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A Statistical Assessment of Tooth Sizes, Arrangement and Arch Form Obtained from Dental Casts Preparatory to the Development of Computer Programming of Malocclusions

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A STATISTICAL ASSESSMENT OF TOOTH SIZES, ARRANGEMENT AND ARCH FORM OBTAINED FROM DENTAL CASTS PREPARATORY TO THE DEVELOPMENT OF COMPUTER PROGRAMMING OF MALOCCLUSIONS

by

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To my wife and children, I dedicate this effort.

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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

A. Introduction:

Electronic computers are rapidly achieving a place in medicine and dentistry. Computers in the biomedical sciences have already been used in the statistical analysis of research data, simulation of physiological systems, storage and retrieval of medical histories, filing of information on drug actions, differential diagnosis, electroencephalography, electrocardiology and many other areas.

Dentistry, like medicine, is finding this device valuable in many areas. Efforts are being made to apply it to diagnosis. Before the dental profession can take advantage of the extraordinary feats of memory and calculation of the computer, investigators must submit themselves to the training and discipline required for programming these electronic calculators.

The electronic computer offers to orthodontics the possibility of entering areas of inquiry which have not been possible in the past because of time factors due to the complexity of the method of solution or the magnitude of the information involved. The computer has the ability to store great masses of heterogeneous information at high speed into physically compact form. It can also retrieve part of all of this information at tremendous speed. With this ability, the computer would appear to be an instrument for accumulating and storing orthodontic research data.

Computer programs have been used by some orthodontists in the study of malocclusions. Telle (1951) used a punched card system in his study of the incidence of malocclusion in children in Hedmark, Norway. He assigned numbers, corresponding to specific positions on the card, to carefully defined symptoms of tooth disharmonies. The card of each child was then punched according to those symptoms observed in the child's mouth.

The collected data were then transferred to a programmed electronic computer. It was then possible to obtain from the computer an accurate accounting of the frequency of single or multiple symptoms in the children examined.

A similar study for epidemiological registration of malocclusion was carried out by Bjork, Krebs and Solow (1964).

The computer program that was developed correlated the symptoms observed, with the age, sex, and stage of dental development of the child. This correlation provided a more meaningful relevance to the incidence of dental anomolies.

Jonsgard (1964), employing the technique used by Bjork, et.al., examined the teeth of children in Bergen, Norway. The data were transferred to magnetic tapes according to a table of code numbers, and the tapes were placed in a programmed electronic computer.

Brader (1965) proposed the application of electronic computing machinery to the solution of specific problems of orthodontic diagnosis and treatment planning. He described various computer program plans which may help provide the means for achieving consistency and excellence in the complex tasks inherent in orthodontic diagnostic procedures.

The orthodontic profession needs to take advantage of electronic techniques and logically derived computer programs. Using these advanced techniques, vast amounts of diagnostic data accumulated from various sources can be conveniently stored and systematically analysed. Many complex problems confronting the clinical orthodontist can be exhaustively investigated. Factors of growth and their association to malocclusion and orthodontic treatment can be studied with accuracy and reliability. Dental and skeletal characteristics of malocclusions can be standardized. Ingredients necessary for post-treatment stability can be illucidated. Eventually, through the combined efforts of those orthodontic researchers working with computers, a systematic orthodontic diagnosis procedure, applicable to an automatic electronic computer, can be developed.

B. Statement of the Problem:

To investigate the relationship between tooth size, overbite-overjet, and arch form on plaster casts and to attempt to use these in the development of an electronic system of programming various types of malocclusions.

CHAPTER II

REVIEW OF THE LITERATURE

In order to develop an orthodontic diagnostic procedure applicable to an electronic computer, a large amount of data must be fed into the machine. In this study, these data will be obtained from plaster casts. Many systems of orthodontic diagnosis based on the analysis of plaster casts have been used in the past. Following is a review of the literature pertaining to this diagnostic aid.

One of the earliest diagnostic aids used in orthodontics to record permanently a malocclusion of the teeth was the plaster cast. The value of an accurate set of articulated models of the teeth was stressed by Angle in 1895. From Angle's time to the present orthodontists have been able to derive valuable information from plaster casts. Jarabak (1963) states:

> "In a comprehensive cast analysis, eleven factors should be appraised: (1) molar relations, (2) axial inclination of canines, (3) symmetry of occlusion, (4) overbite and overjet, (5) arch length, (6) crowding of teeth, (7) spacing of teeth, (8) axial relation of maxillary anterior

> teeth, (9) axial inclination of mandibular anterior teeth, (10) molar rotation and molar axial tipping, and (11) the curve of Spee."

Many studies of tooth disharmonies have been made on plaster casts. Various systems of diagnosis have been devised based on measurements taken from plaster casts. Arch predetermination suggested by Hawley (1905) is one of these. The Hawley Index is based on the Bonwill principle of the standard arch. This method required the use of a series of celluloid charts with graded outlines of the dental arches printed on them. By placing a celluloid chart over the cast, one could supposedly see as a glance the deviation of the cast from the ideal arch described on the chart.

Pont (1909) formulated the theory that wide or broad teeth require a broad arch and narrow teeth require a less wide arch in order to show normal dental alignment. He made measurements of casts of many arches showing no crowding of the teeth, and correlated the width of the maxillary four incisors with the inter first premolar and inter first molar arch breadth. From these measurements and correlations, Pont provided a table of arch widths based on tooth widths. Thus, by the use of the Pont Normal Tooth Index, the approximate amount of change required in the arch could be determined.

Stanton (1916) used engineering principles in his assessment of arch changes required for the correction of a malocclusion. Transparent sheets marked with measurements taken from good occlusions were compared with maps made from the case to be treated. Also an instrument with moveable teeth was then adjusted to simulate the case under consideration. With this method Stanton believed that he could determine whether the maxillary teeth would properly occlude with the mandibular teeth when treatment was completed.

Bogue (1919) presented an index of arch predetermination based on the supposition that if the palatal arch between the linguo-cervical margins of the second deciduous molars measures less than twenty-eight millimeters, expansion should be instituted in the deciduous dentition.

A series of charts developed by Gilpatric (1919) was based on the size of the teeth within the maxillary arch. In his study, Gilpatric measured several casts of normal occlusions and found that the distance from the buccal groove of the first molar on one side to the buccal groove of the opposite first molar varied from 74.5mm., to 101mm. Therefore he made twenty-seven celluloid charts, one millimeter between each chart. By measuring the teeth on the case to be treated, a chart with comparable measurements could be laid over the cast, and deviations from the ideal arch form could be noted.

Neff (1949) felt that one could predetermine the amount of overbite in a finished case by applying what he termed the "anterior coefficient". Using 200 sets of casts, he measured the mesiodistal diameters of both maxillary and mandibular anterior teeth. He then divided the maxillary sum by the mandibular sum and thus arrived at the "anterior coefficient". For an ideal overbite, he stated that the "anterior coefficent" must be 1.20, to 1.27.

Bolton (1958) made a series of measurements on models of fifty-five cases showing excellent occlusions. From the measurements he established certain ratios by which he claimed he could predetermine post-treatment results. The first was a ratio of the sum of the mesiodistal widths of all the teeth from first molar to first molar in the maxillary arch, to the sum of the mesiodistal widths of the same teeth in the mandibular arch. The second was a ratio of the maxillary six anteriors to the mandibular six anteriors.

Another study for predicting post-treatment arch form and esthetics was conducted by Miclavez (1961). He stressed the importance of measuring the widths of the maxillary and mandib- central incisors on casts. He claimed that the ratio of maxillary incisor width to mandibular incisor width should be 4:3 if a correct overbite is to prevail. If the mandibular incisors are too large, correct overbite can only be obtained by finishing with spaces between the teeth in the maxillary anterior region. If the maxillary incisors are too large, deep overbite is the inevitable result.

In an attempt to make cast analysis more meaningful, some investigators have devised methods of constructing dental casts that are related to various cranial landmarks. All of these systems involve complicated devices and techniques. The earliest proponent of such a procedure was Simon (1926). He termed his analysis "gnathostatics," and the device he used was called the gnathostat. Measurements taken on the head, while the impression material and tray were in the mouth, were transferred to this mechanism and the casts were made in relation to these measurements. He felt that it was possible then to employ the casts as an aid in visualizing deviations in three planes of space. This method for cast construction has been employed, with minor refinements, by Dewey (1935), Salzmann (1943), and McCoy and Shepard (1956).

Using Simon's device as an example, Fischer (1940) presented a technique for making oriented plaster casts using a device he called the dentiphore. The main difference between this device and the gnathostat was that with the dentiphore the impressions were taken separately. Measurements taken on the head with the dentiphore were transferred to a platform on which the models were built. The measurements were automatically copied on the base of the plaster models. The casts were made with relation to four planes of the head: median sagittal; auricular; orbital; and Frankfort horizontal.

Systematic sectioning of dental casts has been employed by several investigators. Yost (1948) described such a method for use in diagnosis. He advocated removal of the teeth from the casts in cases which presented arch length discrepancy. By carefully repositioning the teeth, taking care not to expand the arch, he determined whether extraction of teeth should be a part of the treatment plan.

Kesling (1956), in a further refinement of the sectioning technique as an aid in diagnosis, described a way of repositioning the teeth to conform to an angle suggested by Tweed. This is the FMIA angle of 65 degrees. Using the lateral headplate of the patient, the proper position of the mandibular central incisor was determined.

Baldridge (1961) measured the arch lengths on thirty mandibular casts showing a deep curve of Spee. In an effort to determine the increase in arch length when the curve is leveled, he cut the teeth from each cast and repositioned them so that each presented a flat occlusal plane. Then he measured the arch lengths again and concluded that the increase in arch length is directly proportional to the amount that the curve of Spee is leveled. He stated that the increase is predictable according to two formulas:

1. Predicted arch length increase = 0.1055 + 0.106705X. Used when deviation of all mandibular teeth from a flat occlusal plane is measured in millimeters, added, and substituted for X.

2. Predicted arch length increase = 0.51 + 0.488X. Used when deviation of the mandibular tooth on the right and left sides farthest from a flat occlusal plane is measured in mil-

limeters, added, and substituted for X.

Plaster casts of 100 Indian male adults with normal occlusion and pleasing facial appearance were studied by Iyer and Desai (1963). In this study the extent of "acceptable normal" overbite, overjet, slight incisor crowding-spacing and rotations, posterior crossbites, canine occlusion and canine inclination was evaluated as compared with ideal normal. The findings showed: (1) In overbite, nearly two-fifths of the lower incisor was covered by the upper incisor. There was no correlation between overbite and eruptive heights of the incisors or molars; (2) Incisor crowding and incisor spacing was noted in nearly all cases; (3) A low percentage of posterior crossbites precludes them from being normally acceptable; (4) Canine inclination to occlusal plane showed that vertical upper canines and even distally tipped lower canines were within reasonable limits of acceptance; (5) Canine occlusion was cusp-to-cusp in one-half the cases and ideal in the other half. The conclusions drawn from the study prompted the authors to suggest that although one should strive for correction according to "ideal normal", it is sometimes impractible; therefore an acceptable normal should be considered.

CHAPTER III

MATERIALS AND METHODS

A. Selection of the sample:

The material used in this study was obtained from fifty adult Caucasian males having normal occlusions. Five-hundred university students were examined intraorally and extraorally. Fifty-five subjects, who, in the opinion of this investigator, had normal occlusions, not requiring orthodontic correction, were selected. From this group, fifty individuals were chosen meeting the following criteria:

(1) Presence of all teeth (third molars not considered)

(2) No previous orthodontic treatment

(3) Normal gingival condition and good oral hygiene

(4) Symmetrical facial development presenting a pleasing appearance and profile

(5) Absence of temporomandibular joint disturbances

(6) Class I molar relation (Angle) on both right and left sides

(7) Symmetry of maxillary and mandibular arch

(8) Anterior overbite not in excess of 5mm.

(9) Anterior overjet not in excess of 5mm.

(10) Curve of Spee not in excess of 3mm. on either side

(11) Broken contacts causing no more than 5mm. of crowding in the maxillary or mandibular arch

(12) Spacing not in excess of 5mm. in either arch

(13) No teeth rotated over twenty degrees

The age of the subjects in this sample ranged from 20 years, 11 months, to 36 years, 3 months (mean age 25 years, 6.3 months).

In this study, and in a companion study by Gerald Ashley, diagnostic records of the selected cases were obtained. The records for each subject consisted of: lateral cephalometric radiograph; intraoral periapical radiographs; facial photographs; and plaster casts.

Each subject was given a number which was subsequently used to identify his records. This provided an easy method for labeling and identifying the records and prevented a prejudiced appraisal of the findings which might have resulted had the subject's name been used.

B. Collection of the material for investigation:

The area of investigation by this author will be confined to the plaster casts. These plaster casts were made from impressions taken on the same sample used in the study by Gerald Ashley.

Impression trays of the proper size were selected and beaded with Mortite. The subject rinsed his mouth with a silicone liquid (Dow Corning Co.) to reduce the surface tension of the saliva in order to obtain an impression with a minimum of imperfections in it.

The impression material (Supergel, Bosworth) was mixed according to the manufacturers instructions. The mandibular tray was then loaded with the material and guided to place. Care was taken to center the tray over the arch and to seat the tray well down on the teeth so as to incorporate the surrounding alveolar process and soft tissue covering into the impression. The same procedure was followed in taking the maxillary impression. Each impression was rinsed with cold water and wrapped in a wet towel immediately after it was removed from the mouth

These impressions were poured in Kerr Snow-White #1 plaster which was mixed with water according to the manufacturer's specifications and spatulated in a vacuum spatulator (Whip-Mix) until all air bubbles were removed and a smooth mixture was achieved.

After the plaster had set thoroughly (about one hour), the impression material and tray were removed from the casts. The casts were trimmed and finished in the usual manner.

C. Description of selected landmarks:

The configuration of the maxillary and mandibular dental arches, the relationship of the dental arches to one another, and the arrangement of the teeth within their respective arch was determined for each subject from various measurements made on the plaster casts. In this study an effort was made to measure all areas on the casts that are of clinical interest and diagnostic value. The following measurements were made on each set of casts.

(1) Maxillary and mandibular intercanine width--The width of the arch from canine to canine, measured across the arch.

(2) Maxillary and mandibular inter-first premolar width--The width of the arch in the first premolar region.

(3) Maxillary and mandibular inter-molar width--The width across the arch in the first molar region.

(4) Maxillary and mandibular arch length molar to molar--The sum of the mesio-distal widths of all the teeth from distal of left first molar to distal of right first molar in each arch.

(5) Maxillary and mandibular canine to canine width--The sum of the mesio-distal widths of canines, lateral incisors and central incisors in each arch.

(6) Maxillary and mandibular incisor width--The sum of the mesio-distal widths of the lateral incisors and central incisors in each arch.

(7) Maxillary and mandibular spacing--Both the number of spaces and the total space between mesial and distal of adjacent teeth in each arch.

(8) Maxillary and mandibular rotations--The number of teeth rotated over five degrees and the total amount of arch length lost from rotations in each arch.

(9) Broken contact points caused by crowding--The number of broken contacts and total arch length accounted for by the broken contacts in each arch.

(10) Overbite--The superior-inferior relationship of the incisal edge of the maxillary anteriors to the mandibular anteriors.

(11) Overjet--The antero-posterior relationship of the maxillary anteriors to the mandibular anteriors.

(12) Curve of Spee--The degree to which the occlusal platform varies from a flat plane.

(13) Maxillary 6 to mandibular 6 relationship--The mesiodistal relationship of the maxillary first molar to the mandibular first molar.

(14) Maxillary 3 to mandibular 3 relationship--The mesiodistal relationship of the maxillary canine to the mandibular canine.

(15) Maxillary 3 to occlusal plane--The angular relationship of the maxillary canine to the maxillary occlusal plane.

(16) Mandibular 3 to occlusal plane--The angular relationship of the mandibular canine to the mandibular occlusal plane.

D. Methods of measurement:

The instruments used in the measurement of the plaster casts were: a millimeter scale calibrated to 0.5mm.; vernier calipers calibrated to 0.1mm.; celluloid protractor calibrated to 0.5 degrees; a pair of dividers; Korkhaus tri-dimensional calipers; a safety razor blade and fitted metal handle; and a wooden block with a movable arm.

Preparatory to measuring the casts, a data sheet was designed so that information could be recorded in tabular form (Table 1). The data sheet was arranged so that all measurements made with any one instrument were grouped on the data sheet. Readings were made by the principal investigator and recorded by an assistant. Measuring procedures were conducted in a well-lighted room. A dark table cloth was used to contrast with the white models.

The following is a description of the methods employed for obtaining each measurement; the numerical sequence is that found on the data sheet.

(1) Intercanine width: The Korkhaus tridimensional caliper was adjusted to the proper width so that one pointer was on the tip of the cusp of the right canine and the other pointer on the tip of the cusp of the left canine. In cases where attrition had worn the cusp tip, the center of the flattened

area was taken as the measure point. A reading was taken directly on the Korkhaus scale. This procedure was used on the maxillary and mandibular cast.

(2) Inter-premolar width: The Korkhaus caliper was adjusted so that one pointer was on the tip of the buccal cusp of the right first premolar and the other pointer was on the tip of the buccal cusp of the left first premolar. If attrition was noted on the cusp tip, the center of the flattened area was used as the measure point. A reading was taken directly on the caliper scale. Both maxillary and mandibular casts were measured in this way.

(3) Inter-molar width; The Korkhaus caliper was adjusted so that one pointer was on the tip of the mesial-buccal cusp of the right first molar, and the other pointer was on the tip of the mesial-buccal cusp of the left first molar. Cusps showing attrition were treated as above. A reading was taken directly on the scale. The measuring procedure was the same for both maxillary and mandibular casts.

(4) Arch length molar to molar: The mesio-distal width of both first molars, all four premolars, both canines and all four incisors in one arch were measured individually using a

pair of dividers. The teeth were measured in the following sequence: right central incisor; left central incisor; right lateral incisor; left lateral incisor; right canine; left canine; right first premolar; left first premolar; right second premolar; left second premolar; right first molar; left first molar. The width of each tooth was determined by adjusting the pointers of the dividers so that they measured the mesio-distal width of the tooth at the greatest convexity of the mesial and distal surfaces.

The width of the right cental was first recorded on the data sheet by piercing the sheet directly on a horizontal line provided on the sheet with both pointers of the dividers. The width of the left central was then measured and recorded by re-entering the right pierced hole from the right central with the left pointer of the dividers and piercing a new hole with the right pointer again directly on the horizontal line. The width of the right lateral could then be added to the combined width of both centrals by re-entering the hole furthest right with the left pointer and piercing a new hole on the horizontal line with the right pointer. This procedure was followed in the above sequence until all twelve teeth were measured and their combined and individual widths recorded as pierced holes on the horizontal line. This same method was followed for both arches using separate horizontal lines on the same data sheet to record the widths.

The data sheet was then placed on a transilluminated tracing table and the vernier caliper was used to measure the distance from the first pierced hole to the thirteenth pierced hole. The distance was recorded as the molar to molar arch length. The reason for this method of measuring was to permit the operator to make two other measurements with the vernier caliper: (5) Canine to canine width--the distance between the first pierced hole and the seventh pierced hole (equals the combined mesio-distal widths of the six anterior teeth); and (6) Incisor width--the distance between the first pierced hole and the fifth pierced hole (equals the combined mesio-distal widths of the four incisors). These last two meaurements were made in both arches also.

(7) Number of interdental spaces: The total number of spaces between adjacent teeth was recorded. A figure was entered on the data sheet for each arch.

(8) Interdental spaces measured in millimeters: Each space between adjacent teeth was measured with the vernier

caliper; the total amount of space in the maxillary arch was recorded. The same procedure was followed for the mandibular arch.

(9) Number of rotations: The total number of teeth rotated more than five degrees was recorded for the maxillary and mandibular arch.

(10) Space accounted for by rotations, measured in millimeters: The mesio-distal width of each tooth rotated over five degrees was measured with the dividers. Holes were punched on a horizontal line on a sheet of graph paper with the pointers of the dividers for all such teeth, using the same method outlined in (4) above. The total mesio-distal width of the rotated teeth was then determined by measuring from the first hole to the last hole. Next the mesio-distal space occupied by the rotated teeth was recorded in the same manner. The difference between the total mesio-distal width of the teeth and the total space occupied by them was then entered as the total number of millimeters accounted for by rotations. A separate entry was made for maxillary and mandibular rotations. If the teeth were rotated so as to cause a broken contact point and crowding, their measurement was not taken at this point,

but rather was used in (12) below as crowding due to broken contact.

(11) The number of broken contact points: The total number of broken contacts was recorded. A separate figure was entered for maxillary and mandibular broken contacts.

(12) Arch length discrepancy in millimeters due to broken contact points: The mesio-distal width of each tooth displaced from normal alignment due to broken contact was measured with the dividers. Holes were punched in graph paper with the dividers according to the procedure outlined in (4) above. The total mesio-distal width of such teeth was measured with the vernier calipers as in (4). The total space occupied in the arch by these same teeth was recorded and measured in the same manner. The arch length discrepancy was calculated as the difference in millimeters between total width of the teeth and total space occupied in the arch. This was done in both arches.

(13) Total mandibular arch length discrepancy: This figure represents the net amount of discrepancy in the mandibular arch caused by spacing, rotations, and broken contacts. When the tooth measurement and the interdental spaces

were greater than the size of a normal arch free from spaces, a negative entry was made.

A positive entry was made when there was insufficient arch length available to accept the teeth in normal alignment.

(14) Ratio maxillary to mandibular arch length: This figure represents the total mesio-distal width of the maxillary teeth from left first molar to right first molar, divided by the total mesio-distal width of the mandibular teeth from first molar to first molar. These widths were determined in (4) above.

(15) Ratio maxillary to mandibular anterior width: This ratio was obtained by dividing the total mesio-distal width of the six maxillary anterior teeth by the total mesio-distal width of the six mandibular anterior teeth. These widths were measured in (5) above.

(16) Ratio maxillary to mandibular incisor width: The total mesio-distal width of the maxillary four incisors was divided by the total mesio-distal width of the mandibular incisors. These widths were entered in (6) above.

(17) Overbite: The maxillary and mandibular casts were placed in centric occlusion and viewed from the front holding

them so that the occlusal plane was level with the operator's eyes. To aid this a safety razor blade fitted with a metal handle was held in contact with the incisal edges of the incisor and parallel to the occlusal plane. A fine horizontal scratch was made with the blade on the labial surface of the mandibular left central incisor. The overbite was then measured from the scratch mark to the incisal edge of the mandibular left central incisor.

(18) Overjet: This measurement was made with the casts in occlusion. The measurement was taken from the scratch mark on the mandibular left central incisor to the incisal edge of the maxillary left central incisor by means of a narrow scale marked in 0.5mm. In cases showing some attrition of maxillary incisal edge, the measurement was taken to the middle of the attritioned edge.

(19) Curve of Spee: The mandibular cast was held at eye level with the right side of the arch facing the operator; a wooden block was placed on the occlusal surfaces so as to make contact with the highest cusp of the first molar and the highest tooth in the anterior region of the arch. A millimeter scale was then used to measure the distance from the block to the tip of the cusp of the tooth most inferior to the block.

This was recorded as the curve of Spee for the right side. The same was done on the left side.

(20) Maxillary first molar to mandibular first molar relationship: With the casts in occlusion, the relationship of the mesial buccal cusp of the maxillary first molar to the buccal groove of the mandibular first molar was noted. If the cusp of the maxillary molar fit directly in the lower groove, a 0 was entered on the data sheet. If this cusp did not fall directly in the groove, the distance from cusp to groove was measured in millimeters. If the cusp was distal to the groove, a negative value was recorded; if the maxillary molar cusp was mesial to the groove, a positive value was used. This was done on both sides of the casts.

(21) Maxillary canine to mandibular canine relationship: The relationship of the maxillary canine to the embrasure between the mandibular first premolar and canine was noted when the casts were in occlusion. If the maxillary canine cusp tip fit directly in the mandibular embrasure between the mandibular canine and first premolar the value was considered 0. If the maxillary tooth was distal to the embrasure, a negative value was recorded; if the maxillary canine was mesial

to the embrasure, a positive entry was made on the data sheet. The same procedure was used on both sides.

(22) Maxillary canine to occlusal plane: The angle of inclination of the maxillary canine in relation to the occlusal plane was measured by means of an instrument consisting of a wooden platform (10X7 cm.) fitted with a flat steel strip on one edge. The strip could swivel and record the angulation between it and the platform. The canine axis was marked with a pencil on the cast. The cast was then placed with its occlusal surface on the platform and the steel strip adjusted to coincide with the marking on the canine. This gave the angulation of this tooth to the occlusal plane. The inner angle between the canine and the occlusal plane was read with a celluloid protractor. The same method was used to assess the angulation of the right and left canines.

(23) Mandibular canine to occlusal plane: The procedure outline in (22) above was used to record the angle of inclination of the mandibular right and left canines in relation to the occlusal plane.

CASE #____

TABLE 1
DATA SHEET -- CAST ANALYSIS

	MAXILLARY	MANDIBULAR
1. INTERCANINE WIDTH		
2. INTERPREMOLAR WIDTH		
3. INTERMOLAR WIDTH		
4. ARCH LENGTH MOLAR TO MOLAR		
5. CANINE TO CANINE WIDTH		
6. INCISOR WIDTH		
7. NUMBER OF SPACES		
8. SPACING, MILLIMETERS		
9. NUMBER OF ROTATIONS		
10. ROTATIONS, MILLIMETERS		
11. NUMBER OF BROKEN CONTACT POINTS		
12. BROKEN CONTACTS, MILLIMETERS		
13. MANDIBULAR ARCH DISCREPANCY		
14. RATIO, MAX:MAND ARCH LENGTH		
15. RATIO, MAX:MAND ANTERIOR WIDTH		
16. RATIO, MAX:MAND INCISOR WIDTH		
17. OVERBITE		
18. OVERJET		

	RIGHT SIDE	LEFT SIDE
19. CURVE OF SPEE		
20. MAX 6 to MAND 6 RELATION		
21. MAX 3 to MAND 3 RELATION		
22. MAX 3 to OCCLUSAL PLANE		
23. MAND 3 to OCCLUSAL PLANE		

CHAPTER IV

FINDINGS

The statistical analysis of the thirty-five measurements considered in this study can be found in Tables 2 and 3. Table 2 shows the ranges for twenty-two of the measurements, also the mean, standard deviation, and the 95% confidence limits for the range of each value (mean $\pm$ 1.96X standard deviation). The remaining thirteen sets of measurements are shown in Table 3 with their corrected (real) values for the mean, standard deviation, and the 95% confidence limits. These calculations were necessary in order to present a true evaluation of the data. For example, the mean value for the number of maxillary broken contact points cannot be 1.08; the real value for this figure is one. An explanation of the real values for the measurements in Table 3 will be discussed later in this chapter.

All cases selected for this study had a Class I (Angle) molar relationship bilaterally. Each set of casts was examined for exact interdigitation of the mesial-buccal cusp of the maxillary first molar with the buccal groove of the mandibular first molar. Nineteen of the casts showed ideal interdigitation on both right and left side. In nine of the casts one side was in ideal interdigitation while the other had the maxillary molar slightly anterior. In four of the cases the mesio-buccal cusps of both maxillary molars were slightly anterior to the buccal groove of the mandibular molars. In thirteen cases there was an ideal interdigitation on one side, while the maxillary molar was slightly posterior to the buccal groove of the mandibular molar on the opposite side. In two cases the maxillary molars on both sides were slightly posterior. In three cases the maxillary molar on one side was slightly posterior, and the maxillary molar on the opposite side slightly anterior.

The experimental range for this measurement was 2.3 mm. anterior, to 2.7 mm. posterior (means 0.146 mm. ± 0.985 mm. posterior). These slight deviations from "normal" Class I molar relationship were not of sufficient magnitude to disqualify a case from a classification of normal occlusion. In those cases showing some deviation in the molar relationship, the premolars were in perfect interdigitation, indicating that mesial drift of the buccal segments was not the cause of the molar variation.

Each case was examined in centric occlusion to determine the relation of the maxillary canine to the embrasure between the mandibular first premolar and canine. In thirteen cases the tip of both maxillary canine cusps was correctly related to the mandibular embrasure between the first premolar and canine. In twelve of the subjects the relationship on one side was ideal while the cusp tip was slightly anterior to the embrasure on the other. Twenty-one cases had the cusp tips anterior to their respective embrasure on both sides of the arch. In three cases the maxillary cusp tip was posterior to the mandibular embrasure on one side, and had ideal intercuspation on the other side. Both maxillary canines were distal to the mandibular embrasures in one case. Two cases had had the maxillary canine on the left side mesial to the mandibular embrasure and the maxillary canine on the right side distal to the mandibular embrasure.

In all cases where the maxillary canines were forward, the premolar occlusal relationship was normal, indicating that mesial drift of the maxillary buccal units did not cause the forward position of the canines. Ten of the cases had one or both canines forward as well as one or both molars forward; but even in these cases the premolar occlusion was quite normal. This fact also points out that mesial drift of the maxillary buccal segments was not the cause of the mesial positioning of the molars and canines. These occlusal adjustments can be explained by tooth size differentials.

Only three subjects had end-to-end canine occlusion, and in only one case was the condition bilateral. Iyer and Desai (1963), in their examination of casts of 100 Indian males with normal occlusion, showed that one-half of their subjects had normal canine relationships and the other half end-to-end canine relation. They suggested that some discrepancy in size of the maxillary and mandibular teeth might account for this relationship.

Tooth size discrepancy between the maxillary and mandibular dentures may account in part for the forward positioning of the maxillary canines. However, it is the opinion of this investigator that the mesiodistal angulation of the maxillary canine has a definite bearing on the mesiodistal position of the cusp tip of the tooth. The mean and the experimental range of maxillary and mandibular canine inclination with reference to the occlusal plane are shown in Figure 5. Referring to the maxillary canine, it is obvious that as the angle between the tooth and the occlusal plane decreases, the cusp tip moves further forward. In this study, 45.2% of those cases showing a mesial position of the maxillary canine also had a low canine to occlusal plane angle. There was no correlation between mesially positioned canines and increased anterior overjet. This fact also points out that the canines are not bodily forward, instead they are mesially inclined so that the cusp tip is forward.

Referring again to Figure 5, the axial inclination of the canines to the occlusal plane shows that the maxillary canine is usually more mesially inclined than the mandibular canine. Because of the wide range of canine angulation in this study (maxillary, 102.1°,to 69.9°; mandibular, 110°, to 71°), it must be concluded that vertical or even distally tipped maxillary canines, and distally tipped mandibular canines are frequently seen in subjects having normal occlusion. A similar observation was made by Iyer and Desai (1963) in their study of casts of Indian males with normal occlusion.

As a matter of clinical interest, the depth of the curve of Spee was measured on the right and left sides of all mandibular casts. Nine of the subjects had a perfectly flat occlusal plane. The experimental range was from 2.3mm. deep, to 0, or flat occlusal plane. The mean value was 0.701mm. $\pm$ 0.523mm. The minor variations noted in the curve of Spee of the selected cases are to be expected in a population of "normal" occlusions. It is interesting to note that none of the subjects had a curve of Spee severe enough to cause detectable antero-posterior interferences in occlusion.

One of the criteria fulfilled by all the subjects selected for this study was an anterior overbite of less than five millimeters. The experimental range for this measurement was 4.7mm., to 0.6mm. Bolton (1958), in his investigation of casts of fifty-five patients with excellent occlusion, could find no significant coefficient of correlation when the degree of overbite was related to the incisor length, clinical eruptive heights of the teeth, or mesio-distal widths of the anterior teeth. His findings were verified in the study by Iyer and Desai. These investigators concluded that the amount of overbite is not merely a function of tooth elongation, but rather involves the alveolar process and basal bones.

The maximum allowable limit of anterior overjet for those qualifying for this study was 5.0mm. Only one subject had this amount of overjet, while the remaining had 3.5mm., or less. The mean value was 1.69mm.±0.932mm.

The amount of crowding, indicated by broken contact points, was limited to a maximum of 5.0mm. in either arch. Allowable spacing was also 5.0mm. in either arch. No case having teeth rotated over five degrees was used in this sample. All of these limiting factors contributed to an experimental range of 4.5mm., to -1.3mm. for total mandibular arch length discrepancy in this investigation. The mean figure for mandibular arch length discrepancy was 2.39mm.±1.32mm.

Nineteen cases showed spacing or open contacts in the maxillary arch. Twenty-eight cases had broken contacts due to crowding in the maxillary arch.

Forty-seven subjects had broken contact points and crowding in the mandibular arch, indicating there was more tooth material than the arch would accomodate. The experimental range was from 4.5mm., to 0; The mean figure was 2.5mm. ± 1.27.

Twenty-eight patients had crowding of maxillary teeth, and all of these also had mandibular crowding.

The experimental range , mean, standard deviation and 95% confidence limits for all the dental factors which contribute to arch length discrepancy in this study are shown in table 3. Statistical values as well as real values are listed. The statistical data were considered to be confusing in certain instances, and therefore corrections of these data were made and charted as "real" values. The real value appears directly below the statistical finding for each entry.

With the exception of Total Mand. Arch Length Discrepancy all of those statistical findings in the low 95% confidence column which show a negative or minus value are incorrect. Each measurement was taken separately and positive values, which either increased or decreased the total amount of arch length discrepancy, were entered on the data sheet. Therefore the value for total Millimeters Broken Contact, or the Total Millimeters of Space available in the arch was always zero or greater than zero. Corrections have been made to indicate that the low limit for each such measurement is zero.

For each entry which calls for a whole number as a finding, as in the Number of Max. Broken Contacts, the Number of Mand. Broken Contacts, etc., the statistical values (fractional numbers) have been corrected to the practical (real) whole numbers. As an example: Number of Mand. Broken Contacts is seen to have a statistical standard deviation of 1.45, and a real standard deviation of 2; the statistical evaluation of high and low 95% confidence limits show 5.86, and 0.14, respectively; the real values for these two latter figures are 6, and 0, respectively.

Twenty-six cases showed rotation of one or more teeth in the maxillary arch. Rotation of one or more mandibular teeth was observed in forty-one of the subjects. Twenty-five of the cases presented one or more rotations in both arches. No candidate had more than four rotated teeth in either arch.

As previously stated in the methods and materials chapter, any rotated tooth causing a broken contact point was considered to be contributing to arch length discrepancy. Therefore, even though such a tooth was counted in the total number of rotations, its value in the assessment of total arch length discrepancy was as a tooth having a broken contact point due to crowding. Rotated teeth occupying a space in the arch greater than their mesiodistal widths were observed in five cases. In each of these there was only one rotated tooth. These were found more frequently in the mandibular arch. For the above reasons, the entries for Millimeters Mand. Rotations and Millimeters Max. Rotations specify zero for the mean value.

Maxillary and mandibular arch widths were measured in the canine, first premolar, and first molar regions on each set of casts. The results of these measurements are listed in Table 2. Pont (1909) noted that wide anterior teeth are found in broad arches, and narrow anterior teeth in narrow arches. The Pont Normal Tooth Index lists the width of the arch in the premolar and molar region which corresponds to a given value for the width of the maxillary incisors. Similar correlations were attempted in this study. However, no significant interrelationship between the sum of the mesiodistal widths of the anterior teeth and the width of the arch anteriorly or posteriorly could be found. It is the opinion of this investigator that accomodation of the teeth in good arch form is not merely a function of the width of the denture. Other factors such as antero-posterior length of the basal bones, width of the face, and functional characteristics of the buccinator mechanism must be taken into account when evaluating the width of the dental arches.

The mesiodistal widths of all the teeth from left first molar to right first molar in both arches were measured. The mean value for the total mesiodistal width of the twelve maxillary teeth was 98.6mm. ± 4.497mm. The mean value for the combined widths of the mandibular teeth was 90.67mm. ± 3.921mm. For each set of casts, the width of the twelve maxillary teeth was divided by the widths of the twelve mandibular teeth. In this way the ratio of the maxillary to mandibular teeth was determined for each subject. The experimental range for this ratio was 1.17, to 1.05. The mean value was 1.09. Because all of the subjects in this study had normal occlusions, the ratio of maxillary to mandibular arch length can be taken as normal. Bolton (1958) stressed the merit of such a determination in the assessment of tooth size discrepancy between the maxillary and mandibular denture.

In the Bolton study, mandibular arch length was divided by maxillary arch length, and the ratio multiplied by 100 so that the final ratio was stated as a percent. The mean figure for the ratio of mandibular arch length to maxillary arch length according to Bolton was 91.3%. In order to compare

Bolton's value to that determined in this study, it is necessary to mathematically change the percentage in the following way:

$$100/91.3 = 1.09$$

By treating the percent figure in this way, it is apparent that the ratio computed in both studies is the same.

The combined mesiodistal widths of the six anterior teeth were recorded for each arch on all sets of casts. The total maxillary anterior width was then divided by the total mandibular anterior width in order to determine an anterior ratio. The mean value for this ratio was 1.27 ± 0.0475. This ratio indicates the normal tooth size relationship between the maxillary and mandibular six anterior teeth. Using the anterior ratio in conjunction with the total arch length ratio, one can determine if a tooth size discrepancy exists between the two arches, and whether this discrepancy in tooth size prevails in the anterior or posterior teeth.

Bolton also obtained a ratio for maxillary and mandibular tooth sizes of anterior teeth. Again, as in the total arch length ratio, his value was stated as a percent. The value given for the anterior ratio was 77.2%. Treating this percent figure as above:

$$100/77.2 = 1.29,$$

we find that the value obtained in this study is less than the Bolton value by 0.02. The difference between the two values is therefore quite small and statistically insignificant.

As a further refinement in the determination of tooth size discrepancy between maxillary and mandibular teeth, a ratio of maxillary incisors to mandibular incisors was established. The combined width of the maxillary incisors was divided by the combined widths of the mandibular incisors for each case. The mean value was 1.347 ± 0.06. The purpose of this ratio is to aid the orthodontist in deciding exactly where a tooth size discrepancy occurs in the anterior region. If a determination of the anterior ratio indicates that a tooth size discrepancy exists, the incisor ratio should then be computed. If the incisor ratio is normal, the discrepancy in size exists in the canine teeth. If the incisor ratio is not normal, the tooth size discrepancy lies in the incisor teeth.

All the data accumulated in this study were organized and recorded on punch cards for assessment by an electronic computer. A computer program was designed to analyze the data obtained from the casts of each subject. This program (Table 4) spells out the exact sequence of operations necessary in order to establish the relationship of the cast measurements to the measurements taken on the cephalometric radiograph for each subject.

The program can also be used to assess the casts and lateral cephalogram of a patient with a malocclusion. In order to accomplish such an assessment, one measurement (such as overbite, overjet, arch length discrepancy, etc.) from the patient would be chosen as an independent variable. Cephalometric and cast measurements from a subject with normal occlusion, and a value for the chosen independent variable indentical with that of the test patient, would be read into the machine at the appropriate loci within the program. The information from the test patient would then be placed in the computer. The program is designed so that the machine will indicate both the normal and abnormal measurements of the test patient on the print-out.

TABLE 2

STATISTICAL EVALUATION OF DATA

MEASUREMENT	EXP. RANGE	MEAN	STD.DEV.	95% CONFIDENCE LIMITS HIGH	LOW
6/6 Relation	2.3 to -2.7	-0.15	0.98	1.85	-1.99
3/3 Relation	4.1 to -1.5	1.03	1.21	3.39	-1.34
Angle Max 3	102.1 to 69.9	82.7	6.3	95.1	70.4
Angle Mand 3	110.0 to 71.0	89.2	7.9	104.8	73.6
Curve of Spee	2.3 to 0	0.7	0.5	1.7	0.3
Overbite	4.7 to 0.6	2.9	1.2	5.2	0.6
Overjet	5.0 to 0	1.7	0.9	3.5	-0.1
Max Intercanine Width	38.8 to 30.2	33.9	2.1	38.0	29.9
Mand Intercanine Width	29.0 to 21.2	24.8	1.7	27.4	21.1
Max Inter-premolar Width	46.9 to 36.3	41.6	2.4	46.4	36.9
Mand Inter-premolar Width	38.9 to 29.0	34.0	2.2	38.4	29.7
Max Inter-molar Width	58.0 to 46.0	52.1	3.2	58.3	45.9
Mand Inter-molar Width	51.3 to 37.2	44.7	3.3	51.2	38.2
Max Arch Length	109.5 to 89.3	98.60	4.50	107.42	89.78
Mand Arch Length	99.6 to 83.0	90.67	3.92	98.36	82.98
Ratio Max/Mand Arch Length	1.17 to 1.05	1.09	0.03	1.14	1.04
Width Max Anteriors	56.5 to 43.5	48.58	2.67	53.82	43.34
Width Mand Anteriors	41.8 to 34.0	37.96	1.81	40.51	34.41
Ratio Max/Mand Ant Width	1.43 to 1.19	1.274	0.048	1.367	1.181
Width Max Incisors	37.0 to 28.5	31.91	1.84	35.52	27.29
Width Mand Incisors	26.9 to 21.0	23.69	1.14	25.93	21.45
Ratio Max/Mand Incisors	1.55 to 1.22	1.347	0.063	1.470	1.225

TABLE 3

STATISTICAL VALUES AND REAL VALUES FOR FACTORS CONTRIBUTING TO ARCH LENGTH DISCREPANCY

MEASUREMENTS		EXP. RANGE	MEAN	STD.DEV.	95% CONFIDENCE LIMITS HIGH	LOW
Number of Max. Broken Contacts	STAT.	4 to 0	1.08	1.16	3.35	-1.19
	REAL		1	1	3	0
Millimeters Max. Broken Contacts	STAT.	5 to 0	0.84	1.06	3.14	-1.24
	REAL		0.8	1.06	3.1	0
Number of Mand. Broken Contacts	STAT.	6 to 0	3.0	1.45	5.86	0.14
	REAL		3.0	2	6	0
Millimeters Mand. Broken Contacts	STAT.	4.5 to 0	2.50	1.27	4.99	0.01
	REAL		2.5	1.27	5	0
Number of Max. Spaces	STAT.	4.0 to 0	0.88	1.34	3.51	-1.75
	REAL		1	1	4	0
Millimeters Max. Spaces	STAT.	4 to 0	0.78	1.20	3.13	-1.57
	REAL		0.8	1.2	3.1	0
Number of Mand. Spaces	STAT.	2 to 0	0.10	0.36	0.85	-0.65
	REAL		0	0	0	0
Millimeters Mand. Spaces	STAT.	2 to 0	0.10	0.36	0.85	-0.65
	REAL		0	0	0	0

TABLE 3 (CONTINUED)

STATISTICAL VALUES AND REAL VALUES FOR FACTORS CONTRIBUTING TO ARCH LENGTH DISCREPANCY

MEASUREMENTS		EXP. RANGE	MEAN	STD. DEV.	95% CON. LIMITS HIGH	95% CON. LIMITS LOW
Number of Max. Rotations	STAT.	4 to 0	0.82	0.98	2.78	-1.14
	REAL		1	1	3	0
Millimeters Max. Rotations	STAT.	0	0	0	0	0
	REAL		0	0	0	0
Number of Mand. Rotations	STAT.	4 to 0	1.70	1.14	4.12	-0.12
	REAL		2	1	4	0
Millimeters Mand. Rotations	STAT.	1 to 0	0.08	0.63	1.29	-1.12
	REAL		0	0	0	0
Total Mand. Arch Length Discrepancy	STAT.	4.5 to -1.3	2.39	1.32	4.98	-0.21
	REAL		2.4	1.32	5.0	-0.2

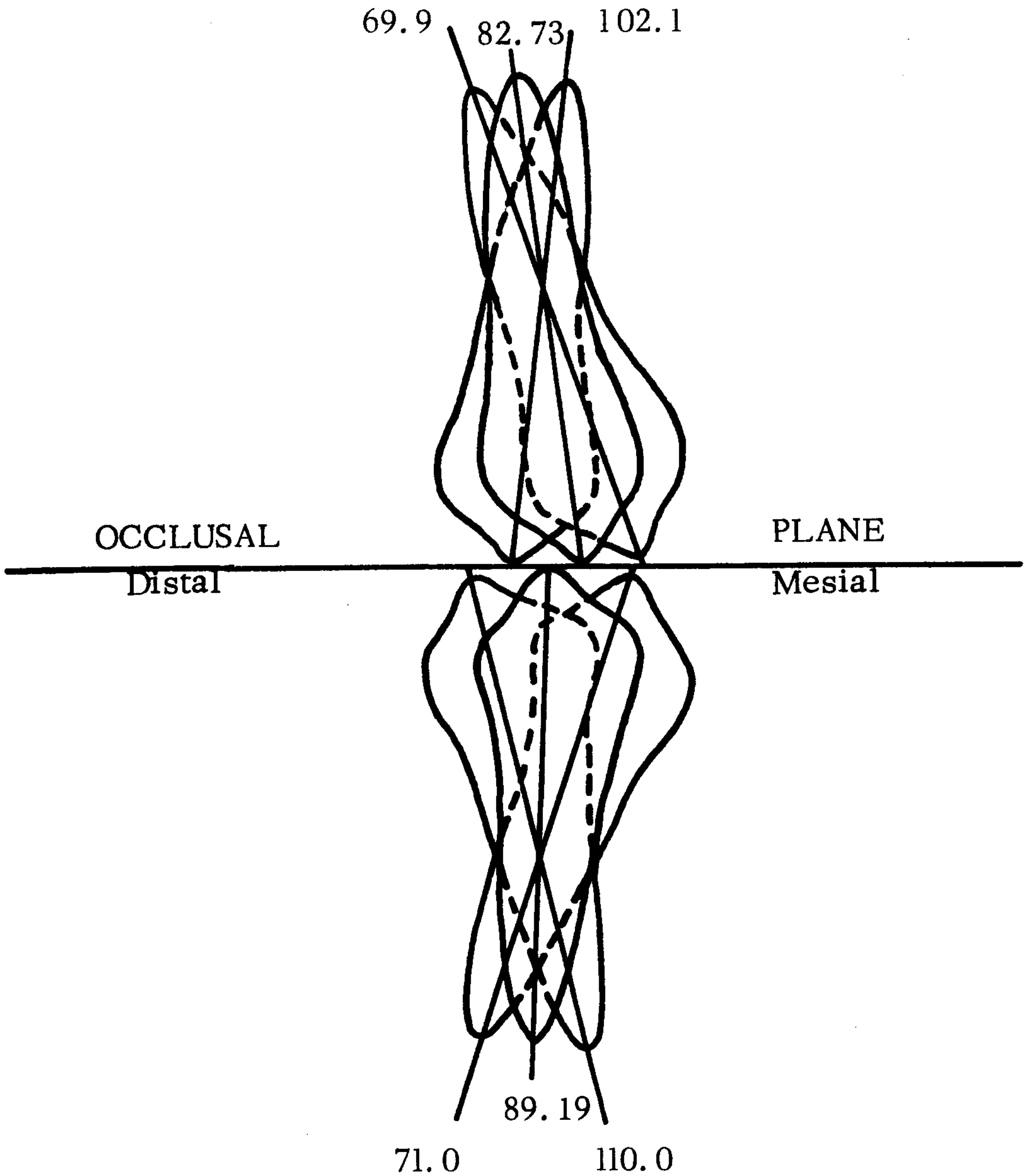

DIAGRAM SHOWING ANGLE OF INCLINATION OF THE MAXILLARY AND MANDIBULAR CANINES TO THE OCCLUSAL PLANE. THE MEAN AND HIGH AND LOW LIMITS OF THE EXPERIMENTAL RANGE ARE SHOWN

FIGURE 1

IBM Flowcharting Worksheet

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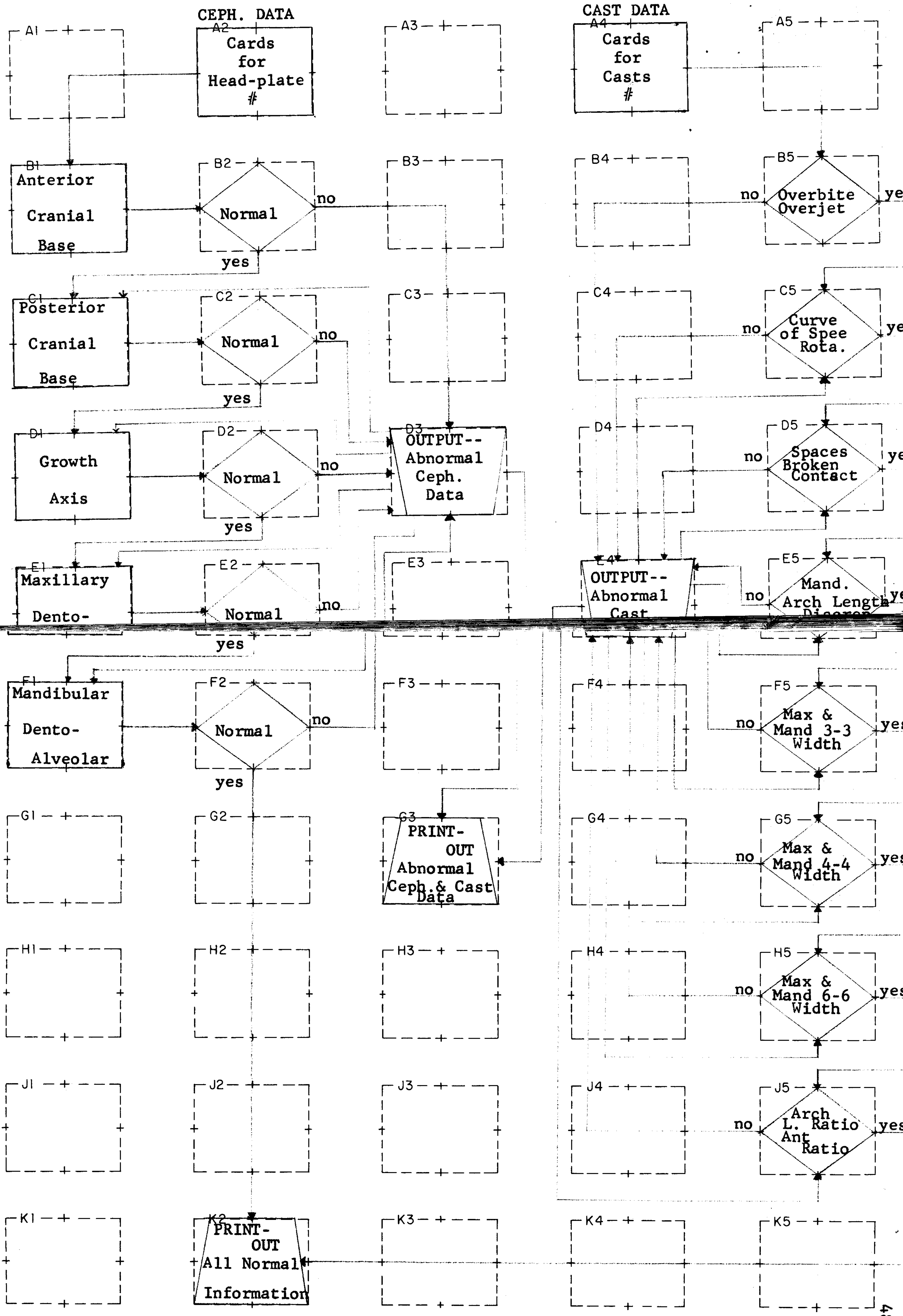
X20-8021-2

Programmer: William Thomas   Program No.: I   Date: ____   Page: ____

Chart ID: ____   Chart Name: Pilot Program   Program Name: Orthodontic Diagnosis



CHAPTER V

DISCUSSION

In order to use the computer to provide an orderly scheme for orthodontic diagnosis and subsequent treatment planning, a great amount of data relating to the cranio-dento-facial complex must be stored in the machine. These data must comprise a complete appraisal of normal occlusion and all types of malocclusions. This investigation, along with a study by Gerald Ashley, was designed to furnish the computer with useful information from patients presenting normal occlusion.

Young adults were chosen for the initial computer study because of the stability of the dental and cranial landmarks. Occlusal phenomena and bony structures are subject to changes incident to growth, which may work to influence favorably or alter unfavorably the development of occlusion, until a person reaches maturity. Normal occlusion of the teeth in the young adult, therefore, reflects the termination of a normal growth pattern. Proper functioning of the entire stomatognathic system during childhood and adolesence is also manifested in the normally occluding denture of the adult.

The dentitions of the subjects used in this investigation conformed to requirements stated in the chapter on methods and materials. Properly articulated plaster models of each subject were constructed. Certain landmarks were then measured on each set of casts in order to determine the similarity and variability of the values for each landmark within the population.

Mean values were computed for each measurement. Because of individual variation within the species, no denture can be expected to comply with all, or indeed any, of the mean values established here. However, a range for each measurement was established as a framework within which a value can vary and still remain an "acceptable normal" value. The significance of the established normal standards and ranges is discussed below.

The term "normal occlusion" implies the existence of a molar relationship consistent with an anterior overjet of two or three millimeters, assuming there is good alignment of the teeth in both arches. It follows then, that a Class I (Angle) molar relationship (neutrocclusion) must obtain on both sides of the arch if the relationship of the maxillary and mandibular anterior teeth is to be esthetically and functionally correct. All of the cases in this study had the first molars in neutrocclusion.

The position of the mesial-buccal cusp of the maxillary molar during centric occlusion was examined on each set of casts. This cusp was found to exactly intercuspate with the buccal groove of the mandibular first molar in less than one-half of the cases. The usual relationship of the maxillary cusp was slightly mesial or distal to the mandibular buccal groove. However, these small variations in the molar relationship had no effect on the centric relationship of the premolar teeth or the canines, and did not influence the anterior overjet relationship.

The relation of the maxillary canine to the embrasure between the mandibular canine and first premolar was examined in each case. This interrelationship is dictated by neutrocclusion of the molars in patients showing normal tooth alignment. Here again, as in the molar interdigitation, fewer than one-half of the cases presented "ideal" canine occlusion. The majority of cases had maxillary canines slightly forward of the proper mandibular embrasure. No correlation was found between mesially positioned molars and mesially positioned canines in this sample. Neither was there any correlation between mesially positioned canines and increased anterior overjet.

The method used to measure the relationship of the maxillary canine may account for the apparent forward position of this tooth in the majority of the cases. The tip of the maxillary canine cusp was used as a point of reference. If the tip of the cusp was forward to the mandibular embrasure, the canine was considered to be forward. The diagram (Figure 5) in the findings chapter illustrated the range of movement of the cusp tip as the axial inclination of the canine changes. It was observed that, although the measurements indicate mesial positioning of most of the maxillary canines in this study, these teeth are not bodily forward, but they are mesially inclined so that the cusp tip is mesial to the embrasure.

In all cases, regardless of the slight variations in the interdigitation of molars and canines, the premolar occlusion was found to be normal. That is, the maxillary second premolar interdigitated in the embrasure between the mandibular first molar and second premolar, and the maxillary first premolar interdigitated in the embrasure between the mandibular second premolar and first premolar. In nearly every case the buccal cusps of the maxillary premolars approximated correctly in their respective mandibular embrasures. The premolar occlusion, therefore, was much less diverse than the occlusion of the molars and canines.

The axial inclination of maxillary and mandibular canines was found to be quite variable. Maxillary canines ranged from mesially inclined (69.9^{o} angle to the occlusal plane), to distally inclined (102.1^{o} angle with the occlusal plane). The mean value for the angle between occlusal plane and maxillary canine was 82.7^{o}. The mean figure for the angle between occclusal plane and mandibular canine was 89.2^{o}. The mandibular canines had a range from mesially tipped (110.0^{o} angle with the occlusal plane), to distally tipped (71.0^{o} angle with the occlusal plane). It was concluded that the axial inclination of both maxillary and mandibular canines is not necessarily ideal in relation to functional forces of occlusion. It seems more likely that the mesio-distal angulation of these teeth is dictated by their eruption pattern and remains virtually unchanged despite forces of occlusion.

The mean figure for anterior overbite in this study was 2.87mm. ± 1.77mm.. Because the denture tends to become less procumbent as a person grows older, the crowns of the maxillary and mandibular incisors tip lingually and the amount of overbite tends to increase with age. Although incisal attrition tends to offset the increase in overbite, adults generally have a greater measured anterior overbite than children. It follows, therefore, that the mean figure for overbite in this study is larger than one would find in a population of children with normal occlusion.

The mean value for anterior overjet in this study was 1.69 mm. ± 0.932 mm.. Clinically, a minimal amount of overjet can be observed when the canines are in a Class I relationship and all the anterior teeth in both arches are in tight contact. Several arrangements of the anterior teeth can prevent the attainment of a good overjet condition even though the canines are in a Class I relationship. These are: (1) broken contact points due to crowding in the mandibular anterior teeth; (2) spacing of the maxillary anterior teeth; (3) tooth mass discrepancy between maxillary and mandibular anterior teeth; (4) combination of the above.

Mandibular arch length discrepancy was found to be a feature of nearly all the subjects in this study. Forty-seven of the fifty candidates had some broken contact points between the mandibular anterior teeth. The mean value for mandibular arch length discrepancy was 2.39 mm. ± 1.32 mm. Normal physiologic mesial drift of the teeth is known to occur in nearly all human dentures. The affect of this phenomenon frequently manifests itself in crowding of the anterior teeth in man in modern culture. This is not seen in primitive cultures because their food is more abrasive, and causes interproximal wear of the teeth. Diet of modern man consists almost entirely of soft foods, and therefore interproximal wear rarely occurs in his denture. As a person gets older, the mandibular anterior teeth become less procumbent. The crowns of the anterior teeth tend to tip lingually and the roots labially. In the absence of interproximal abrasion, crowding in this region of the adult denture occurs frequently. Some orthodontists provide for this lack of interproximal wear by stripping some interproximal tooth material.

The width across the arch in the canine, premolar, and molar regions seems to be of little diagnostic value. However, in future assessment of data with the computer, various interrelationships involving these measurements may prove to be significant in the diagnosis of malocclusions.

For each case, the total mesiodistal width of the maxillary teeth from left first molar to right first molar was divided by the total mesiodistal width of the mandibular teeth from left first molar to right first molar. In this way, the total arch length ratio was determined. The mean value for this ratio was 1.09 ± 0.03. Use of this ratio can be of value not only in the computer analysis of malocclusions, but to the clinical orthodontist as well. Determination of the total arch length ratio indicates whether there is tooth size discrepancy between the mandibular and maxillary dentures. If the value for the ratio is 1.09 in a case that is being analysed, there is no tooth size discrepancy. If the ratio is less than 1.09, the tooth material in the mandibular arch is greater than average for the amount of tooth material in the maxillary arch. If the ratio is greater than 1.09, it can be stated that excess tooth material is present in the maxillary arch. In either of the latter two cases, judicious stripping of the interproximal contact points in the arch showing excess tooth material can provide a much better clinical result of the treated malocclusion.

The left-hand column of Appendix I lists twenty-eight possible maxillary arch lengths ranging from 85mm., to 112mm. The mandibular arch length which corresponds to the 1.09 ratio is listed in the right-hand column, opposite the appropriate maxillary value. To use this chart, one would first compute the total arch length ratio for a given patient. If the ratio were greater than 1.09, he would then locate on the chart the mandibular reading which corresponds to that of the patient. Opposite this he would find the correct value for the maxillary arch length. By subtracting this value from the value obtained from the patient, the amount of excess tooth material in the maxillary arch could be determined. If the ratio were less than 1.09, one would consult the chart for the value corresponding to the patient's maxillary measurement. The mandibular value listed to the right of this measurement would then be subtracted from the patient's mandibular reading to determine the amount of excess tooth material contained in the patient's lower arch.

As a further aid in the determination of tooth size discrepancy between the maxillary and mandibular arch, an anterior ratio was formulated. This was done by dividing the total mesiodistal width of the maxillary six anterior teeth by the total mesiodistal width of the mandibular six anterior teeth. The mean value for this ratio was 1.27 $\pm$ 0.048. By ascertaining the anterior ratio for a case, the existence of a tooth size discrepancy in the anterior region can be discovered. This can be of particular value where a tooth size differential between the upper and lower teeth is suspected. Also, in cases where discrepancy has been found through the use of the total arch length ratio, the anterior ratio will indicate whether the size discrepancy is in the anterior or posterior teeth.

Appendix II lists various maxillary anterior widths and the appropriate mandibular anterior widths which correspond to the 1.274 ratio. The use of this table follows the same format as the use of Appendix I as directed above.

In order to be able to pinpoint the oversized teeth in a case of anterior tooth size discrepancy, the incisor ratio was developed. The total mesiodistal width of the maxillary central and lateral incisors was divided by the total mesio-istal width of the mandibular central and lateral incisors. The mean value for this ratio was 1.34 $\pm$ 0.063. If an anterior tooth size discrepancy exists, as determined by the anterior ratio, the incisor ratio will indicate whether the discrepancy is in the incisor teeth or the canines. If the anterior ratio shows a discrepancy, and the incisor ratio shows an equal discrepancy, the incisors are the offending teeth. However, if the anterior ratio indicates a discrepancy and the incisor ratio is normal, the canines have a size discrepancy.

Tooth size discrepancies in the anterior region, even though minor in nature, can cause undesirable esthetic results in a treated case. If the mandibular anterior teeth are proportionally large for the size of the maxillary anteriors, the finished case will show maxillary anterior spacing and good mandibular arch alignment. If the spaces in the maxillary arch are then closed, broken contact points due to crowding will result in the mandibular arch. The solution to such a problem lies in the determination of the tooth size differential, and subsequent stripping of the contacts of the mandibular anterior teeth. Through the use of the anterior ratio and the incisor ratio, one can determine the exact amount of stripping that will be necessary, and which teeth should be stripped.

If the maxillary anterior teeth are proportionally larger than the mandibular anterior teeth, increased overjet is the result, if both arches are in good alignment. The alternatives are, spacing in the lower arch, or broken contacts due to crowding in the upper arch, either of which will tend to solve the overjet problem. However, judicious stripping of the interproximal contacts in the maxillary arch can result in good arch alignment and a desirable overjet relationship.

Appendix III lists a range of upper incisor widths and corresponding lower incisor widths determined by the 1.347 ratio. Use of this index is idential to that described for Appendix I.

Appendix IV presents a composite of the tables in Appendix I,II and III. The method for determining each of the three ratios is given. Instructions for the use of the ratios and tables are also included. It is felt that this index can be an aid to the clinical orthodontist in the analysis of a malocclusion. As explained above, the adverse effects of tooth size discrepancy can best be negated if the existence of a discrepancy is discovered in the original analysis of the plaster casts.

All of the data accumulated in this study have been organized and recorded on punch-cards for analysis by an I.B.M. 1401 electronic digital computer. The standard (mean) values for each landmark and their statistical and experimental ranges have been written in a computer language (Fortran IV) and stored in a compact form for easy assessement by the machine. All or any part of the information can be recalled for use in future research. New information, organized in the same or a different way on punch cards, can supplement these data.

The computer program proposed in this study provides a means for establishing interrelationships between measurements on the casts and measurements obtained from the cephalogram of each subject. Through the use of programs such as this, complex relationships between heretofore unrelated phenomena as observed clinically and on various diagnostic aids can be discovered and made meaningful in the future diagnosis of malocclusions.

This study, along with the investigation by Gerald Ashley, provides some material for the construction of an orthodontic diagnosis computer program. The values obtained in the two studies are recorded as standards for one segment of the adult population. The program outlined here makes these data significant as an overall picture of normal occlusion combining dental and cranial factors. After the program has been tested future studies will add new data stating standards for other groups within the population. Additional information will be provided from investigations of: Young adult females with normal occlusion; children with normal occlusion; children with various malocclusions; adults with various malocclusions; and racial and ethnic groups with normal occlusion and various malocclusions.

In addition to the data which must be collected from untreated subjects, certain information from treated patients must be accumulated. The reason for this is to discover what factors are incident to relapse and what elements contribute to stability of the treated denture.

Only through further research in the combined fields of orthodontics and computer logic can a valuable program for orthodontic diagnosis and treatment planning be developed. Much data are yet to be collected and organized. Many computer programs must be written to make such data meaningful. When this has been accomplished it will be possible to base a treatment plan on an exhaustive diagnosis of the malocclusion. And, it will be possible to base the diagnosis on knowledge obtained from a competent appraisal of <u>all</u> facts pertinent to orthodontic discipline.

The journey toward the development of a computerized orthodontic diagnosis system requires a point of departure. This study provides such a point. Although the destination is still out of sight, these first steps provide the direction for future research to take in order to achieve the final goal.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study was undertaken to determine the dental characteristics of young adult Caucasian males with normal occlusion. The purpose of such a determination was to establish a criterion for normal occlusion which can be incorporated into an orthodontic diagnosis system programmed for an electronic computer. Five hundred subjects were examined before a final sample of fifty was selected to participate in this investigation. These participants fulfilled certain requirements with regard to morphology and function of the craniofaciodental complex, as set forth in this experiment.

Thirty-one dental landmarks were selected as points from which measurements of diagnostic value and clinical interest were taken. The configuration of the dental arches, the position and size of the teeth within the arches, and the relation of the dental arches to each other was studied and evaluated. The values obtained from the measurements were considered to represent standards describing normal occlusion by virtue of the design of the experiment. These standards were placed on I.B.M. punch cards for assessment by an electronic digital computer. A computer program was written to establish a total picture of normal occlusion in a given subject. This program combines all the data obtained from the casts of a subject with all the data from the subject's lateral cephalogram. Through the use of this program, it is also possible to determine the abnormal dental and cranial measurements in a patient with a malocclusion.

Evaluation of certain of the data furnished methods for determining the existence of size discrepancies between teeth in opposing dental arches. Through the use of these methods, charts were designed to provide the clinical orthodontist with a means for easily recognizing tooth size discrepancies.

The following may be concluded from this study:

1. Variations from normal occlusion occur in all human dentures. A description of normal occlusion can serve only as a guide for comparison with "individual normal" occlusion.
2. There is a wide range of "acceptable normal" variations for each measurement in this study.

3. Premolar occlusion is less variable than canine and first molar occlusion.
4. The normal axial inclination of maxillary and mandibular canines varies from mesially inclined to distally inclined.
5. In normally occluding dentures there is no correlation between the width of the anterior teeth and the posterior width across the arch.
6. Size discrepancies between maxillary and mandibular dental units can be recognized using normal ratios.
7. Crowding of mandibular anterior teeth occurs in nearly all adults. A small amount of arch length discrepancy should be considered normal in adults.
8. Overbite within the range of 0.6mm., to 5.0mm., should be considered normal.
9. Anterior overjet within the range of 0.0mm., to 5.0mm., should be considered normal.
10. In normally occluding teeth, the depth of the curve of Spee should be no more than 2.5mm. at its deepest point.
11. Tooth measurements were established that accurately

describe normal occlusion for a specific race, sex, and age group within the population.

12. These data are suitable for computer assessment.
13. Through the use of the program designed in this study, the tooth arrangement of a patient can be correlated with the skeletal arrangement of the patient's cranium.
14. The computer program provides a means for rapidly evaluating the abnormal skeletal and dental characteristics of a patient with a malocclusion.
15. With this study as a basis, future investigations can eventually provide a complete, unbiased computer program for orthodontic diagnosis.
16. In order to expedite the development of computer oriented orthodontic diagnosis, orthodontists will need training in the field of computer logic and programming.

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APPENDIX I

VALUES FOR MAXILLARY ARCH LENGTH AND CORRESPONDING VALUES FOR MANDIBULAR ARCH LENGTH COMPUTED USING THE ARCH LENGTH RATIO (1.09)

METHOD: $\frac{\text{Mesiodistal Width of 12 Max. Teeth}}{\text{Mesiodistal Width of 12 Mand. Teeth}} = \text{Arch length Ratio}$

Mean = 1.09; Exp. Range = 1.17 to 1.05; Std. Dev. = 0.03.

MAXILLARY ARCH LENGTH (mm.)	MANDIBULAR ARCH LENGTH (mm)
85	77.9
86	78.8
87	79.8
88	80.7
89	81.6
90	82.5
91	83.5
92	84.4
93	85.3
94	86.2
95	87.1
96	88.0
97	89.0
98	89.9
99	90.8
100	91.7
101	92.6
102	93.5
103	94.5
104	95.4
105	96.4
106	97.3
107	98.2
108	99.1
109	100.0
110	100.9
111	101.8
112	102.7

APPENDIX II

VALUES FOR TOTAL WIDTH OF MAXILLARY SIX ANTERIORS AND CORRESPONDING VALUES FOR TOTAL WIDTH OF MANDIBULAR SIX ANTERIORS COMPUTED USING THE ANTERIOR RATIO (1.274)

METHOD: $\frac{\text{Mesiodistal Width of Max. Six Anteriors}}{\text{Mesiodistal Width of Mand. Six Anteriors}} = \text{Anterior Ratio}$

Mean = 1.274; Exp. Range = 1.43 to 1.19; Std. Dev. = 0.048.

MAXILLARY ANTERIOR WIDTH (mm.)	MANDIBULAR ANTERIOR WIDTH (mm)
42.0	33.1
42.5	33.4
43.0	33.8
43.5	34.2
44.0	34.6
44.5	35.0
45.0	35.4
45.5	35.8
46.0	36.2
46.5	36.6
47.0	37.0
47.5	37.4
48.0	37.8
48.5	38.2
49.0	38.6
49.5	39.0
50.0	39.3
50.5	39.7
51.0	40.2
51.5	40.6
52.0	40.9
52.5	41.3
53.0	41.7
53.5	42.1
54.0	42.5
54.5	42.9
55.0	43.3
55.5	43.7

APPENDIX III

VALUES FOR TOTAL MAXILLARY INCISOR WIDTH AND CORRESPONDING VALUES FOR TOTAL MANDIBULAR INCISOR WIDTH COMPUTED USING INCISOR RATIO (1.347)

METHOD: $\frac{\text{Width of Max. Four Incisors}}{\text{Width of Mand. Four Incisors}} = \text{Incisor Ratio}$

Mean = 1.347; Exp. Range = 1.55 to 1.22; Std. Dev. = 0.063.

MAXILLARY INCISOR WIDTH (mm.)	MANDIBULAR INCISOR WIDTH (mm.)
26.0	19.3
26.5	19.7
27.0	20.0
27.5	20.4
28.0	20.8
28.5	21.2
29.0	21.5
29.5	21.9
30.0	22.2
30.5	22.6
31.0	23.0
31.5	23.4
32.0	23.7
32.5	24.1
33.0	24.5
33.5	24.8
34.0	25.2
34.5	25.6
35.0	26.0
35.5	26.3
36.0	26.7
36.5	27.1
37.0	27.4
37.5	27.8
38.0	28.2
38.5	28.6
39.0	29.0
39.5	29.3

APPENDIX IV

LOYOLA INDEX FOR DETERMINING TOOTH-SIZE DISCREPANCIES

Arch length ratio = 1.09 ± 0.03 Range = 1.17 to 1.05

PROBLEM: $\dfrac{\text{Sum Max. 12 teeth \_\_\_\_\_\_ mm.}}{\text{Sum Mand. 12 teeth \_\_\_\_\_\_ mm.}} = \dfrac{\_\_\_\_\_\_}{\text{(ratio)}}$

Anterior ratio = 1.274 ± 0.048 Range = 1.43 to 1.19

PROBLEM: $\dfrac{\text{Sum Max. Ant. 6 teeth \_\_\_\_\_\_ mm.}}{\text{Sum Mand. Ant. 6 teeth \_\_\_\_\_\_ mm.}} = \dfrac{\_\_\_\_\_\_}{\text{(ratio)}}$

Incisor ratio = 1.347 ± 0.063 Range = 1.55 to 1.22

PROBLEM: $\dfrac{\text{Sum Max. 4 incisors \_\_\_\_\_\_ mm.}}{\text{Sum Mand. 4 incisors \_\_\_\_\_\_ mm.}} = \dfrac{\_\_\_\_\_\_}{\text{(ratio)}}$

If any of the three ratios is greater than the mean value given above, the discrepancy is caused by excess tooth material in the maxillary arch. In the chart below locate the patient's mandibular measurement; opposite it is the correct maxillary measurement. The difference between the actual and the correct maxillary measurement is the amount of excess tooth material in the maxillary arch. If the ratio is less than the mean value, the discrepancy is in excess mandibular tooth material. Refer to the maxillary measurement in the chart and find the corresponding mandibular measurement to determine the difference between actual and correct mandibular tooth material.

APPENDIX IV (Page 2)

LOYOLA INDEX FOR DETERMINING TOOTH-SIZE DISCREPANCIES

CHARTS

ARCH LENGTH (mm.)		ANTERIOR WIDTH (mm.)		INCISOR WIDTH (mm.)	
Max. 12	Mand. 12	Max. 6	Mand 6	Max. 4	Mand. 4
85	77.9	42.0	33.1	26.0	19.3
86	78.8	42.5	33.4	26.5	19.7
87	79.8	43.0	33.8	27.0	20.0
88	80.7	43.5	34.2	27.5	20.4
89	81.6	44.0	34.6	28.0	20.8
90	82.5	44.5	35.0	28.5	21.2
91	83.5	45.0	35.4	29.0	21.5
92	84.4	45.5	35.8	29.5	21.9
93	85.3	46.0	36.2	30.0	22.2
94	86.2	46.5	36.6	30.5	22.6
95	87.1	47.0	37.0	31.0	23.0
96	88.0	47.5	37.4	31.5	23.4
97	89.0	48.0	37.8	32.0	23.7
98	89.9	48.5	38.2	32.5	24.1
99	90.8	49.0	38.6	33.0	24.5
100	91.7	49.5	39.0	33.5	24.8
101	92.6	50.0	39.3	34.0	25.2
102	93.5	50.5	39.7	34.5	25.6
103	94.5	51.0	40.2	35.0	26.0
104	95.4	51.5	40.6	35.5	26.3
105	96.4	52.0	40.9	36.0	26.7
106	97.3	52.5	41.3	36.5	27.1
107	98.2	53.0	41.7	37.0	27.4
108	99.1	53.5	42.1	37.5	27.8
109	100.0	54.0	42.5	38.0	28.2
110	100.9	54.5	42.9	38.5	28.6
111	101.8	55.0	43.3	39.0	29.0
112	102.7	55.5	43.7	39.5	29.3

APPROVAL SHEET

The thesis submitted by Dr. William W. Thomas has been read and approved by the three members of his examining board.

The final copies have been examined by the Director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

May 24-1966
(Date)

Joseph R. Jarabak
(Signature of Advisor)