.0- 53.5	46.3	5.11	0.95	36.9- 60.1	*2.56
GO-PO	73.4	3.63	0.52	66.1- 81.3	76.0	5.60	1.04	65 - 89.6	*2.41
AR-ME	104.3	4.36	0.63	95.2-111.7	109.2	8.06	1.50	92.3-124.0	*3.43

$\bar{X}$ = Mean
S.D. = Standard Deviation
S.E.M. = Standard Error of the Mean
N = Number included in sample
* = Significant at 0.05 probability level

APPENDIX A

The following is a compilation of the values used to determine the number of individuals required in the samples of this study.

Angles	S.D.	S.E.	N	
S-N-A	3.85° (a)	0.83° (f)	23	
S-N-B	3.06° (a)	0.67° (f)	22	
SN-MP	4.67° (a)	1.23° (f)	15	
MXI-MDI	8.80° (d)	1.39° (e)	38	
MP-MDI	3.78° (c)	2.23° (f)	3	(error variance > 10% total variance)
AR-S-N	1.76° (d)	0.40° (e)	18	
AR-GO-ME	5.4° (b)	0.93° (e)	34	
Distances				
ANS-PNS	2.83 mm (d)	1.37 mm (e)	4	(error variance > 10% total variance)
GO-PO	4.12 mm (d)	0.57 mm (e)	39	
AR-GO	3.6 mm (d)	0.79 mm (e)	20	
O.J.	2.18 mm (d)	0.27 mm (e)	63	
O.B.	1.75 mm (d)	0.31 mm (e)	31	
N-ANS	2.65 mm (b)	0.49 mm (e)	28	
ANS-ME	4.72 mm (b)	0.48 mm (e)	93	

S.D. = Standard Deviation
S.E. = Standard Error of the estimate
N = Number required in sample

Samples from which standards were determined:

(a) Riedel: 24 children, 8-11 yrs., excellent occlusion
(b) Wylie: 57 children, 11-13 yrs., good facial proportions
(c) Downs: 20 children, 12-17 yrs., normal occlusion
(d) Bjork: 322 Swedish boys, 12 yrs. old

(e) SE using Bjork's 1947 data
(f) SE using Baumrind and Franz's data, 1971

APPENDIX B

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

1. ANS - Anterior Nasal Spine - This point is the tip of the anterior nasal spine.
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 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 the angle 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.
8. Po - Pogonion - The most anterior, prominent point on the chin on the anterior border.

9. B - B Point - The deepest midline point on the mandible between infradentale and pogonion.

10. L_1Ap - Lower Central Incisor Apex - The root apex of the most anterior mandibular central incisor.

11. L_1Ed - The incisal edge of the most anteriorly located mandibular central incisor.

12. U_1Ed - The incisal edge of the most anteriorly located maxillary central incisor.

13. U_1Ap - Upper central incisor apex - The root apex of the most anteriorly located maxillary central incisor.

14. A - A Point - The deepest point on the maxillary midline between the anterior nasal spine 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_1Ed-U_1Ap and the long axis of the most anteriorly located mandibular central incisor.

20. O - Orbitale - The lowest point on the infraorbital margin. When images of both orbits are present, the midpoint between the two shall be used.

21. Por - Porion - The highest point on the superior surface of the soft tissue of the external auditory meatus.[10]

APPENDIX C

Landmarks must be located in the following sequence:[18A]

1. PNS
2. ANS
3. N
4. S
5. Ar
6. Go
7. Me
8. Po
9. B
10. L_1Ap
11. L_1Ed
12. U_1Ed
13. U_1Ap
14. A
15. MA_6
16. MD_6
17. P_1
18. P_2
19. P_3
20. Or
21. Por

APPENDIX D

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 lateral facial polygon.
2. S-N-B - That angle formed by connecting the three points Sella, Nasion and B point and lying within the lateral facial polygon.

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 lateral facial polygon.
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 lateral facial polygon.
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 lateral facial polygon.
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 lateral facial polygon.
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 lateral facial polygon.
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 lateral facial polygon.
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 anteior 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.[10]