CRANIAL FORM AND DENTAL STATUS OF A PREHISTORIC AMERINDIAN POPULATION

A Thesis

Presented To

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfilment

of The Requirements for the Degree

Master of Science

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by

William F. Smith

Department of Preventive Dental Science

February, 1975

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WILLIAM F. SMITH

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ACKNOWLEDGEMENTS

In the course of a work such as this, numerous people play parts which together make everything possible.

In the list of these people thanks is given firstly to my supervisor, Dr. Maurice McKeown, for his aid in every aspect of this work from its inception to its completion. Thanks is also given to adviser, Dr. William Wade, for his continuing aid, and to the Department of Anthropology for making the materials available for this work.

I would like to acknowledge Dr. John Cleall who made the facilities of the Department of Orthodontics available to me. In particular, thanks is given to Sandy Pubantz for her aid in the radiography and Dr. John Coen who opened his own home to a collection of skulls and provided the base for the photographic work. Also associated with this Department, I would like to acknowledge the encouragement of Dr. Kauko Isotupa who, during his year at this University provided encouragement and consultation for this work.

Particular thanks is given to Kenneth Tarte who not only aided with the photography but printed photographs many times long into the night and more, gave encouragement and friendship during my stay in Winnipeg.

Thanks is also given to Miss Jill Parsons who suffered patiently through penmanship and an accent during the typing of this thesis.

Thanks, finally, is extended to Dr. F.A.C. Wright without whose encouragement, advice and concern, this thesis would never have materialized.

INTRODUCTION

The object of this investigation is to examine the skulls of an American Indian population with particular emphasis on the variability present in the dentition and jaws.

The Gray Site burial near Swift Current in south-eastern Saskatchewan presents an opportunity to examine a sizeable group of individuals of substantially similar backgrounds. At the present time there is apparently no analytical nor comprehensive method available to evaluate the dental status of such a group, also lacking at the present time is a methodology for defining arch form in a manner which lends itself to a correlation with cranial or mandibular form.

In realizing the absence of adequate technique for such studies it was found necessary to develop and adapt new methods. For the evaluation of the dental status certain techniques presently used in modern clinical dentistry were applied. For the consideration of variability of form and its correlations, a standardized photographic technique was utilized. Utilizing these techniques, concepts of variability of form and the dental status of this Indian group were sought.

With the dental evaluation it is hoped that a report of more relevance for such an ancient population can be gained. For the arch form/cranial form it is hoped that correlations of form can be found which could relate different aspects of the cranium to themselves and to the arch form.

REVIEW OF LITERATURE

The belief that there is a certain definable form to the dental arch is not recent. Hunter in 1778 saw that the upper jaw had a circular arrangement as did the mandibular arch. The anterior aspect of the lower arch was defined by a smaller circle than the maxilla but it also extended farther posterior. Both circles he continued had their convexities turned toward the anterior. Bonwill in 1885 defined the mandible by an equilateral triangle defined by the condyles and the midpoint of the mandibular central incisors. Each side of this triangle was four inches plus or minus 1/4 inches. Distal to the canines Bonwill saw the premolars and molars extending in a straight line to the condyles. This was in accord with the most efficient concept of nature. Bonwill's anterior segment was an arc of a circle defined by the incisors and canines.

G.V. Black in 1902 stated that the upper dentition was arranged in a semiellipse. The premolars and molars were arranged in a straight line or slightly curved line and the third molars were outside the ellipse. The mandibular arch had a similar arrangement but on a smaller curve, this enabled the maxillary teeth to fall buccal to the mandibular arch. Stressed by Black was the individual variation involved. Angle in 1907 also accepted this aspect of individuality. The arch for Angle, in general had the form of a parabolic curve. The variances of this were according to race type and temperament of the individual. Since these variables were present he saw Hawley's adaptation of Bonwill, to be discussed shortly, to be too inflexible.

As mentioned in reference to Angle, temperament was a method utilized to categorize people at this time. Temperament generally defined differences in the mental and physical makeup of an individual. At this time each temperament was associated with a specific arch form. This was the result of a belief in correlation and interrelation of different aspects of the individual. Both Broomell (1902) and Turner (1907) consider this correlation. The Bilious type, strong dark, had a square arch, the Sanquine, athletic and light, had a rounded square arch, the Nervous type, small, dark had a smaller arch still circular, the Lymphatic, large plodding, had an arch of the largest circle. Broomell also related each of these by a triangle between the central fossa of the second molars and the interproximal of the central incisors. For the Bilious/Sanquine this triangle was equilateral; the Sanquine had a molar to molar segment which was shorter, the Nervous molar to molar segment was very much shorter while the Lymphatic type had a molar to molar segment which was the largest aspect of the triangle. Though the relationship was categorized by temperament the concept of these men did attempt to relate an arch which they observed to other aspects of the individual and also tried to define the arch itself in a precise and measurable triangle.

Actually located between these two authors, Hawley in 1905 took the concept of Bonwill which was used for prosthetics and attempted to extrapolate to orthodontics. In his methodology he took the widths of the central, lateral and canine and used them to define a circle. From the distal aspect of this circle an equilateral triangle was established with sides passing through the distal of both canines with the third side a tangent to the centrals. The length of one side of this triangle was then used as a radius for another circle the anterior aspect again intersected the incisors. On this large circle six times the radius was marked off. Lines were drawn to the distal of the canines. The first circle defined the anterior circular aspect, the last lines defined the straight line of the posterior teeth. The importance of this lies in a form not linear dimension, in relation to the initial measurement of the incisors and canine.

From this point various authors including Carrea (1919), Gaillard (1921), Rickter (1909), Herbst (1907), Gysi (1895) and Koerbitz (1911) (from Izard, 1927), sought out methodologies to define the circle that described the anterior arc of the dental arch. Koerbitz utilized the diameter of two incisors while the former group utilized the diameter of the central, lateral and the canine as did Hawley above.

Grunberg in 1912 brought in a new aspect to the concept of arch form. The symmetroscope was an apparatus to measure the symmetry of the arches. Via this, models of the dentition could be evaluated for symmetry in a buccal lingual as well as a mesial distal plane. It is an important concept at this stage in that it questioned the symmetry which, up to this time, was not considered of importance. The earlier statements of individuality became even more particular questioning the right and left symmetry in a given individual. For this reason he queried Bonwill's triangle. But in regard to the dental arch symmetry, Cryer (from P.N. Williams, 1917) felt that if the arch was symmetrical as well as the mouth and palate, then the cranium would likewise be symmetrical. This was an early attempt at interrelating the forms of the individual.

P.N. Williams in 1917 returned to the concept above of the anterior arch being defined by an arc of a circle. This circle had its midpoint midway between the buccal grooves of the two maxillary first molars. The arc defined the incisors and mesial of the canines. The distal of the canine aligned in a straight line to the buccal groove of the first molar. The second molar was inside this line. The relationship of the buccal aspect of the first molar to first molar and then to the incisors and then canine to canine was established. The molar to molar compared to the canine to canine for the American type was a ratio of 14:9. This is a linear dimensional relationship. Included in the concept of racial types, Hellman in 1919 considered arch shapes in animals and humans. He concluded that just as facial types are ascribed to certain races so may arch shapes be attributed to races.

In 1922 Stanton published a paper which stated that the arch form ranged from elliptic, ovoid, approached circular, U-shaped, parabola, 'horse shoe' shapes. In this article he established an arch index which was determined by the length times 100 divided by the width. The indices ranged from 90 to 150. The width defined by buccal groove of first molar to midpalatal suture varied by 5mm, while the length varied within 13mm in length from mid-buccal groove line to upper incisal edge. From these scales and linear calculations Stanton defined three types of arches. The Dolicouranic had an index below 110, the Mesouranic had an index of 110 to 115, while the Brachyuranic arch would have an index above 115. Stanton did stress the individuality and variability of the arch even quoting Hrdlicka who saw a great variety of arches.

Gilpatric in 1923 concerned himself with the size of the dental arch. The sum of tooth substance for a 'normal' arch was 74 1/2 to 100 1/2mm measured to the buccal grooves of the first molars. These 'normal' arches were determined from average values while the tooth size was determined from charts of G.V. Black.

Izard in 1927 tried to establish a relation of the face and the dental arch. In this he found a constant ratio of the width of the arches and the width of the face. The arch width taken on the buccal bone at the widest width ranged between 53 to 73.5mm. The bizygomatic width ranged between 106 to 151mm. The ratio is 2:1. The form of the arch according to Izard was predominantly elliptical while parabolic arches occurred about 20% and other forms included about 5% of arches. The other forms included U-shaped arches which approach anthropoid form. The elliptical form Izard considers infinitely variable, when wide it can approach a circle while when it is long and narrow it approaches a parabola. From his above measurements Izard constructed his ellipse. The small axis of the ellipse was 1/2 the bizygomatic width while the long axis was the auriclo incisal radius. He superimposed these on an ellipsograph. The writers grouped above who utilized various circles to define the arch Izard grouped and discarded because they were too invariable. His discussion is a correlation of linear dimensions extrapolated to define form.

Chuck in 1934 defined ideal arch form for orthodontic wires. In this he recapitulated the methodology of Hawley for establishing arch form via equilateral triangles.

In 1927 Sim Wallace illustrated variability of arch form via photographs. Also in the article linear indices are given to stress the variability.

Wheeler in a text on dental anatomy in 1950 defined the arch as a parabolic curve. The incisors to the first premolars are part of an arc of an imperfect circle. He did question the mathematical applications to the arch which attempted precise definition.

Meredith and Higley (1951), utilized direct facial measurements, casts of the arches and posterior anterior x-ray films. Via these the widths of the dental arch, the bizygomatic width and the palatal width were compared. In addition the mandibular dental arch width was compared with the width of the lower face. Unlike Izard, no correlations were found with these linear aspects.

In 1952 Sved applied engineering principles to the form of the dental arch. In this process two lines were utilized. The first of these was the molar line which extended from the buccal grooves of the first molars. The second line was the posterior line which extended from the buccal groove of the first molars to the tip of the canine. His characteristic angle defining the arch was the angle formed via the posterior and molar lines intersecting. This characteristic angle for a given arch remained the same for an arch even through growth. The most important concept of this is that the author avoided the aspect of linear dimensions. In this article he continued and became concerned with linear dimensions with canine and molar arch widths. This he did to calculate the ideal dimensions of a given arch. This he did via the formula W=2U-K + D. The W represents the molar width, the U represents the widths of the central lateral and mesial half of the canine, the K is a constant and the D is the difference between molar and canine widths.

In 1953 another evaluation was made concerning zygomatic and arch widths by Lundstrom and Lysell. The width of the maxillary dental arch was taken at the first premolars, the first molars, the length was taken from the first molars to the central incisors and the palatal height was registered at the first molars. The author found no correlation in this linear investigation between the width, length index of the head and the length width index of the maxillary dental arch.

In 1958 an article was released by Okyay and Baz which was concerned with relations of arch and facial shapes. In the article they related linear measurements, done by Chateau, Henriquis, Olow and Reese. The arch form for Baz was determined by indices of Pont which established a normal arch via averaging many arch values. The authors then utilized geometric methods to apply their linear values.

Sicher in 1965 considered the maxillary arch form to be ellipsical while the lower arch was parabolic. By this destinction Sicher attempted to define the divergence of the premolar and molar regions as decreasing steadily in the maxillary arch while there is an increase in divergence in the lower arch. He also stated there is great variation for example with the U-shaped arch. In this type of arch the anterior teeth approach a straight line while the canines act as corners to enable the posterior teeth to also constitute a straight line which closely parallel to the mid-sagittal plane.

Anderson (1960), in his Practical Orthodontics saw that the normal arch was an approximation of symmetry with the normal size of the teeth. The form was established by a study of the face, cranium and tooth forms. For the maxilla, the six anterior teeth formed a true arch, the laterals being slightly higher and lingual to the centrals and canines. The posterior segment was a straight line from the distal of the canines to the buccal grooves of the first molars. The segment distal of this curved lingually. For the mandible the incisors are on an even arch. Distal to the lateral incisors the canines are prominent labially with a straight line to the buccal groove of the first molars and again a lingual inclination distal to this.

Begg in 1971 saw the arch as being individual. He stated the shaping of arch form in orthodontics was not an exact science rather an empirical art.

In various determinations of arch form linear aspects have held paramount interest. Lavelle, Foster and Flinn in 1971 studied dental arches in Modern British, New Guinean, West African and Australian aborigines. In this they attempted to type groups according to linear dimensions between the second molars, the first molars, the first and second premolars and the canines, the first molars and from the canines to the first molars. To establish form from this information the area enclosed was calculated.

In 1972, F.W. Worms considered Pont's index and dental arch form. The index was established as a norm from averaging linear dimensions. This averaging to establish a norm, the author stated was not justifiable. With his study a low correlation between arch predetermination and arch form was found. Worms again reiterated that arch form is individual.

Another linear application was L.F. Mills (1964), who correlated arch width, length and tooth size. From this study a relationship was found between arch width and crowding.

Various analysis of the dental arch utilizing its linear aspects, have been done by authors such as Bolton (1962), and Carey (1952), etc., but these are not concerned specifically with arch form and as such are not related to overall cranial form.

A new concept brought to the form of the dental arch is that of a catenary curve. MacConail and Scher in 1949 desired to define the occlusal line of the dental arch form. Since the maxillary and mandibular forms interdigitated at intercuspation they stated one could not be elliptical while the other was parabolic. For the authors the line in contention was the buccal cusp line of the mandibular arch. This was their area of the catenary curve. The concept of the catenary curve is a linked chain suspended by its two ends. For the alignment the curve was greatest at its point of suspension and least at its lowest point. The curvature is symmetrical and as a result will have a diameter from its apex between the sides of the curve. The arch so suspended will have an inverse relation between curvature and width at points of suspension, that is the least apical curvature will have greatest distance between suspension points. The natural length of a catenary is found by the apical tangent having a 45° line which is also tangent. The distance from two points thus defined by tangents will be the radius of apical curvature. The catenary, the authors claim, is the curvature of minimum extraneous force. From this concept an analogy is drawn as to the weight of the chain being mesial force for drift and the inward force the apposition of bone bucally.

The catenary aspect was applied by Burdi in 1966 to fetal material. In this study the catenary curve was established by 9.5 weeks in utero.

James H. Scott in 1957 agreed with the concept of the human arch being a catenary form but differential growth changed this early situation. Scott extended the concept of dental alveolar bone being defined as a catenary curve and stated the mandibular basal bone is also a catenary curve. This he stated, is the situation with the basal bone of not only many, but animals generally. The catenary for Scott is the same as for MacConnail and Scher in that it is the same for the maxillary and mandibular alveolar arches as defined by the mandibular buccal cusps and maxillary central fossae.

In recent literature there has been utilization of various mathematical expressions to define the arch form. Lu in 1964 analyzed arch symmetry in a polynomial equation of the fourth degree. By substituting various arch measurements symmetry as either linear or cubic can be determined or the lack of symmetry can be established. By an equally involved mathematical means Erickson in 1972 established human palatal morphology by a least squares multiple regression equation. In 1965 Mills and Hamilton utilized mathematics for computing arch circumference from arch length and width measurements. The accuracy of the equation was verified by direct circumference measurements utilizing a wire. Biggerstaff in 1972 utilized a quadratic equation to evaluate arch form. By the equation the arch was determined to be elliptical, parabolic or hyperbolic. This form was taken over the cusps of the arches.

In 1969 Currier compared the ellipse and parabola as methods of defining the arch form. In his evaluation, three areas were considered as definitions of arch form. These were the buccal cusp line, the central fossa line, and the lingual cusp line for both the maxillary and mandibular teeth. From their computerized evaluation he concluded that;

1) The facial aspect of the maxillary arch was closest to an ellipse of all the areas evaluated.
2) The ellipse was a better fit to the buccal aspect than to the lingual or fossa lines.
3) The central fossae of maxillary arch and mandibular fossa line more closely approximated a parabola.
4) Neither a parabola nor an ellipse defined the lingual aspect of the maxillary nor the mandibular arch.

In 1964 Kato, Kubota and Hashimoto et al, used x,y co-ordinate computerized system to establish tooth positions. From this they established differences in sizes and positions of teeth. They did see a significant difference between the upper and lower jaws but the polygonal lines of upper and lower jaws are similar. This means that although the size is different the form was similar.

Investigation of arch form by Remsen in 1964 considered three angular measurements. The first was the incisor angle which was defined as 'that angle with its apex at the central incisor contact point, formed by lines which pass through the cusp tips of the right and left cuspids.' The second angle was the cuspid angle which was stated to be 'that angle with its apex at the cuspid tip formed by lines which pass through the buccal groove of the first molar on the same side and through the central incisor contact point.' The third angle is the characteristic angle of Sved defined as 'that angle with its apex at the first molar lines which pass through cuspid tip on the same side and buccal groove of the first molar on the opposite side.'

Remsen's investigation of ideal arch form evaluated arch predetermination according to Hawley as well as utilization of parabolas and 45° ellipses. This investigation included ideal 'normal' dentitions of 13 young men and 12 young women. All the occlusions, evaluated via plaster casts, had Class I molar relationships, an occluding second molar, and a Class I canine relationship.

From the investigation he found the incisor angle was valuable in determining proportional changes in the area of greatest curvature. It did indicate a broad or a narrow arch and tendencies toward each. He felt that this angle was a more scientific method of classification than dolico, meso and brachyuranic or square ovoid, etc. For arch predetermination he found that the parabolic construction best outlined the anterior arch segment regardless of arch form.

The straight posterior segment, however, did not describe the normal relationship of the posterior teeth. The 45° ellipse did not represent the form of the dental arches. The Bonwill Hawley method of predetermination did not have sufficient variability to be valuable. No correlations were found between angles of the same arch or of the same angles in opposing arches.

Izard in 1927 attempted to correlate maxillary arch width and bizygomatic width. Although he found there to be a correlation it has since been questioned by Meredith and Higley who in 1952 found no correlation. In 1953 Lundstrom and Lysell also found no correlation of width length index of the head with length width index of the maxillary dental arch. In 1958 Okyay and Baz found a correlation of arch and facial shape utilizing bizygomatic width of the face. In this investigation Pont's index was used as a basis of comparison. Filipsson and Goldson in 1963 sought a correlation of tooth width, length of head and stature. These authors found a low correlation of tooth width and width of head with no correlation in the other aspects. All of these studies relied upon linear aspects of measurement.

Cozza in 1967 sought the correlation of the maxillary central incisor, the maxillary arch and skull via angular measurements. This study investigated 30 subjects to seek a correlation of angles of the three aspects defined by angles of their widest and their narrowest dimension.

For the form of the skull a posterior anterior x-ray of the skull was utilized oriented in the Frankfurt Horizontal. The widest extension on the cranium and the gonial points on the mandible were connected by lines extended to form a triangle. The maxillary arch was investigated via models. The widest points taken were at the mesial buccal cusp on the first molars. The narrowest point was taken at the cuspids. These points were likewise connected on each side with the lines extended anteriorly to establish a triangle. A similar arrangement was established via photography for the central incisor. With these angles no correlations were found.

The development of an adequate method for the definition of cranial form which is suitable for evaluation and comparison is also a subject for continuous concern. Hooton (1946) has stated that descriptive definitions for example those of Sergi, for describing cranial contours are not only cumbersome and difficult to apply, but do not lend themselves to statistical evaluation. Krogman (1932) also utilized a descriptive approach and applied it to the Australian Aborigine skull material. His description of elongate oval and rounding form is not acceptable for statistical evaluation. In an attempt to overcome these limitations Hooton (1946) described the cranial index which is a ratio of breadth of the skull to the length of the skull. The dolichocephalic or long head registers less than 75%, the brachycephalic, or broad head, registers more than 80% with the mesocephalic registered in between 75-80%. This, although a crude approximation of form lends itself to statistical evaluation. Abbie (1947) in applying this type of index felt it was composed of measures which were not consistent. By this he meant that since the area of greatest width differed in position on different skulls, the applicability of the index to establish comparative form was lacking.

A similar index (Hooton, 1946) has been established for facial form (length is a percentage of width) with a broad faced, ie. euryprosopic less than 84%, 85-88% (85-89.5% for dry skulls) mesoprosopic and 88% (90% for dry skulls) and above being leptoprosopic or narrow faced individual.

In addition to indices of this sort linear dimensions are frequently listed for height, width and length in an attempt to define the cranial form. Hooton (1946) lists various linear dimensions utilized. In an attempt to derive characteristic genetic form from this type of measure, Howells (1957) utilized correlations of various measures. McKeown (1971) also evaluated cranial form and found significant correlations of endocranial height, width and length, but less significant relations were found with lower facial height.

In the evaluation of certain similar anthropological materials certain of these aspects have been utilized to establish the homogeneity of the groups and to illustrate their form. Anderson (1964) describes the crania of an Iroquois Ossuary by linear aspects as well as various indices. Hoyme and Bass (1962) in an evaluation of Tollifero and Clarksville materials again utilized linear aspects and indices and concluded that the metric differences did not reflect any clear differences between the groups (Pg. 392). Loukides, Thiessen and West (no date) in an osteology preparation of Gray site material and Glen William's Iroquois Indian ossuary material utilized a combination of linear aspects and the mandibular angle in evaluating the mandibles. These data were utilized only to indicate age and sex differences in the mandibles. Abbie (1947) concurred that linear aspects had value for sexing materials unlike the cranial index. Bennett (1973) evaluated the Indians of Point of Pines, Arizona utilizing again linear aspects and various indices. These observations resulted in a hyper-brachycephalic index due to cradleboard deformation (Pg. 37). Other indices were also affected by this and a lack of difference between the sexes was reported. For dating the population, certain of the indices were applied to the females and values varied with successive populations. With the Indian Knoll skeletal materials (Snow, 1948) indices, linear definition and descriptions were provided for the cranial material. The description forms were ellipsoid, ovoid, spheroid, pentagonoid, rhomboid, spenoid and brisoid--for the general cranial form. Other areas were also described verbally in addition to the linear definitions. Skull capacity was also considered. From these indices and measures the authors derived that this was a significantly homogenous group when compared via the linear definitions with the Egyptian E series which has been recognized as a homogenous grouping.

In considering the Indians of Pecos Pueblo, Hooton (1930) utilized various cranial and facial indices. Observations were also made concerning, for example, the shape of the foramen magnum. For the group of 250 skulls he devised eight cranial types extending from the Basket Maker who had a small, narrow face with poorly developed chin, to the 'large Hybrid' characterized by massive crania, heavy projecting malar, long faces and ponderous jaws and evert gonial angles. No great difference was found in the craniometrics for the different periods studied in this group. With these materials, sexed correlations of linear aspects were given, for example, bizygomatic diameter was correlated at the .598 level with the breadth of the orbits. The correlations generally seen were around .4 for these linear relations.

For evaluation of cranial, mandibular and dental arch form the indices described are stated by Moorees (1957) to lack definition of varying shapes when applied to dental arches.

In the evaluation of form, however, McKeown (1972) has utilized an angular methodology. The definition of form by angles he stated is consistent for dogs throughout their growth and into adult stages. He has also used the angular methodology for grouping breeds of dogs with significant results (1974 and 1973). Meiklejohn (1968, Masters thesis) has utilized angular evaluations for genetic groupings of anthropological material. The angles he utilized are the 'upper transverse angle' (2 fronto malare, orbitale points and nasion) and the 'lower transverse angle' (2 zygomaxillare, and sub naso-spinale or sub acanthion).

From these studies it appears further investigation into the application of angular evaluation of cranial, mandibular and dental arch form is indicated, and that the use of angular studies may afford a better method of correlating cranial areas than previously used techniques.

MATERIALS AND METHODS

MATERIALS

The skeletal materials used in this study are from an archaeological excavation at the Gray Site near Swift Current, Saskatchewan. The excavations of this area were begun in 1963.

The materials are, to date, the oldest large grouping recovered in North America. The C14 dating of the material ranges from 3485 ± 195 years Before Present (BP) for burial number 30 to 5100 ± 390 years BP for burial number 46. (Wade, 1974)* During the course of the excavation, burial numbers were made to delimit a burial unit which designated bones which were buried together. The burial types at the site included single, double, multiple as well as bundle and extended burials (Knutson, 1974).

For use in this investigation some of the materials were found to be unacceptable. The criterion for acceptance required that the piece not be fractured, fragmented or

* The C_{14} dates for the Gray Site are:

Burial No.	Sample No.	Date
23	S619	4955±165 years BP
42	S648	3755±100 years BP
46	S647	5100±390 years BP
59	S693	3550±295 years BP
30	S706	3485±195 years BP
65	S707	3750±180 years BP

distorted in such a manner that the piece no longer remained solid in form. Some of the material which had fractured with handling and had been restored with glue or tape was also not considered acceptable.

Included in the skeletal remains were skulls of young children. These were identified by the presence of deciduous teeth and unerupted 2nd molars. On skulls such as these the sutural systems were still open lending these crania to fragmentation. Both due to the age and due to the fragmentation this material was excluded from the study.

For the study, therefore, only intact adult crania and mandibles were used. In numbers this included 27 crania and 57 mandibles, all considered adult. Another factor considered with this material was that the crania and mandibles were evaluated separately and were not sexed. The elimination of sexing was due to the relatively small sample.

Certain craniae and mandibles came from multiple secondary burials and as such could not be articulated with certainty. As a result of this, in spite of the fact that materials from single or double burials could be associated, dental concepts of overjet, overbite and articulated occlusion were eliminated from consideration.

The cultural information on this material has indicated that it is part of the Oxbow Culture which was a Plains Archaic culture. Information on the culture was initially gathered by Nero and McCorquodale (1958) from the area of the Oxbow Dam of the Souris River in southeastern Saskatchewan. The carbon dating on the site was 3250 ± 130 years B.C. The site revealed various projectile points as well as remains of bison, elk, wolf, fox and coyote.

Other areas which have been investigated by Dyck (1970) include the Moon Lake Site and the Harder Site. These areas revealed the side notched basally thinned projectile points and the same animals. The dating on the Moon Lake Site was 2150 ± 70 years B.C. The site, according to Dyck revealed activities of killing and butchering of bison as well as controlled use of fire. The Harder Site was dated 1410 ± 120 years B.C. and evidenced the same aspects but indicated more hunting.

The population was believed to be a wandering group living in an environment subject to extreme climatic changes existing at about 4000 years ago. The diet did have meat and working with hides has been evidenced.

METHODS

The following techniques were used: (1) Photography of crania and mandibles, (2) radiography of the jaws, (3) and clinical examinations of the materials including bone level measures and attrition evaluation.

For the evaluation of variability of form a photographic technique was used. A 35mm single-lens reflex camera with a 400mm telephoto lens was utilized at a 6 meter distance from the object. The material itself was mounted in a fixed manner in a portable cephalostat which was capable of rotation through 360° (McKeown, 1972, Ph.D. Thesis). The film was treated in a standardized manner for development and fixation and a reproducable printing method was established. The final photographs were printed on a dimensionally stable paper and were not fixed. (Appendix I).

The printed photographs, after being coded for identification were placed on a digitizer. With the digitizer a series of points were precisely defined (Appendix I) on an x,y co-ordinate system. These readings were recorded on computer punch cards.

Using a computer program devised by Cleall and

Chebib (1971) the material recorded on the punch cards was transformed to a universal x,y co-ordinate system. After this was accomplished, angular measurements were obtained from the computer both for each piece and for the group as a whole. From these values correlation coefficients between various parameters were established.

The radiography of the jaws was undertaken utilizing panorex radiography. With this single extra oral x-ray film a view of the mandibular and maxillary dentition as well as the bony support could be observed. When abnormalities were evidenced, local periapical x-ray films were used for verification.

In utilizing the panorex x-ray technique which is a clinically orientated device, a method was devised for mounting the skull or mandible. Also needed and established was the exposure time of the x-ray which had to be reduced from the normal clinical ranges. These radiographs evidenced radiolucencies, opacities, root abnormalities and generalized bone status. (Appendix II).

For the clinical evaluation various aspects of the material were considered. After the presence of absence of each tooth was recorded, consideration was given the status of the bone support. The level of the bone surrounding each tooth was measured with a graded periodontal probe. Measurements were taken at six points around each tooth from the crest of the bone to the cemento-enamel junction. These values were recorded on charts and later transferred to punch cards and processed by the computer. (Appendix III).

Attrition, or wear on the teeth, was also considered. For this a scale was established. The first part of the scale on attrition consisted of four values which measured occlusal wear as to its nature and severity. Two more areas were also recorded to indicate interproximal wear. The data on the punch cards were evaluated by the computer for variability and frequency. For both of these clinical aspects, methodology tests were done to establish the reproducibility of the methods and scales. (Appendix IV).

The information from these studies as indicated above was recorded on computer cards, with one card recording this information for one tooth of one piece (crania or mandible). (Appendix II).

RESULTS

PHOTOGRAPHIC EVALUATION

RESULTS

Photographic Evaluation

The angles defined for the mandibles are illustrated in the lift-outs in the back of the volume and are listed along with their standard deviations in Table 1 . The standard deviations generally noted approximate 4°. As seen in the listing, angles 29-34 have greater variations. This, however, is discussed in Appendix I and is related to lack of reproducibility of points.

The first six angles defined on the mandibles have large deviations. These angles are all defined by dental landmarks as illustrated on the occlusal view of the mandible. Of note also is that angle 7 (defined by the two first molars and the symphysis point) has a deviation greater than angle 8 (defined by 2 canines and the symphysis point) by more than 3°. Both these angles (7 and 8) are defined by both dental and bone landmarks.

With the lateral view a similar situation is seen with the angles including bone and dental landmarks. These angles again, have greater standard deviations than other angles of this view (eg. angles 19, 21, 24, 26).

On the occlusal view of the mandible where bony landmarks are used the standard deviations of the angles, as stated above, approach 4° (angles 9, 10, 11 and 12). A similar deviation is also seen on the occlusal view with two bony landmarks and the third landmark at the central incisors. (Angles 14, 15 and 16). Angle 13, however, to the gonial points has a greater deviation observed.

From this it is seen, therefore, that angles associated with bilateral dental landmarks or landmarks associated with the distal area of the dentition (lateral views) illustrate greater variability. The angles having the central incisor point as a landmark with two bony points for other landmarks illustrate less variability than angles defined by bony landmarks alone.

For the maxilla the deviations seen are generally less than those seen for the mandibles. (Lift-out illustrations and Table 2). Again, the angles associated with dental landmarks are highly variable (angles 1, 2, 3, 4, 5, 6). Unlike the mandible, however, there are no angles defined by two dental landmarks and one bone landmark on the basilar view. On the basilar view, however, the angle defined by the palatine foramen (angle 9) has a high standard deviation.

Quite unlike the lateral view of the mandible the angles associated with dental landmarks on the lateral views (angles 13 and 16) are closer to the 4° standard deviation generally seen. On the facial and posterior anterior views the angles defined via bilateral dental landmarks (angles 19 and 22) have very low standard deviations approaching the 1° level. On the same two views (facial and posterior anterior views) very wide angles associated with the incisor point had very large standard deviations (angles 20 and 23). Generally seen on these two views are very low standard deviations seen in association with both dental and bony landmarks (angles 18, 19, 24, 25, 26, 27).

The maxilla, therefore, presents as did the mandible with the angles defining the dental arch having high standard deviations. Quite unlike the mandibles, however, are the results on angles utilizing a dental point on the lateral views. With the maxilla the angles have low standard deviations. These angles (13 and 16) in fact illustrate less variability than similar angles extending to the anterior bony landmark. (Point A rather than the mesial of the 1st molar [angles 14 and 17]). In addition with the maxilla the angles defined by two dental points (angles 19 and 22) have low variability while the angles defined by the incisor point (angles 23 and 20) are very highly variable. For both the maxilla and mandibular material the standard deviations associated with angles defined by bony landmarks approximate a standard deviation of 4°.

The listing of the correlation values for the mandibular angles is given in Table 3 . From the angles defining the arch form the highest correlations are seen between angles 1 and 3 and 2 and 4. These are complementary angles. Generally, however, there is a relationship of the arch angles of approximately .5 correlation. This includes the overall arch angle (5) and the side arch angles (1,2,3,4). The exception seen is that the canine arch angle (angle 6) has very poor correlations with the side angles (1,2,3,4).

The angles defined by two dental landmarks and the bony point at the symphysis are quite different in their correlations. Angle 7 which extends to the 1st molars is correlated with angles 5 and 6 which are the arch angles extending from the incisors to the 1st molars and from the incisors to the canines, respectively. This is unlike angle 8 which is correlated with angles 1, 2, 3, 4 and 7. This is the exact opposite of angle 7 above and illustrates the poor relationship of this angle to the overall arch angles.

The angles (9, 10, 11 and 12) are defined completely by bony landmarks. The relations of these angles to the dental angles are poor although 10, 11 and 12 are related to the molar arch angle (angle 5). The relationship of these angles between themselves show correlations at the .8 level for angles 10/11, 10/12, 11/12, for 9/10 a correlation of .64 is seen.

The next group of angles are those defined by the incisor point and 2 bony landmarks (angles 13, 14, 15, 16). These angles are correlated above the .5 level for their relation to each other and to the above group of angles composed of 3 bony landmarks (angles 9, 10, 11 and 12).

The right and left lateral views of the mandibles are defined by angles 17-21 and angles 22-26 respectively. For these views corresponding angles on the left and right sides are correlated to a high degree (for example 17/22, 18/23, 19/24, 20/25 and 21/26). Also seen is a general interrelation of the angles 17, 18 and 19 with themselves and with the corresponding angles (22, 23, 24). This is in exception to angles 20, 21, 25, 26 which are not related to other angles on the same view nor to angles on the opposite view, but only to their corresponding angles (20/25, 21/26).

Of interest from the correlations of the angles on the side view of the mandible are the inverse .5 correlations of angles 17 and 22 with the arch angle (5) which extends from the incisor point to the first molars. Angles 17 and 22 are also correlated above .43 to angle 2. Angle 17 is also related to angle 12 (defined by 3 bony points on the occlusal view of the mandible).

On the posterior anterior view of the mandible only 4 angles were accepted due to lack of reproducibility in the method tests. Angles 27, 28, 29 and 30 however, were used and are seen to generally correlate well to angles on the occlusal view (angles 10, 11, 12, 14, 15, 16).

In addition to the above and the relations existing between each, the angles of this view are also correlated well with certain angles of the lateral views, for example 19, 22, 23, 24. These are generally negative correlations (the angles are inversely related). Of note here also is that angle 29 is correlated at .673 to the molar arch angle (angle 5).

The crania illustrated a very similar picture for the angles defined by dental landmarks to that seen for the mandibles. From the basilar view the side to side relations, the correlations of the canine arch angle (angle 6) with the molar arch angle (angle 5) are generally the same. Both of these angles in the crania illustrate poor relationships to the side arch angles (1, 2, 3, 4), (Table 4).

On the basilar view there are few correlations indicating relationship of angles defined by bony landmarks to angles defined by dental landmarks. Angles 7 and 8 have correlations below the .5 level with the angles of the dental arch. Angle 9 is related at the .57 level to the canine arch angle (angle 6). Angle 10 which utilizes the incisor point and the posterior palatal foramenae is also related to the canine arch angle (angle 6) and a large and a small arch angle (angles 2 and 4). The correlations listed for angle 11 are generally very poor.

The angles of the lateral views of the crania have high correlations side to side (12/15, 13/16, 14/17). Of considerable interest is that the coronal angles (12 and 15) are very poorly correlated with the anterior angles (13, 14, 16, 17) on the lateral view.

The coronal angles (12 and 15) are inversely related to angle 7 on the basilar view which extends from the zygomatic arches to the posterior point on the cranium. These angles of the lateral view (angles 12 and 15) are also correlated well with angles 9 and 10 which are associated with the palatine foramen. Angle 16 is also related to the molar arch angle (angle 5).

The posterior anterior view of the crania is defined by angles 18, 19 and 20. Angle 18 is related only to angle 11 (the incisor to zygoma area of the basilar view). It is not related to the coronal angle on the lateral view (angles 12 and 15). Angles 19 and 20 are related to these angles (12 and 15) on the lateral views as well as to angles 9 and 10 on the palatal areas. On this view these angles are not correlated well to each other.

The facial view of the crania has numerous angles utilizing dental points. Of high correlation in this group is angle 22 with angle 19. These utilize the same points, but one is from the posterior while the other is from the anterior views. Other angles related to these (angles 22 and 19) are the other angles which utilize the dental points (angles 24, 25, 26, but not 27). Angle 10 which is defined by the incisors and posterior palatal foramenae is selectively related to angles 21, 22, 26 and 27. These are not corresponding angles. Equally selective are angles 25 and 27 which are related to the molar angle (angle 5) at approximately the .6 level of correlation. Selectivity in relationship is seen again with angles 21 and 25 being related to angle 20 but not its corresponding angle on the right side (angle 17).

These results of the angles for the maxilla and mandibles as well as the correlations of angles for the maxillae and mandibles indicate a general trend towards uniformity of form of the crania and mandibles respectively.

RADIOGRAPHIC SURVEY

RESULTS

Radiographic Survey

Chart 1 illustrates the total incidence of the various recorded states of the teeth and their relation to the supporting bone with regards to apparent 'normality'. In the tables which segment the statistics to groupings of maxillary 3rd molars, 2nd molars, etc., as well as similar mandibular groupings, the specific locations of the various conditions can be appreciated.

From these charts apparent agenesis is seen associated only with the 3rd molars. This is unlike the number 3 state of the tooth which illustrates that numerous teeth are seen to be unerupted. The majority of unerupted teeth, however, rest in the 3rd molar category. Obviously taurodontism and fused roots apply only to the molars and as such the maxillary molars presented with a greater proportion of apparently fused roots while the apparent increased size of the pulp chambers is seen to be more common in the lower arch.

Impactions were also registered mostly in the 3rd molar category but the maxillary canines also evidenced three impactions. The partially erupted grouping included only two premolars and one incisor, both of the maxillary arch.

Radiolucencies were noted to be lacking in the 3rd molars and maxillary canine areas with the majority of radioluscencies being located on the mandibular 1st molars. Only one radioopacity evidenced itself and that was associated with a maxillary incisor.

The majority of the teeth evidenced roots and associated bone which appeared 'normal'. Similarly, the majority of the sockets appeared 'normal'. In some of the materials, however, there was no evidence of teeth or tooth sockets.

Chart 1

Teeth are numbered 1-16 for the maxillary arch and 17-32 for the mandibular arch. The conditions of the teeth are as follows:

1 - Partially erupted tooth (clinical or x-ray film)

2 - Apparent agenesis of a tooth

3 - Unerupted tooth

4 - Taurodontic tooth (increased size of pulp chamber)

5 - Apparent fused roots of a tooth

6 - Apparent impaction of a tooth

7 - Radioopacity evident around the tooth

8 - Radiolucency around the tooth (some obvious clinically as bony perforations)

9 - The root and supporting bone appear within normal limits

11 - The tooth socket is present

12 - No evidence of a tooth socket

Maxillary Arch	1	2	3	4	5	6	7	8	9	---	11	12
1 & 16	0	1	12	1	5	2	0	0	3	---	44	9
2 & 15	0	0	4	7	8	0	0	1	23	---	31	6
3 & 14	0	0	0	0	4	0	0	4	62	---	6	4
4,5,12,13	0	0	10	0	0	0	0	2	52	---	90	7
6 & 11	0	0	4	0	0	3	0	0	31	---	37	5
7,8,9,10	0	0	4	0	0	0	1	2	44	---	101	7

Mandibular Arch	1	2	3	4	5	6	7	8	9	---	11	12
17 & 32	0	5	30	10	0	16	0	0	31	---	36	18
18 & 31	0	0	18	16	2	0	0	8	43	---	42	14
19 & 30	0	0	6	4	0	0	0	22	84	---	20	10
20,21,28 & 29	0	0	38	0	0	0	0	2	107	---	131	11
22 & 27	0	0	28	0	0	0	0	1	61	---	64	2
23,24,25 & 26	0	0	14	0	0	0	0	1	95	---	179	3

Total 1-Way for Maxillary and Mandibular Dentitions

1	2	3	4	5	6	7	8	9	---	11	12
0	6	158	38	19	21	1	46	640	---	783	92

ALVEOLAR BONE LEVEL EVALUATION

RESULTS

Alveolar Bone Level Evaluation

The values of the measurements recorded from the cemento-enamel junction (CEJ) to the bone level are illustrated in Chart 2. These values indicate that the group in which attrition did not eliminate evidence of the cemento-enamel junction evidence a level of bone around 2 mm from the CEJ.

Chart 2 illustrates the measurement from the occlusal surface of the teeth when the attrition obliterated evidence of the cemento-enamel junction. These values generally indicate the clinical crown height of this group of teeth. The values recorded at the mid buccal point and mid lingual point appear to be most variable.

Chart 2

Bone level values for the population

ALVEOLAR BONE LEVELS

Group 0 - Measurement from Alveolar Crest to Cemento-Enamel Junction

	Mean	SD
Distal Buccal	1.53	1.12
Mid Buccal	2.12	1.61
Mesial Buccal	1.59	1.07
Distal Lingual	1.53	1.18
Mid Lingual	2.08	1.54
Mesial Lingual	1.65	1.24

Group 9 - Measurement from Alveolar Crest to Most Occlusal Area

	Mean	SD
Distal Buccal	4.06	2.21
Mid Buccal	4.36	3.18
Mesial Buccal	4.06	1.86
Distal Lingual	4.63	2.03
Mid Lingual	5.73	2.08
Mesial Lingual	4.51	1.72

WEAR OF THE DENTITION

RESULTS

Wear of the Dentition

The values of attrition for the entire group, both craniae and mandibles, for all occlusal scales and interproximal scales are illustrated in Figure 1 . The generalized severity of the attrition is seen in the first scale while other scales suggest that the form of the attrition occlusally tends to be either natural (anatomically cusped) form or flat form. The form of the occlusal surface if altered will most likely be slightly cupped. Interproximally for the group, contacts tend to be either lacking or broad both mesially and distally on each tooth.

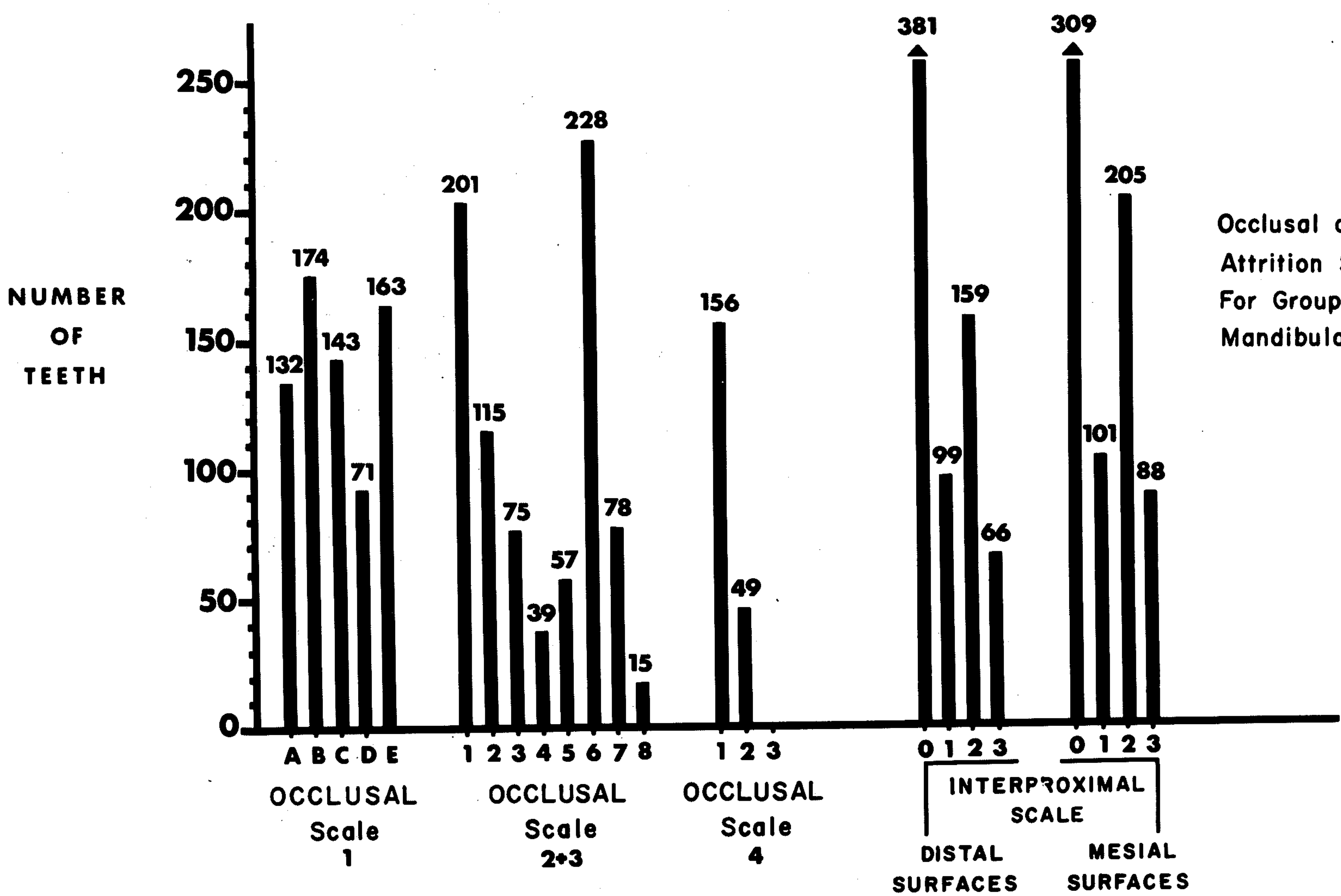
In the first scale for occlusal attrition the maxillary arches and mandibular arches are similar, with the 2nd and 3rd molars tending towards less extreme values while the 1st molars illustrate attrition tending towards the most severe. (Figure 2,3). The more anterior teeth of the maxillary arch maintain a relatively even distribution of wear while the anterior mandibular teeth evidenced a greater incidence of extreme attrition. (Figure 2,3).

Scales 2 and 3 (Figure 4,5) showed the dominance of the natural and flat forms for both groups. For the maxilla, however, it is also noted that value two is registered frequently indicating that the buccal aspect of the maxillary teeth is higher when wear is evidenced. This is in contradistinction to the mandibular 1st and 2nd molars and premolars which have the lingual aspects registered as being higher than the buccal aspect. From the scale the maxillary 1st molars also have a higher distal area than mesial as opposed to the mandibular arch which has a relative balance at the 4 and 5 values (mesial and distal height values) of the scale. Of note in the anterior segment is that the maxillary incisors and canines tend towards flatness while the mandibular anterior segment show more rounding as evidenced by values 7 and 8.

The third scale for the maxilla registered some cupping of the 1st degree while the mandibular arch had cupping of the 1st and 2nd degree generally seen.

The interproximal attrition values (Figure 6,7,8,9) as seen with grouped data, illustrated a preponderance of broad contacts and contacts which are lacking. The distribution for the maxilla and mandibles are similar but the more posterior, that is the 2nd and 3rd molars, have major differences in their mesial and distal values with the distal tending more toward the lesser value. The anterior areas of the premolars, canines and incisors illustrate similar values for the mesial and distal for both maxillary and mandibular arches. The first molar for both illustrates a similar pattern for mesial and distal areas although the incidence of the extreme value (3) is greater on the mesial.

Figure 1



Occlusal and Interproximal Attrition Scales: For Grouped Maxillary and Mandibular Dentitions

Figure 2

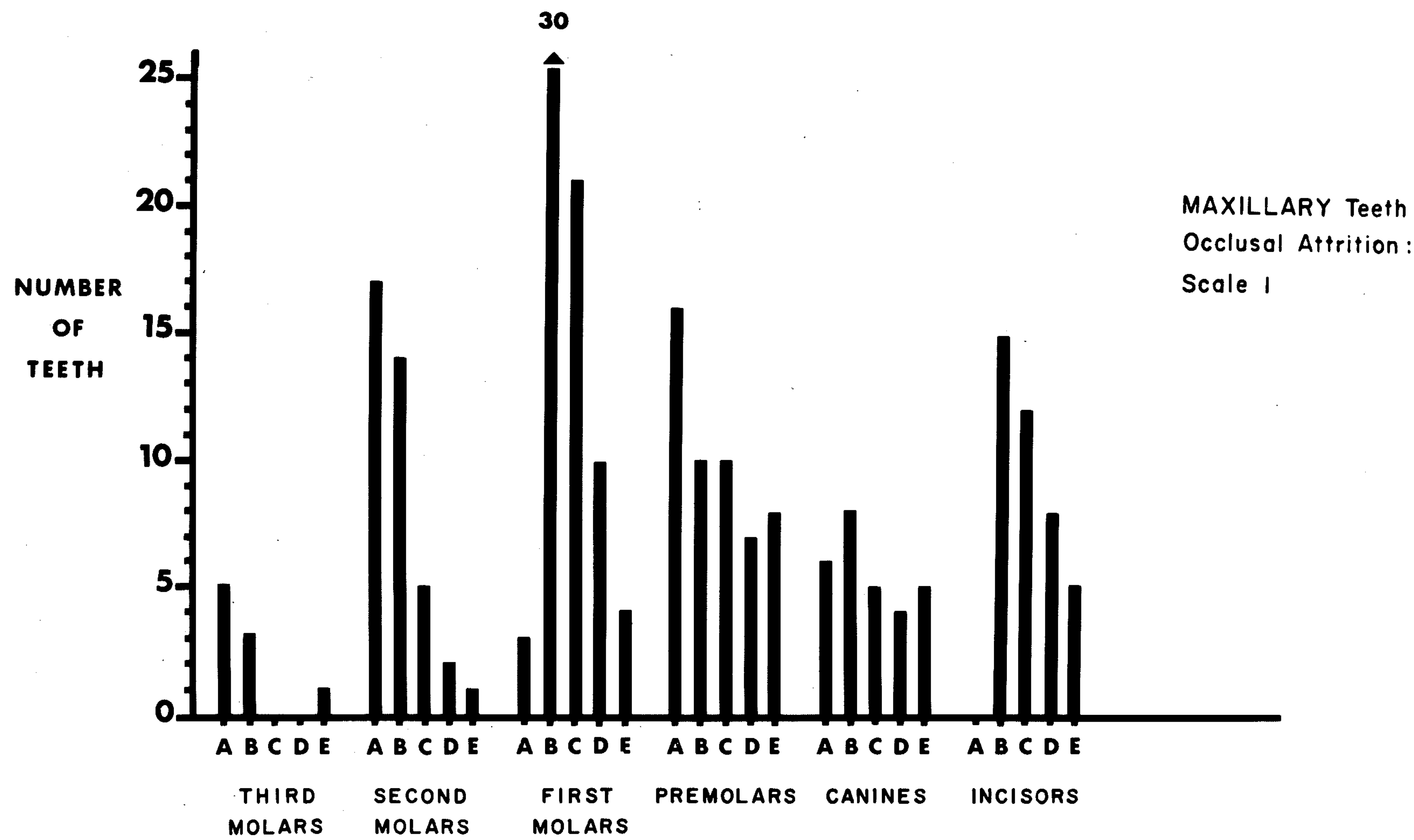

MAXILLARY Teeth
Occlusal Attrition:
Scale I
NUMBER OF TEETH
0
5
10
15
20
25
30
A B C D E
THIRD MOLARS
A B C D E
SECOND MOLARS
A B C D E
FIRST MOLARS
A B C D E
PREMOLARS
A B C D E
CANINES
A B C D E
INCISORS

Figure 3

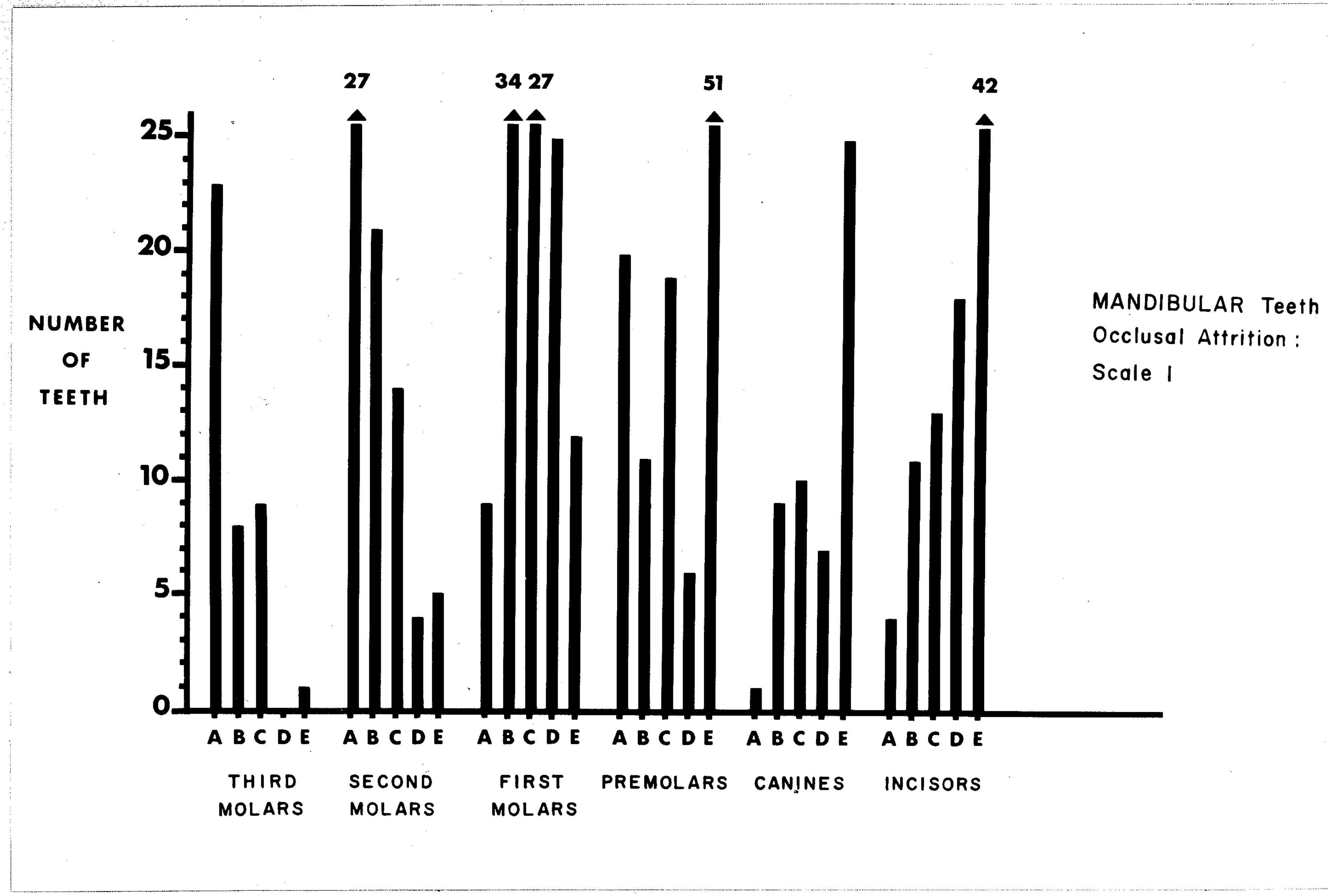

27
34 27
51
42
NUMBER
OF
TEETH
25
20
15
10
5
0
A B C D E
THIRD
MOLARS
SECOND
MOLARS
FIRST
MOLARS
PREMOLARS
CANINES
INCISORS
MANDIBULAR Teeth
Occlusal Attrition :
Scale I

Figure 4

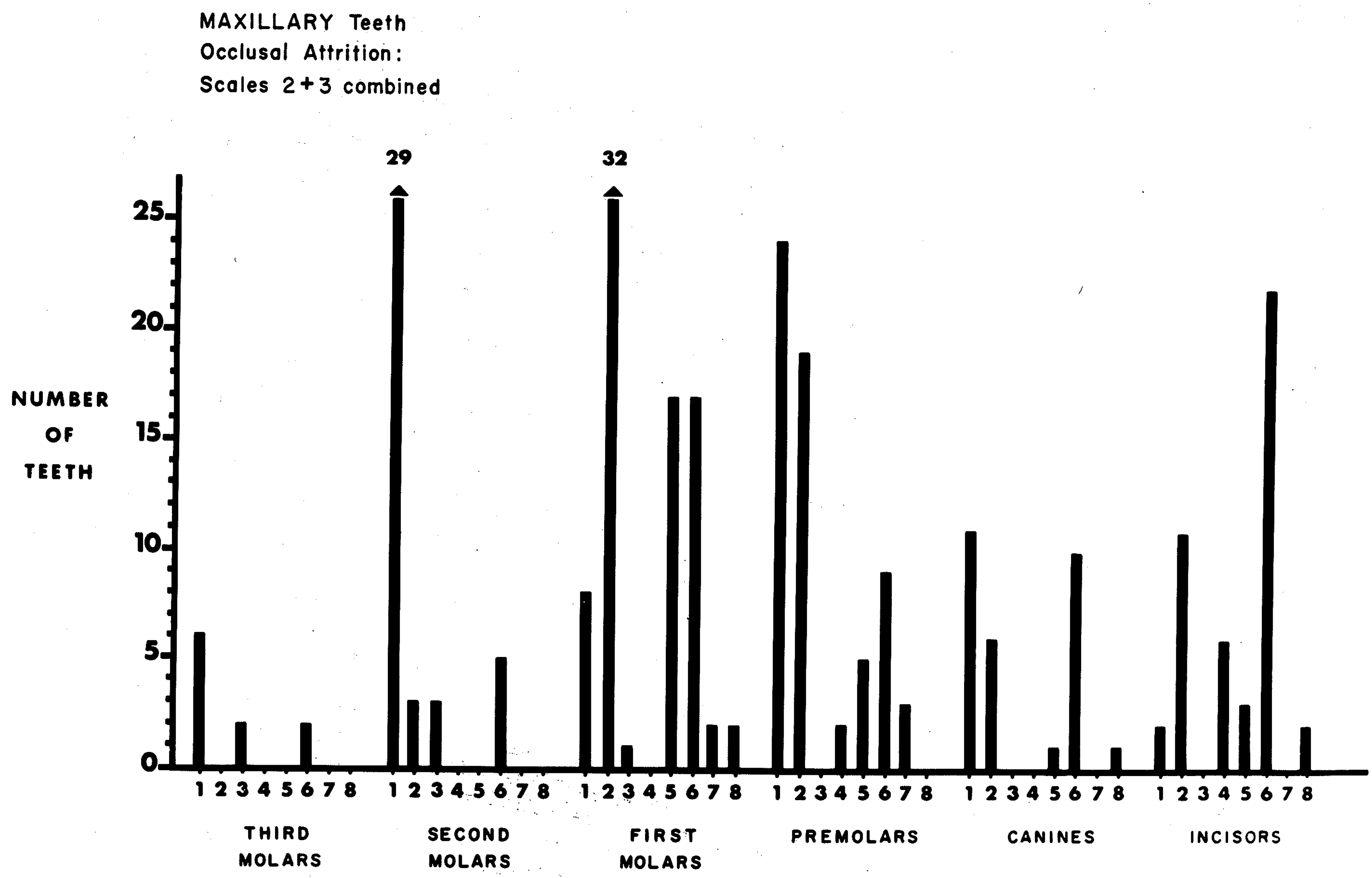
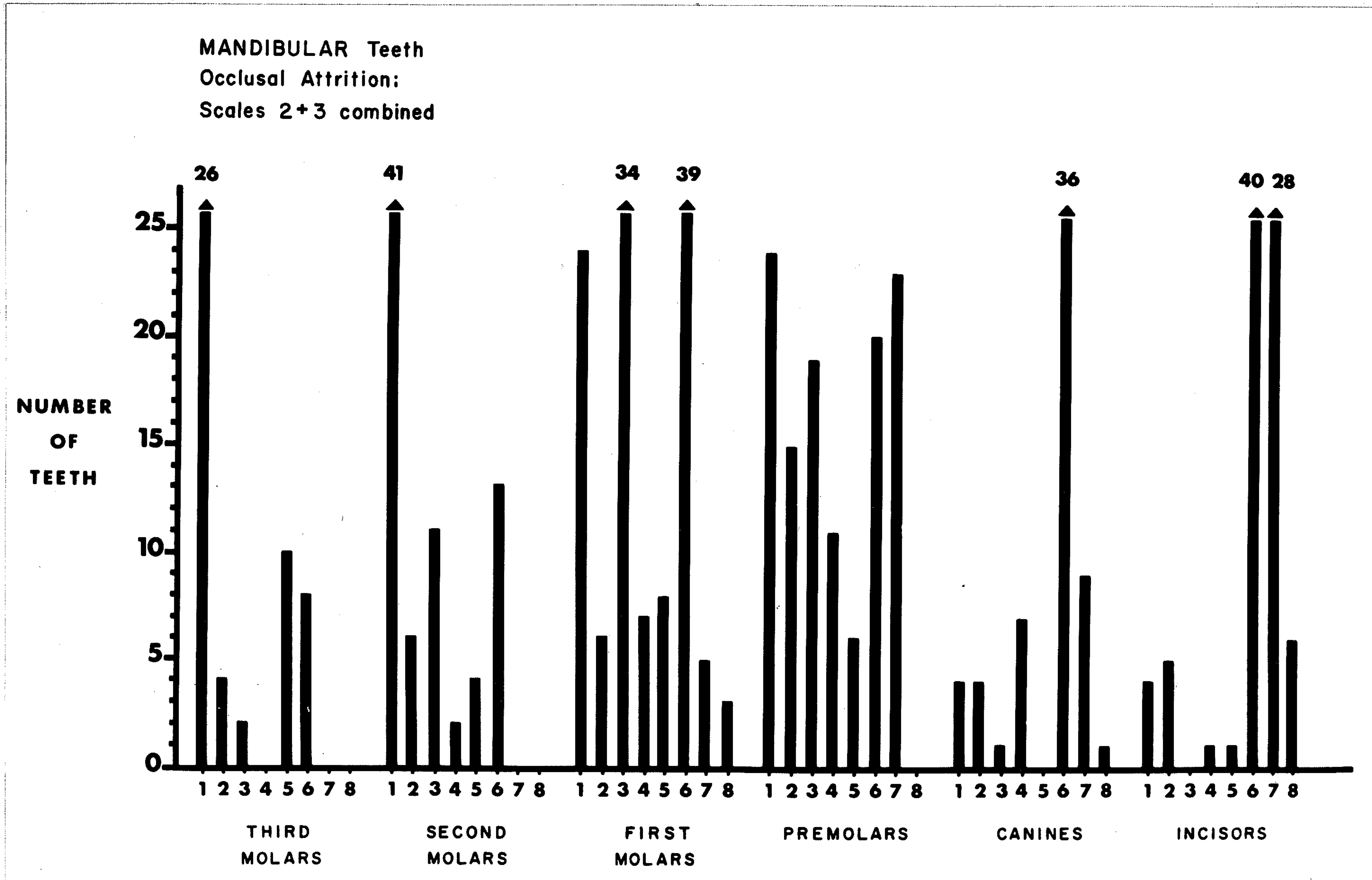

MAXILLARY Teeth
Occlusal Attrition:
Scales 2+3 combined
NUMBER OF TEETH
0
5
10
15
20
25
29
32
1 2 3 4 5 6 7 8
THIRD MOLARS
SECOND MOLARS
FIRST MOLARS
PREMOLARS
CANINES
INCISORS

Figure 5



MANDIBULAR Teeth
Occlusal Attrition:
Scales 2+3 combined
NUMBER OF TEETH
0
5
10
15
20
25
26
41
34
39
36
40 28
1 2 3 4 5 6 7 8
THIRD MOLARS
1 2 3 4 5 6 7 8
SECOND MOLARS
1 2 3 4 5 6 7 8
FIRST MOLARS
1 2 3 4 5 6 7 8
PREMOLARS
1 2 3 4 5 6 7 8
CANINES
1 2 3 4 5 6 7 8
INCISORS

Figure 6

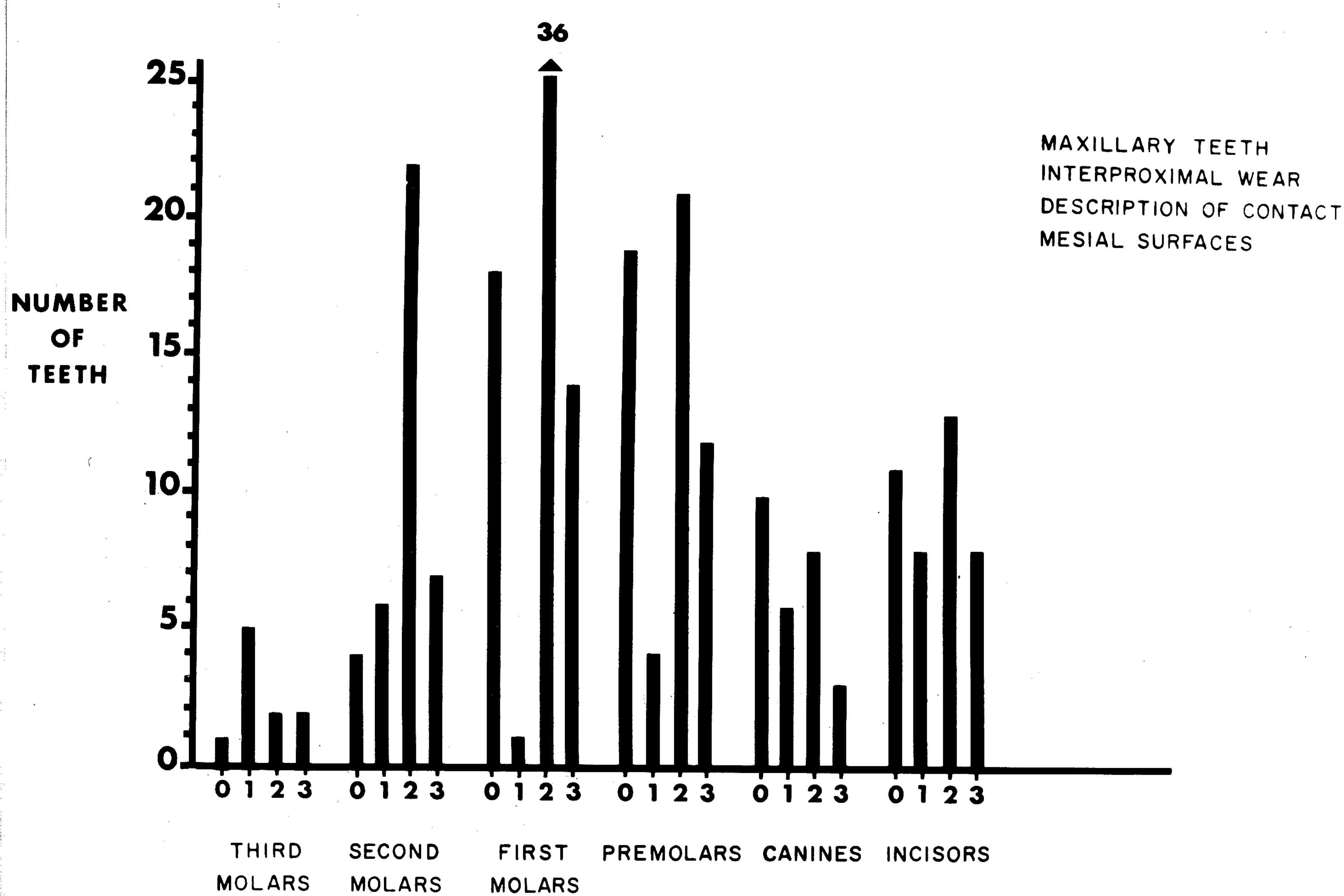

MAXILLARY TEETH
INTERPROXIMAL WEAR
DESCRIPTION OF CONTACT
MESIAL SURFACES
NUMBER
OF
TEETH
0
5
10
15
20
25
36
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
THIRD MOLARS
SECOND MOLARS
FIRST MOLARS
PREMOLARS
CANINES
INCISORS

Figure 7

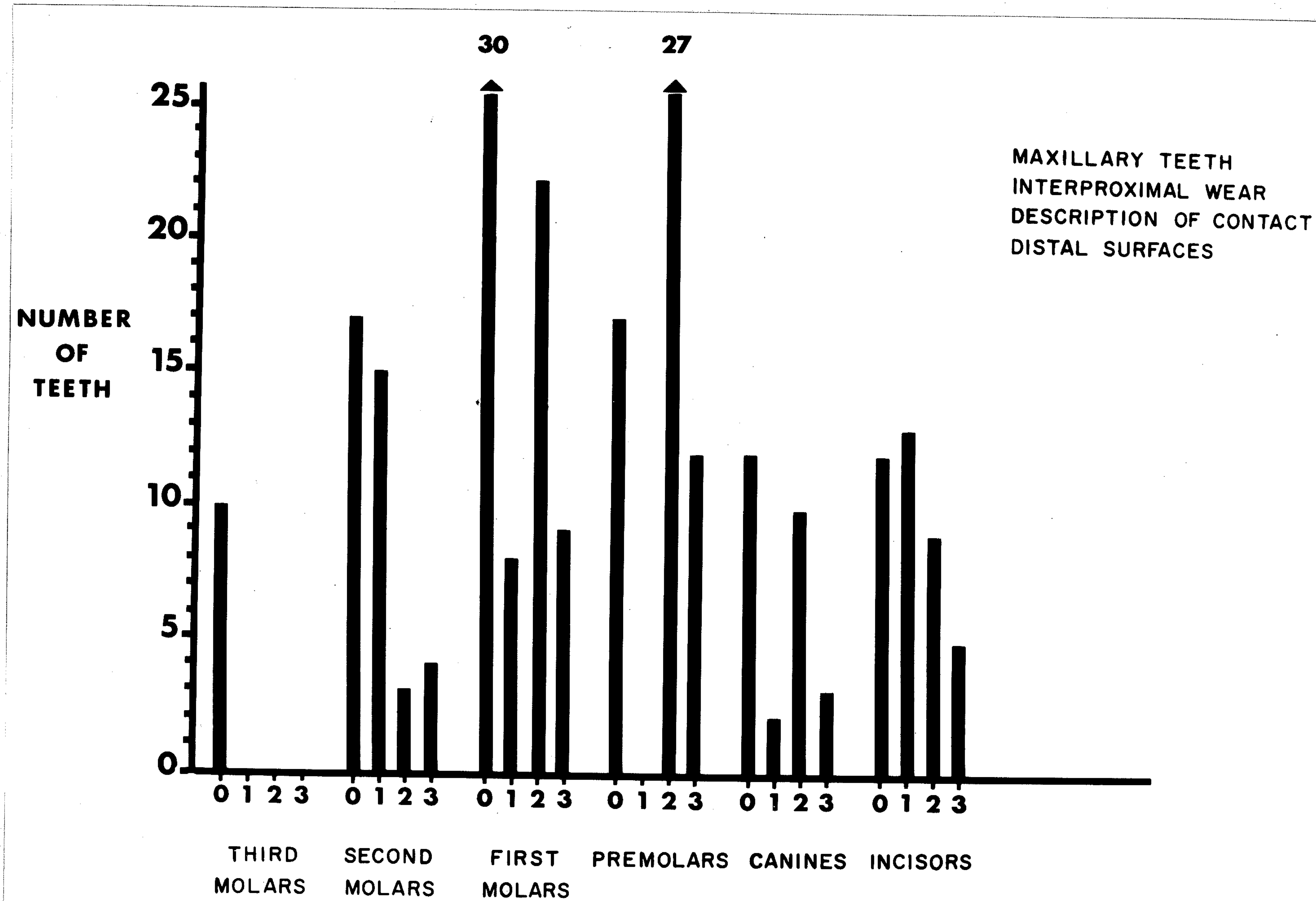
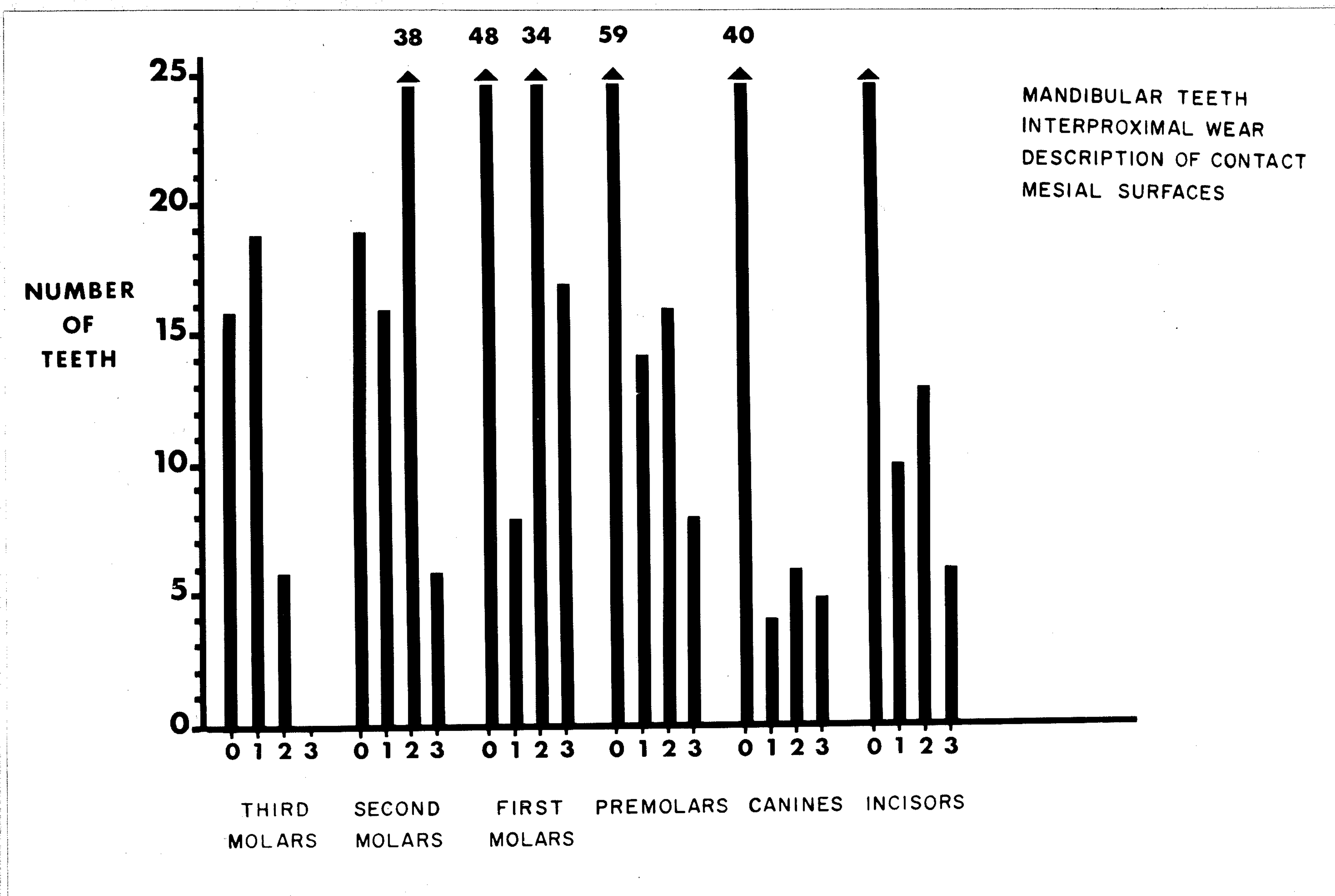
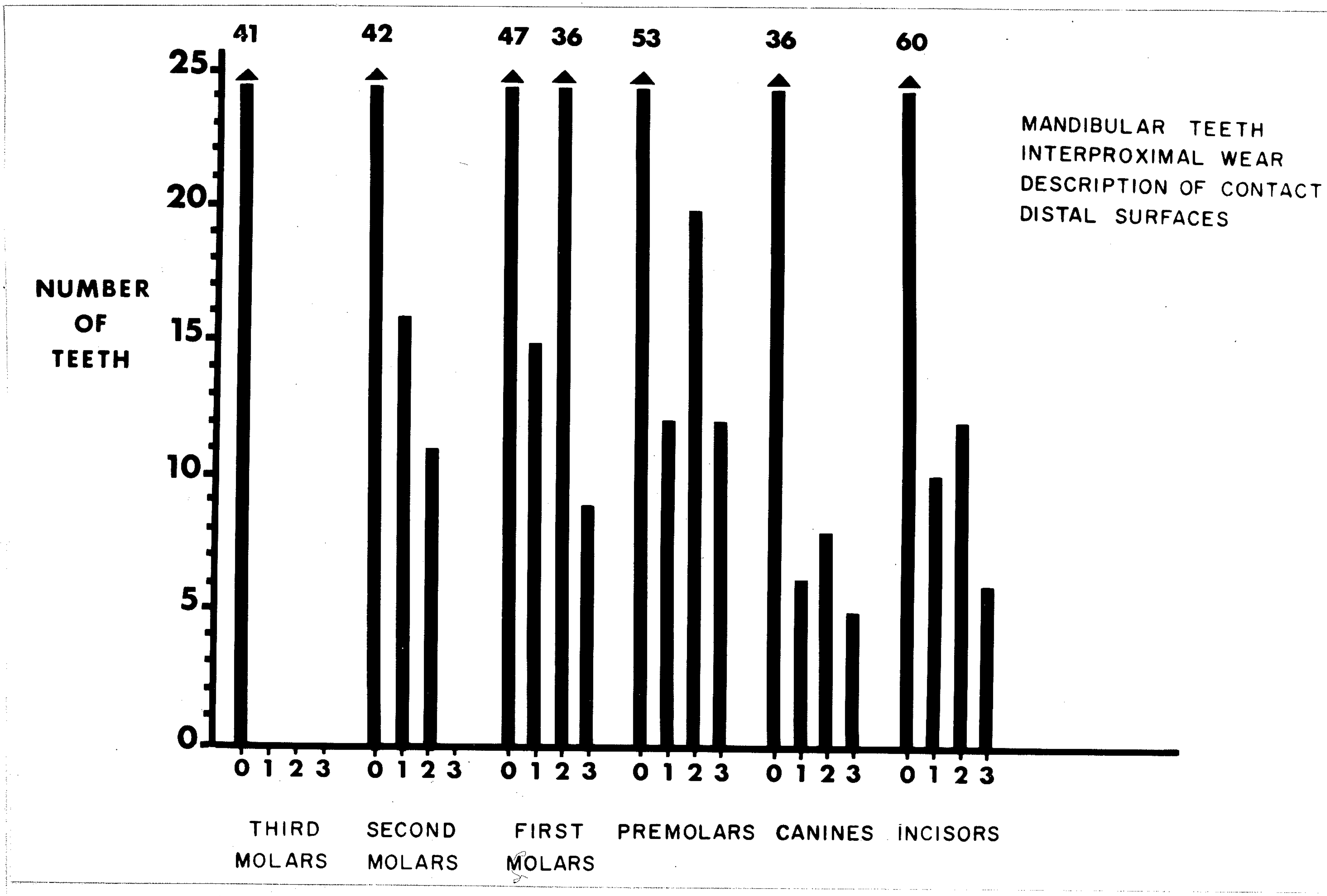

MAXILLARY TEETH
INTERPROXIMAL WEAR
DESCRIPTION OF CONTACT
DISTAL SURFACES
NUMBER
OF
TEETH
25
20
15
10
5
0
30
27
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
THIRD
MOLARS
SECOND
MOLARS
FIRST
MOLARS
PREMOLARS
CANINES
INCISORS

Figure 8



MANDIBULAR TEETH
INTERPROXIMAL WEAR
DESCRIPTION OF CONTACT
MESIAL SURFACES
NUMBER OF TEETH
0
5
10
15
20
25
38
48
34
59
40
0 1 2 3
THIRD MOLARS
SECOND MOLARS
FIRST MOLARS
PREMOLARS
CANINES
INCISORS

Figure 9



MANDIBULAR TEETH
INTERPROXIMAL WEAR
DESCRIPTION OF CONTACT
DISTAL SURFACES
NUMBER OF TEETH
0
5
10
15
20
25
41
42
47
36
53
36
60
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
0 1 2 3
THIRD MOLARS
SECOND MOLARS
FIRST MOLARS
PREMOLARS
CANINES
INCISORS

DISCUSSION

PHOTOGRAPHIC EVALUATION

DISCUSSION

Photographic Evaluation

Up until recently little has been known about the nature and magnitude of variation in any mammalian species. In spite of, or perhaps because of, numerous linear analysis and their related indices, no picture of form variation of the human skull has emerged. The results presented here cannot, therefore, be compared with existing records on human material. They can, however, be related to similar analyses in a number of other species.

McKeown (1974) has shown that as the skull grows angular values alter. In some cases they increase and in others they reduce. Thus adult values are a reflection of the growth process. He has argued that a very small range of variation in adult angular values for a given angle of a group of animals suggests that a degree of consistency exists in the end product of growth, which strongly supports the view that genetic influences are predominant in the determination of shape. A large range of variation does not, however, by necessity, indicate environmental involvement. Studies on variation in overall skull angles in dogs and foxes have shown that some angles vary much more than others in a group and the way in which these vary suggest that environmental influences are not a major factor.

In the present survey certain angles were taken to establish the cranial and mandibular form of the material. The mean and standard deviation for each of the angles was calculated for the group and are presented in Tables 1 and 2. From this information it is indicated that the variability of each of these angles for the group is actually quite minimal. In McKeown's work with the angular evaluations of five groupings of dogs the range of the angles defined by bony landmarks approximated the value of 10° and less. For the assorted breeds of dogs this variability extended to much greater heights and in some angles approached 40°. As is seen by the diagrams here the variability indicated by the standard deviations centred more closely to the 4° area. Of note is that the deviations seen for the crania are consistently less than the deviations seen for the angles defined on the mandible. In spite of this, however, assuming that the work of McKeown is generally applicable to the mammalian skull, the variability of the angles seen in this grouping indicate a certain homogenity from which it is indicated that a limited genetic pool is in evidence.

In considering various areas of the crania and mandibles certain aspects of the variability as illustrated by certain areas of the crania possess standard deviations of a degree significantly different from those of the mandible. In particular, the frontal view of the crania is defined by angles which have standard deviations of less than a full degree while there is no such area obvious in the mandible. Quite possibly this could indicate an area not subject to environmental modifications which is manifesting the uniformity of the genetic pool. In contradistinction to this, the increased variability of the deviations of the mandible could quite possibly indicate the influence of the environment. Even with this, however, it should be realized the variability of these angles is still at a level comparable to the inbred breeds of dogs examined in a like manner by McKeown (1974).

In the area of the dental arch the angles present manifested some of the greatest deviations seen in the angles of this group. This is quite unlike the findings of McKeown in his evaluations of the dental arch of the fox. In his finding the anterior arch angle had a standard deviation of less than 2° while the posterior angle had a deviation approaching 4°. In this study the basic shape of the arches as well as the dental conditions themselves are quite different. Of note is that the dentition has been subject to extensive attrition which is associated with mesial migration of the dental points defining the dental landmark. Most assuredly this is an example of the environmental factors manifesting themselves. Important to note is the variation in attrition as it was recorded, for from that aspect the increased variability of arch form must in part be derived. Also of consideration is that the methodology utilized here to evaluate form is sensitive to such a variation. It should be noted also that this appears to be one factor contributing to this heightened variability.

For the above descriptions the landmarks in question were all located on the dentition. In contradistinction to that group are those angles having landmarks for the angle being defined by bone and dental points. Quite unlike the extensive variations in the standard deviations above, the deviations of this group more closely approximate those angles illustrated by bony landmarks only. This is in agreement with McKeown's results on the foxes.

In the course of this evaluation of form the symmetry of the left and right sides as defined by the angular method becomes susceptable to analysis. To interpret the side to side relationship it is necessary to group the angles according to the landmarks defining them, ie. the angles defined by dental points and the angles defined by bony landmarks. In addition, it should be noted that the variation of side to side relations is different for an individual mandible or maxilla than the relationship as illustrated for the group for side to side relationships.

For the mandibles the lateral views provide the angles for side to side evaluation. The corresponding angles varied for a given individual mandible by as much as 8°. In the grouped material the defined angles representing corresponding areas on the left and right sides had differences in mean values of not greater than 4° and extending to as low as 0.3° for certain angles.

For the crania, the landmarks defining the angles on the lateral views frequently were points common to both views and as a result are not used to illustrate symmetry of the crania. Instead the facial (anterior posterior) view was used. The angles of this view are less variable than those seen with the mandibles but variation for a given individual frequently approached 2° for corresponding angles of left and right sides. For the grouping of the material these same corresponding angles have variations of less than 1° for the mean.

The angles defined by dental landmarks for arch symmetry illustrate much the same variation. For the mandible the variation of the small lateral angle for a certain individual varied as much as 4° while the larger angle varied as much as 13°. The maxillary dentition illustrated variability of 3° and 9° for the corresponding angles for a certain individual in the grouped material the greatest variation seen was in the large lateral angles of the maxillary arch which varied 1° in their corresponding mean value. The other side to side correlations closely approximated each other with the variations of the mean side values.

This material indicates that there is an individual variation of symmetry both in the bone and dental aspects. The bony areas are apparently not as variable for the individual as are the dental aspects. This increased variation of dental left and right side angles for a given individual could indicate environmental influences and modifications due to function. Of import here, also however, is the overall picture provided by the group. The similarity of the corresponding left and right angles for the group reinforce the group similarity and possibility of common genetic pool.

The high correlations between certain angles which in many cases were anatomically remote and often derived from different views of the skull suggest that a considerable degree of cohesive variation in overall form is present in the cranium. This calls into question the results of previous studies which concluded from linear analyses that little relationship exists between various parts of the cranium. It suggests that angular measures are a more valuable measure of form and should be more extensively used in future investigations.

RADIOGRAPHIC SURVEY

DISCUSSION

Radiographic Survey

With the use of the Panorex radiographs a comprehensive picture of the dental status was obtained. Mentioned above is that the sockets for certain teeth appeared missing. The majority of these findings were in material presenting with extensive attrition. For example, only 44 cases of missing sockets were seen out of the 1,480 total cases in group 0 while group 9 which had extensive attrition had 48 cases which included 15% of the teeth evaluated. The value of the x-ray films in this case rests in the verification that these teeth were not impacted and that there is no radiographic evidence of a socket. It does not, however, rule out the possibility that they were never present. In this particular work it is accepted as Begg (1971) described it, 'That the tooth gradually exfoliated itself in the presence of great attrition.' The question as already stated, however, remains that teeth which generally showed less wear than the teeth remaining were usually the ones lacking evidence of a socket, that is 2nd and 3rd molars.

In the present survey impactions were evidenced by the films. These included 3rd molars and maxillary canines as illustrated in Chart 1. It was felt that if the root was completely formed and the tooth was still completely incased in bone, it was considered impacted. In those cases where it appeared remotely possible that the tooth could erupt the term unerupted was used. The use of younger material is evidenced in this section in that the sample size is increased and the premolars are listed as unerupted as are many of the 2nd molars. This material as described was added for evaluation for the dental status.

As mentioned above agenesis or lack of formation of a tooth was also evaluated. In the total group there were only six instances where it was felt that there was lack of formation of a tooth. These were located in the 3rd molar catagory. This is distinct from the above discussion in that there was evidence of the 2nd molars and the attrition stages of Begg did not apply.

The majority of these descriptions of the teeth were indicated by the level 9 or 11 in my scale. The 9 indicated that the tooth present was apparently within normal limits, while the 11 indicated the socket in the absence of the tooth, appeared within normal limits. Unlike these, level 8 indicated a radiolucent, or darkened area at the apex of the tooth. In fact, the majority of these evidenced themselves on clinical exams in that a hole from the apex extended through the buccal plate of bone. Once again, the highest percentage of these was seen in the group with severe attrition. This area was usually associated with an opening in the occlusal surface to the inner chamber of the tooth. Although these were evidenced on numerous teeth, the majority in both groupings fell to the mandibular molars.

In the same survey radio-opaque areas were evaluated. Only one was evidenced in the groupings and no precise etiology could be assigned to it. Fused roots were also evaluated but no great number was evidenced. It was felt also that in so far as the film is only two dimensional such an appraisal of a three dimensional phenomena was unreliable. This is particularly true in this study in that the majority of fused roots were seen in the maxillary molars which have a palatal root.

Of considerable interest initially was the evidence of taurodontism. At the outset it was felt that the incidence was quite high. This would be in accord with Moorees (1957) who reported on other American native peoples. The majority of those cases seen here were in the mandibular molar areas. The panorex films frequently evidenced taurodontism which when checked by local x-ray films was, in fact, not present. Also questionable was a small radio-opaque area in the pulp chamber which when initially evaluated appeared to be a pulp stone. Again with local film this was found to be nothing abnormal. Therefore, the panorex radiography should be used with caution in anthropological dental surveys and should be supported by any necessary local radiographs.

For the present survey the general evidence or absence of tooth structure was obvious, but possibly due to error in orientation of a specimen, distortions of other areas were seen.

Figure 10

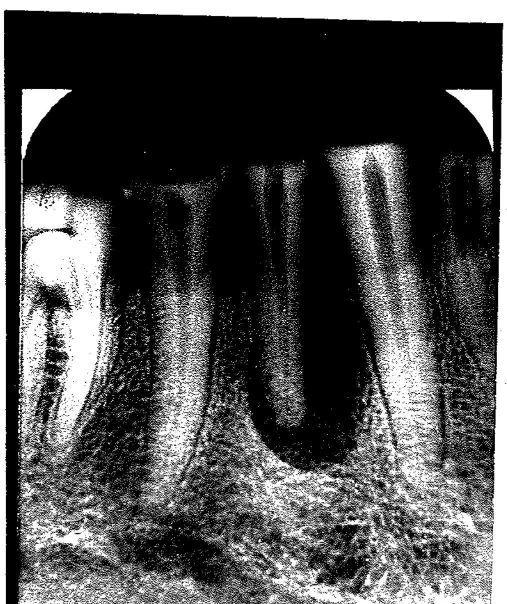
Photographic illustrations of periapical radiographs verifying:

a. An impacted 3rd molar

b. A periapical radiolucent area

(Both areas were initially observed on the Panorex radiographs).

a



b

ALVEOLAR BONE LEVEL

DISCUSSION

Alveolar Bone Level

In the course of the present dental survey an attempt was made to obtain an appraisal of the levels of the bone which would enable firstly, an accurate group standard or presentation and secondly, to establish a basis for comparison with other groups, preferrably living groups as well as materials such as was used here. Such an evaluation is commonly called a periodontal examination or index.

In consideration of this, it must be remembered that periodontal disease and health necessitate the presence of both hard and soft tissue the latter of which was obviously lacking here. For these reasons the information here is felt merely to be an indication of the alveolar bone level in reference to one of two set points. In the process of analysing the results, however, that aspect of periodontal evaluation dealing strictly with bone levels is of importance.

In establishing periodontal indicies in living patients (the goal of which is to indicate the state of health of supporting tissue) the pocket depth, or bone level, is frequently measured from the soft tissue margins, (Cohen, 1973).

An attempt was made by Ramjford (1959) to establish a more general index and method of measurement. The indices devised by Ramjford took measures from the cemento-enamel junction to the pocket depth but considered only four measures on six representative teeth. Davies, Picton and Alexander, (1969) in considering human skulls utilized two measures of the cemento-enamel junction to alveolar bone on each tooth. These values were averaged for a given mouth to provide an index.

For the present study six measures were taken for each tooth as described in Appendix III. Some of the measures were from the alveolar bone to the cemento-enamel junction, (when possible) and others were measured from the bone to the occlusal most point on the teeth in the particular area of measure.

The six measures for each tooth do not reveal any major discrepancies between the six measures. This would lend support for the methodologies of both Ramjford (1959) which used four measures to indicate the bone levels and also support Davies, et al (1955). The present results indicate the overall application of the mid buccal and mid lingual values as approximate indicators of the bone levels. The utilization of the six values would indicate areas of alveolar bone loss, etc. as described by Cohen, (1973). He stated the value of a measurement gains import by its ability to describe a bony defect. This would be done by the six measures but when considering a population such a description is lost by the amount of material. For significance such a bony defect would have to be present generally in the sample and as seen here, this was not the case.

The present material surveyed presented with measurements of approximately 2mm and less for the group. Gargiulo, Wentz and Orban (1961) utilized autopsy material and established a 'normal' range for this value. This value varied according to four age phases from 1.08 to 2.81 for mean values. The increase of this value with age has also been reported by Belting, Massler and Schour (1953) as well as by Schie, Waerhaeg, Loudal and Arno (1959). With these live studies and roetgenograms the direct measurements were utilized.

The first study of Gargiulo, et al (1961) postulated that the process of continued tooth eruption to be natural. Begg, (1971) agrees that there is a normal continual eruption which is associated with, but not caused by attrition. Evidence of this continual eruption is also supported by Murphy (1959) who considers a survey of modern day men 19-33 years of age who had an increase in lower facial height between those years. The original function of this was to maintain a clinical crown with continuing attrition, according to Begg (1971). Murphy states that this compensation overshoots its mark with modern men resulting in an increase of facial height in the absence of significant attrition.

The results here attempt to establish the bone level and lend support to the view that the teeth continue to erupt. This is seen with the clinical crown which has its occluding surface below the cemento-enamel junction. In this study, however, definitive support of continued eruption has not been supplied since the maxillae and mandibles were not articulated and thus could not be evaluated for the vertical facial height changes associated with attrition.

The bone level, however, does become more distant from the cemento-enamel junction with excessive attrition. This could be evidence of bone loss rather than eruption. Extensive pockets were not observed, however, and absence of evidence of bone sockets in many cases where the teeth had been lost support Beggs' (1971) hypothesis of normal eruption of stone age man's dentition which in the final stages erupts out of its socket.

Of interest is that the teeth that were shed in the present sample were the 2nd and 3rd molars which would have erupted later than the premolars and the 1st molars. Assuredly, the 2nd and 3rd molars had less attrition when present. Their possible loss could be due to the excessive mesial migration with their continuing eruption or due to morphological differences, for example, smaller roots.

For the group without excessive attrition judging by the standards established by Gargiulo, et al (1961) this group would be within exceptable limits for their bone level as measured from the cemento-enamel junction. We could, therefore, postulate that they did not suffer from significant periodontal disease.

WEAR OF THE DENTITION

DISCUSSION

Wear of the Dentition

Attrition or the wear on the teeth has been described by the progression of dentin exposure by numerous authors, for example, Leigh (1929), Klatsky (1939), Campbell (1939), Davies and Pedersen (1955), Murphy (1959) and Lavelle (1970). A major limitation, however, is that the descriptions provided for the attrition are basically limited to the gradual vertical reduction of molars without a description of the associated changes in form. Molnar (1970) devised a scale to more appropriately 'describe' attrition and from his work the present scale was adapted.

Dental wear depends, according to Taylor (1963) on the tooth density, the nature of the food and the character of the bite, or as Perlow (1943) describes it, the degree of the development of the masticatory apparatus. In addition to the dietary aspects parafunctional habits, for example clenching (Davies and Pedersen, 1955) and utilization of teeth as tools (Clements, 1971 and Molnar, 1971), must be considered as influential factors of attrition as well as the dietary aspects.

Tooth density was evaluated by Mooreas (1957) for the living Aleutian Equamaux. In his studies the tooth density was greater in the older than the younger living generations. Inferred is that there is no reason to assume that the tooth structure per se was of a character that was more conducive to wear in the anthropological groups than in the present populations. Assuming this, the other areas affecting tooth wear are, therefore, implicated for this population.

For dietary influences in dental wear Cross (1930) and Rihan (1932) (from Clements, 1971) have indicated maize and cereal products to be highly abraisive. Meat is also indicated but according to Leigh (1925) less attrition is seen in the Sioux Indians which were meat-eaters than comparable Kentucky Indians who consumed large amounts of cereals. Also of import for this particular area is the method of preparation of the food which would effect its abraisiveness, Clements (1971). The Oxbow culture did have controlled use of fire as indicated by Dyck (1970) allowing the possibility of soft foods.

The present population is from a sandy plains area and as such the environment must be considered in regard to dental attrition. According to Mehta and Evans (1966), and Clements (1971), this type of environment is very influential in dental attrition. For in spite of the softening of foods in preparation, the incorporation of sand in the course of preparation, for example via grinding with motar and pestle, has been indicated by Clements (1971).

The other aspect which could be influential in dental attrition is the use of the dental apparatus as tools. Molnar (1971) reports notching of the maxillary central incisors due to such parafunctional habits and Dalberg (in Brothwell, 1963) reports use of the dentition to soften leather in the Eskimo populations. In the present survey no anterior notching was observed but working with leather cannot be excluded due to the fact that the population worked with leather or hides as indicated by Dyck (1970). Partly in support of this type of parafunction is that only a small percentage of the group present with the dramatically extreme wear. The influence of the daily diet, however, is most assuredly indicated since marked attrition is also evidenced on the deciduous dentition. Obviously no clear distinction of the dominating factor does emerge but assuredly the use of refined carbohydrates associated with caries and lack of attrition is not seen in the present survey. This would be in agreement with anthropological materials from the Tollifero site which presented with wear and no caries and opposed to the Clarksville Indians (Hoyme and Bass, 1962) which were dated later and did have less attrition and more caries associated with a soft diet. The Tollifero site which had materials comparable to the ones evaluated here are dated considerably earlier than the Clarksville materials but later than the present materials.

Associated with the occlusal attrition both Begg (1954) and Sicher (1953) observed interproximal wear. In spite of this wear interproximally both authors observed the continued contact of adjacent teeth. This is attributed by these authors to a mesial or forward movement of the teeth in the dental arch. In this particular study a scale was adopted to define the wear on the interproximal surfaces of the teeth. The results of this survey indicate wear which is generally moderate to severe on the mesial and distal surfaces of the teeth. The teeth exhibiting this wear are still in contact thereby lending credence to the above authors and the mesial force vector of the dentition. In cases of extreme attrition (Begg's senile attrition) the interproximal contacts are lacking. This would seem to indicate that the mesial drift explained by Sicher (1953) is limited in that the mesial force vector reaches a limitation and cannot maintain the contacts interproximally. Both Begg, (1965) and Brash (1953) are in agreement with this limitation.

It is from this observation of mesial vectors that Begg (1971) deducted that the mesial migration of the dentition provided space for the 3rd molars to erupt. As is seen in Figure 10 impacted 3rd molars did exist in the presence of extreme attrition. This complete bony impaction was located by the panorex x-ray film and isolated via a periapical film. Most assuredly, however, the incidence of mesial angular impactions could be reduced by the interproximal attrition and space loss. As such mesio angular impactions were not seen in the present survey associated with excessive wear. In fact, this type of impaction was seen in dentitions with less wear. In this particular survey, however, unless the roots were completely formed such positioning of the teeth was termed unerupted. The incidence of this is seen by the number of unerupted 3rd molars as applied to the statistics for the impacted 3rd molars.

As discussed in Appendix III the teeth were numbered 1-32 and evaluated independently. In Molnar's 1972 work mandibular central incisors were considered together as were the laterals, canines, 1st premolars, etc. In this particular work an attempt was made to be more discriminating and to evaluate left and right sides independently. As Murphy (1959) reports of Campbell's work, however, it was found that the left and right sides are basically the same. In addition to this it was found here that all the mandibular incisors were basically the same as were the premolars. The occurrence of ectopic function as described by Molnar (1972) could be indications against such a generalization.

The attrition as observed in this grouping is severe and is apparently due to dietary factors and compares in a favourable fashion with a similarly dated grouping. Indications of specific parafunctional habits do not appear, for example Molnar's (1972) notching of the incisors. This, however, is not ruled out.

SUMMARY AND CONCLUSIONS

SUMMARY

1. An investigation was carried out on a prehistoric Amerindian population to study variations in cranial form and the conditions of the teeth and hard supporting tissues.
2. Cranial form was analysed using a reproducible photographic technique which permitted an angular analysis of overall cranial form and dental arch shape to be carried out.
3. A dental survey consisting of Panorex radiographs, bone level measures and dental wear values was carried out.
4. The angular analysis of form showed a limited variability in angular variation suggesting a high degree of homogeneity of the group.
5. Greater variations found in angles derived from dental points suggest a high degree of environmental involvement.
6. A correlation study indicated high correlations between a number of angles suggesting a cohesive process of variation in cranial form. Of particular interest was the correlation between certain arch angles and remote cranial angular measurements.
7. The dental survey concluded that bone levels were compatible with those found in healthy living subjects.

8. The radiographic investigations showed instances of radiolucencies, radiopacities, impacted teeth and other hard tissue conditions.

9. Dental wear was found to be severe in many instances and could be attributed to a number of environmental factors.

10. The survey methods are a valuable investigative tool for examination of the cranial area. It is hoped that similar studies can be carried out on other populations and can form the basis of useful comparison.

CONCLUSIONS

The photographic technique in this study provided records which were found to be reproducible to a highly acceptable degree. From the photographs mean values for the group were derived for a large number of angles. Standard deviations approaching 4° for angles defined by bony landmarks and 6° for angles defined by dental landmarks were commonly recorded. The small variations found in certain angles indicate a substantial degree of homogeneity in the population and also infers that environmental influence acting on the growing skull, is strictly limited, because of the small variation found in these adult skulls. The correlation coefficients indicated the general interrelation of the parts to one another and thus to the whole. It appears, therefore, that angular analysis is a more valuable measuring tool for the study of form than linear measurements.

The panorex radiographs provided records to observe impacted teeth, radiolucencies (indicating possible periapical infections), fused roots as well as numerous other hard tissue anomalies. The distortion evidence in the technique necessitated verification of certain abnormalities with local x-ray films.

An evaluation of the bone levels in reference to the cemento-enamel junction yielded values which indicate an apparent state of periodontal health. The results of the study indicate that fewer measurements are required to give a general indication of bone levels of the population. Further work is required to investigate which areas best represent the bone level for the anterior teeth and which would indicate the level for the posterior teeth in similar anthropological material.

The scales applied to the wear of the teeth indicated a general condition of excessive wear both occlusally and interproximally. The definition of interproximal wear could possibly be modified so as to include a more precise definition of the wear on teeth not having any interproximal contact.

The survey technique employed here is a simple and useful method of examining the teeth, jaws and skull of a skeletal group. Similar studies on other populations could provide a valuable means of comparison, which should lead to a better understanding of the variations and relationships between different human populations.

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APPENDICES

APPENDIX I

PHOTOGRAPHIC EVALUATION

APPENDIX I

Photographic Evaluation

Photography has developed in the last 30 years into a methodology increasing in value in providing a measurable record system. Tanner and Weiner (1949) evaluated the reliability of a photographic technique for anthropometry. From their study they found the records to be as reliable as records taken on the living, and stated posing was a major part of the error encountered. This problem of posing was again evaluated in 1950 by Dupertius and Tanner. In 1952 Gavin, Washburn and Lewis again evaluated photographic techniques for anthropometry. Their work indicated distortion is greatly minimized by increasing the lens subject distance to approximately 20 feet. Utilizing this increased distance Lettig (1964), Geoghegan (1953), compared measurements of live adults with those taken from photographs. Both found the measurement error to be less with the photographic records. The same was found by Lewin, Tengroth and Bergkvist (1961), using dry skulls. The latter authors found less measurement error with photographs but the measurements were generally seen to be larger than the original.

In 1972, Maurice McKeown (Ph.D. thesis) developed a photographic technique utilizing a long lens subject distance, a specific lens system, mounting system and printing technique. In his work a detailed account is given of various distortions and problems encountered with the technique. He concluded the distortion error at his 12 meter distance was less than 0.8% over a 25 mm depth of field.

The technique utilized here is similar to McKeown's (1972), the only difference lying in the materials and the distance of the film to the lens. The problems of optical and object distortion are essentially solved by placing the object at a long distance from the camera and telephoto lens. Stability of the photographic paper is achieved by using a special paper*. For consideration of the specifics of the above problems reference is made to his thesis.

The materials evaluated here were a number of crania and mandibles as has been previously described. For each crania six photographs were taken with a set orientation while for the mandible four different views were recorded. This procedure utilized a cephalostat for mounting the materials in a consistent manner, a camera with a 400 mm telephoto lens, 2 photographic lamps and Kodak Panatomic X -

* Ilfoprint stabilization paper

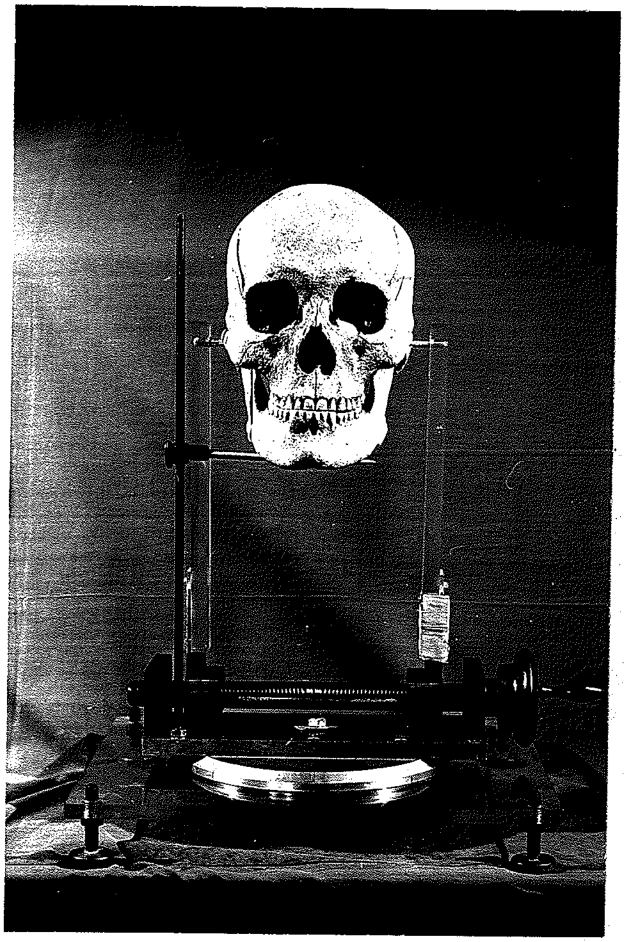
a fine grain 35 mm film. The film was processed and printed in a standardized manner.

The mounting of the material was in a portable cephalostat. The cephalostat had earrods which were adjustable in distance from one another via a screw mechanism. By this screw mechanism the earrods remain an equal distance from a midpoint regardless of the absolute width. The posts supporting the earrods are situated on a revolving base. (Figure 11). This base is marked at 90° intervals to enable reproducible positioning as the cephalostat is turned. For registration of a horizontal plane a pointer is present which was utilized via insertion in the infraorbital foramen. This enabled the establishment of the Frankfurt Horizontal Plane for orientation. For stability the cephalostat was clamped in a specific position on a table which in turn was fixed to the floor. For the photography a black back drop was utilized.

The camera used was a single lens reflex camera (Mamyia 500 TL). To this camera a 400 mm telephoto lens was attached. The camera was mounted on a tripod and levelled with a spirt level. The vertical height for the camera was established utilizing the cephalostat. The earrods were arranged parallel with the line of the camera and the height determined accurately when the earrods were superimposed on one another. The distance utilized for the photography was 6 meters from the front face of the lens of the camera to the midplane of the cephalostat. After this was measured,

Figure 11

Cephalostat with skull mounted via ear rods. (In the main study the pointer supporting the chin was placed in the infraorbital foramen and the mandible was photographed separately).



the camera was stabilized by fixing it to the floor. At this time a long extension cable release was set up on the camera. This was to enable the photograph to be taken without contacting the camera. The camera was focused, set on time exposure with the f stop at 22 to aid the debth of field. The aperature was stopped down which necessitated an exposure of two seconds.

The lighting for the cephalostat was supplied by two 60-watt bulbs. These were located 18 to 24 inches from the midpoint of the cephalostat. One was set higher on one side while the other was low. This was to eliminate excess shadows and provide contrast.

Utilizing the above equipment the photographs to be described were taken. As a method sample three specimens were recorded three times in each pose to test the accuracy of the mounting.

The six photographs of the crania were the frontal, the posterior, the 90° right and left lateral, the 90° basilar and the coronal reverse views. For the frontal, lateral and posterior views the crania were mounted with the earrods in the external auditory meatus. For the establishment of the Frankfurt Horizontal Plane, the pointer already described was used. With this probe the Frankfurt Horizontal was parallelled to the cephalostat base. After each crania was mounted the four views were taken in succession by rotating the earrods on their stabilized base. Thus the skull was not disturbed in its position in the cephalostat.

The basilar and coronal views were taken with the earrods again in the external auditory meatus. The Frankfurt Horizontal Plane in this case, however, was vertical and perpendicular to the cephalostat base.

The mandible was photographed in four positions. The first of these is the occlusal view. For this view the mandible was suspended via the earrods which contacted the ramus of the mandible at the buccal approximation of the mandibular foramen. When this was done the anterior aspect of the mandible was directed to the floor. A plane was then established for orientation in the midplane of the cephalostat. This was done by lining up the mandibular foramen with the mental foramen. Most of the mandibles suspended as described, naturally assumed this position. Others were guided to this position via a string tied to the earrods.

The posterior anterior film of the mandible was taken with the mandible again supported by the earrods at the buccal point corresponding to the mandibular foramen. The anterior aspect was supported by a rod which was secured to the base of the cephalostat. The plane defined by the mandibular and mental foramenae was parallel to the floor.

The right and left lateral films of the mandible were taken with the body of the mandible resting on the tangent flat plane. For the orientation of the lateral films the outer point of the condyle and the mid point at the alveolar bone between the central incisors lay parallel to the film. This plane of the mandible was in the mid plane of the cephalostat.

The developing, fixing, and drying of the film were carried out according to standard methods. For the printing of the films a Beseler Model C B 7 Enlarger was utilized. This printer has three scales which enable accurate reproducibility. The A scale was at 4.5, the B scale at 35 mm, and the C scale at 31 1/4. This printer used a 250-watt bulb, a 50 mm lens at F8 setting. The exposure time was 10 to 15 seconds according to density. The paper used was the ILFO-print #2*. The Ilfoprint stabilization paper is guaranteed to less than 0.1% dimensional distortion during processing. The prints were not fixed.

The illustrations of the various photographs with the points to be used in the analysis are given in the lift-out illustrations.

Absolute measurements were not being considered, thus no scaling system was added to the photographs. They were, however, all printed at precisely the same magnification.

In spite of the utilization of the technique as

* Ilford Photographic Paper, Ilford Limited, Ilford, Essex. Made in England.

described by McKeown, (1972) it was felt an error of the method study should be performed to evaluate the set-up of equipment used in this particular survey. The accuracy of the method of recording and analysing the data was tested. For each of the views 3 crania and 3 mandibles were mounted, photographed and removed on three separate occasions. The printed photographs from these were all digitized in a manner to be described. The information was then evaluated with the aid of the computer.

By this method, the reproducibility of the overall methodology was indicated by the consistency with which points were recorded and compared on a given specimen. This meant that each of the 3 crania and each of the 3 mandibles was compared to itself three times. Some of the method samples are given in Tables 5 and 6.

An elaboration of this test was made to include the reproducibility of the angles which were to be used for the final analysis. This utilized the same 3 crania and 3 mandibles whose points were tested above. From this method of sampling certain points and angles were found to be satisfactorily reproducible while others were not.

It is, however, necessary to carry out this type of testing to evaluate possible error as the error incurred in certain circumstances, which differed only slightly, proved to be of importance.

After the photographs were prepared, defined points on each view were recorded. The relation of these points were used to provide the angular definitions of form for comparison. For the recording of the points the photograph was mounted on the screen of a Ruscom* strip chart digitizer (Figure 12). With the digitizer the points of concern for a given photograph were recorded (x y co-ordinates) via an IBM printing card punch onto punch cards.

A computer program described by Cleall and Chebib (1971) was used to convert the different co-ordinate systems to a common co-ordinate system. This the computer does by superimposing the co-ordinates over a certain chosen point--the origin, (which in this case was the first point recorded on the digitizer). The computer then takes another determined point on the digitizer as the direction or orientation about which the other points will be transcribed. Due to the import of the order of recording of the points, all the points were recorded in the same order for a given view. When a point could not be registered a value of 999999 was punched in and by this was eliminated from the study.

Once the points were in a common co-ordinate system a co-ordinate analysis computer program was utilized.

* Ruscom Logics Ltd., Unit 7, Alness Street, Downsview, Ontario. M3J 2H1

Figure 12

Photograph of Ruscom Chart Digitizer (1) set for punch card recording (2) of selected landmarks on mounted photograph (3).

This program has three aspects which were utilized here. These are consideration of the co-ordinates, angles and distances.

The co-ordinates were used to establish the mean and standard deviation for a given landmark for the group. This program also checks co-ordinate values which lie beyond a previously chosen degree of variation in order to draw the attention of the operator to a possible error.

Distances can also be given by the computer either between two landmarks or between a landmark and a line connecting two other landmarks.

Particularly important here are the angles the program can provide. An angle can be defined by three landmarks (points) or by the intersection of two straight lines. These angles must be described by vectors in a clockwise direction for accurate registration.

After the angles were recorded the interrelations of the various angles were examined. For this, the same co-ordinate analysis computer program was used. With this the mean angular value of a given angle for a given view was established. After this, the correlation coefficient was given by the computer (Factor Analysis Program) between all angles. It is from these that a correlation of form was sought.

The photographic technique, as has been stated, was developed by McKeown in 1972. The application of the technique with this material inclusive of the mounting of the materials, photographic records as well as the recording with the digitizer of the established points was investigated with a test of the methods. This test of the methodology evaluated all of the above stages by seeking the reproducibility of landmarks on certain crania and mandibles. For this three mandibles and three crania were each orientated, mounted and photographed in the various positions on three separate occasions. The three recordings for each specimen were compared. As can be seen with the associated example, (Table 5,6) the points as defined were generally seen to be reproducible to a high degree. This can certainly be noted particularly in the landmarks used to evaluate the dental arch which evidence variation in the points of less than .1 mm in the x y co-ordinates.

Certain landmarks, it should be noted, did possess a heightened variability. This is usually seen in areas where the point appeared precisely defined on the x co-ordinate value whilst the y value was variable. This was evident in broad areas for example at the angle of the body of the mandible. Of note, however, is that the variability of a landmark or of all the landmarks defining an angle do not necessarily indicate the variability the angle itself possesses. This is seen in the method sample on the occlusal view of the mandible in which an angle of high variability had points defining it which had low variability. The converse is also seen (eg. mandibular angles 4, 2, 13, 2 vs. 6, 2, 11, 2).

In attempting to evaluate this variability it is felt that high variability of a co-ordinate of a point expresses only linear aspects and as such might not influence the value of the angle. In addition, however, it is felt that if the length of the arms of the angle do influence its variability, then a defined angle which has shorter sides would be more prone to higher variance. For any given range of variation of both x and y co-ordinates in all three points comprising an angular measurement, the range of variation of that angle will depend upon the absolute difference in distance between the points. The closer they lie together the greater will be the amount of angular variation. This is seen in the basilar view of the crania where points of nearly the same variability defined two angles and the angle with the shorter arms had a deviation six times the other angles (maxillary angles 13, 1, 7, 1 vs. 4, 3, 16, 3). The size of the angle also seems to be related to its variability as a smaller angle has less variance than a bigger one. Statistically, one would tend to reject this hypothesis in that the size of the angle as is presented is merely a mean point from which the deviation could be sought.

From the method sample the majority of the angles evaluating the posterior view of the mandible were rejected. This resulted from the lack of reproducibility in the method sample. This was probably caused by minor positional alterations in the specimen causing large angular variations due to the morphology of the object and the associated linear separation of measuring points when related to the camera.

All the other parameters were judged to be of sufficient accuracy to be included in the study. Certain other points were, however, eliminated due to frequent lack of registration for example, the mounting method obscured tentative points at the zygomas on the facial view of the crania.

Points Recorded on the Mandibles

Occlusal View of Mandible

1. Midline of symphysis at inferior border of mandible
2. Midpoint buccal lingually between mandibular central incisors
3. Midpoint buccal lingual between 1st premolar and canine on right side of mandible (left side of photograph)
4. Midpoint buccal lingual between 2nd premolar and 1st molar on right side of mandible (left side of photograph)
5. Outermost point on right gonial angle of mandible
6. Distal point on lingula on right side of mandible
7. Outermost point on right condyle
8. Innermost point of right condyle
9. Innermost point on left condyle
10. Outermost point on left condyle
11. Distal point on left lingula
12. Outermost point on left gonial angle
13. Midpoint buccal lingual between 2nd premolar and 1st molar on left side of mandible (right side of photograph)
14. Midpoint buccal lingual between 1st premolar and canine on left side of mandible (right side of photograph)

Left and Right Lateral View of Mandible

1. Point on tangent to lower border of mandible at distal point of 1st molar
2. Distal point of 1st molar at most superior point on alveolar bone
3. Most superior point on coronoid process
4. Distal superior point on condyle
5. Gonial point on angle of mandible
6. Most anterior inferior point on mandible

Posterior Anterior View of Mandible

1. Crest of alveolar bone between mandibular central incisors
2. Midpoint at most inferior point at symphysis of mandible
3. Lowermost point on left gonial angle
4. Lowermost point on left mandibular foramen
5. Outermost point on left condyle
6. Most superior point on left coronoid process
7. Most superior point on right coronoid process
8. Outermost point on right condyle
9. Lowermost point on right mandibular foramen
10. Lowermost point on right gonial angle

Points Recorded on the Crania

Basilar View of Crania

1. Posterior point on sagittal suture
2. Posterior point on nasopalatine foramen
3. Midpoint buccal lingually on alveolar bone crest between the maxillary central incisors
4. Midpoint buccal lingually between left canine and 1st premolar
5. Midpoint buccal lingually between left 1st molar and 2nd premolar
6. Central point on left posterior palatine foramen
7. Outermost point on left zygomatic process
8. Outermost point on left foramen ovale
9. Outermost point on left side of foramen magnum
10. Posterior point on foramen magnum
11. Outermost point on right side foramen magnum
12. Outermost point on right foramen ovale
13. Outermost point on right zygomatic process
14. Central point of right posterior palatine foramen
15. Midpoint buccal lingually between right 1st molar and 2nd premolar
16. Midpoint buccal lingually between right canine and 1st premolar

Left and Right Lateral View of the Cranium

1. Lowermost point on mastoid process
2. Most superior point on crania (utilizing F H)
3. Most posterior point on crania
4. Nasion
5. Point A - (subspinale) - The most posterior midline point on the premaxilla between the anterior nasal spine and prosthion
6. Most occlusal point on alveolar bone mesial to 1st molar
7. Most occlusal posterior point on tuberosity

Posterior View of Crania

1. Most superior point on mid sagittal suture
2. Intersection of lambdoidal sutures and mid sagittal sutures
3. Lowermost point on left mastoid process
4. Most superior buccal point on alveolar crest of left tuberosity
5. Most superior midpoint on alveolar bone crest between maxillary central incisors
6. Most superior buccal point on alveolar crest of right tuberosity
7. Lowermost point on right mastoid process

Anterior View of the Cranium

1. Most superior point on cranium on mid sagittal suture
2. Most superior midpoint at alveolar crest between the maxillary central incisors
3. Most superior buccal point on alveolar crest at tuberosity on right side
4. Outermost point on zygomatic process right side
5. Midpoint on right infra-orbital foramen
6. Midpoint on left infra-orbital foramen
7. Outermost point on zygomatic process on left side
8. Most superior buccal point on alveolar crest on tuberosity on right side

APPENDIX II

RADIOGRAPHIC SURVEY

APPENDIX II

Radiographic Survey

In clinical dental practice the evaluation of a given individual must include a comprehensive examination of the dentition including the bony supporting areas of the jaws. It is for consideration of these areas of the dental status that roentgenograms are utilized. The types of roentgenograms presently available include numerous intra-oral film sizes as well as numerous extra-oral films and techniques. Each of these methods and techniques are applied for quite specific reasons.

To evaluate the present materials, panorex* roentgenograms were utilized. It was felt that with these materials a method was needed to screen the group for unerupted teeth both partly and completely formed, to observe the presence or absence of a tooth as well as radiolucent or opaque areas, to consider the general status of bone levels around the teeth to appraise certain aspects of the teeth morphologically.

The inception of the panorex by Hudson and Kumpula (1957) provided a screening device for the dental status of

* S.S. White, Dental Products Division, Philadelphia, Pennsylvania. 19102

the U.S. Armed forces recruits. As a screening devise the panorex film was designed to give a visualization of the entire dentition along with the alveolar bone and related areas on a single low-exposure extra-oral film.

The ability of the film to grossly present the above aspects of the dental status has been stated by Kumpula (1957), O'Brien (1972) and Ennis, Berry and Philips (1967) among others. Also, generally accepted by these authors is that precision of detail is somewhat lacking with this technique and as a result all recommend verification of apparent abnormalities with small local intra-oral x-ray films (periapical films). The lack of precision of detail is basically a distortion which Kite and Swanson (1962) stated was quite unpredictable.

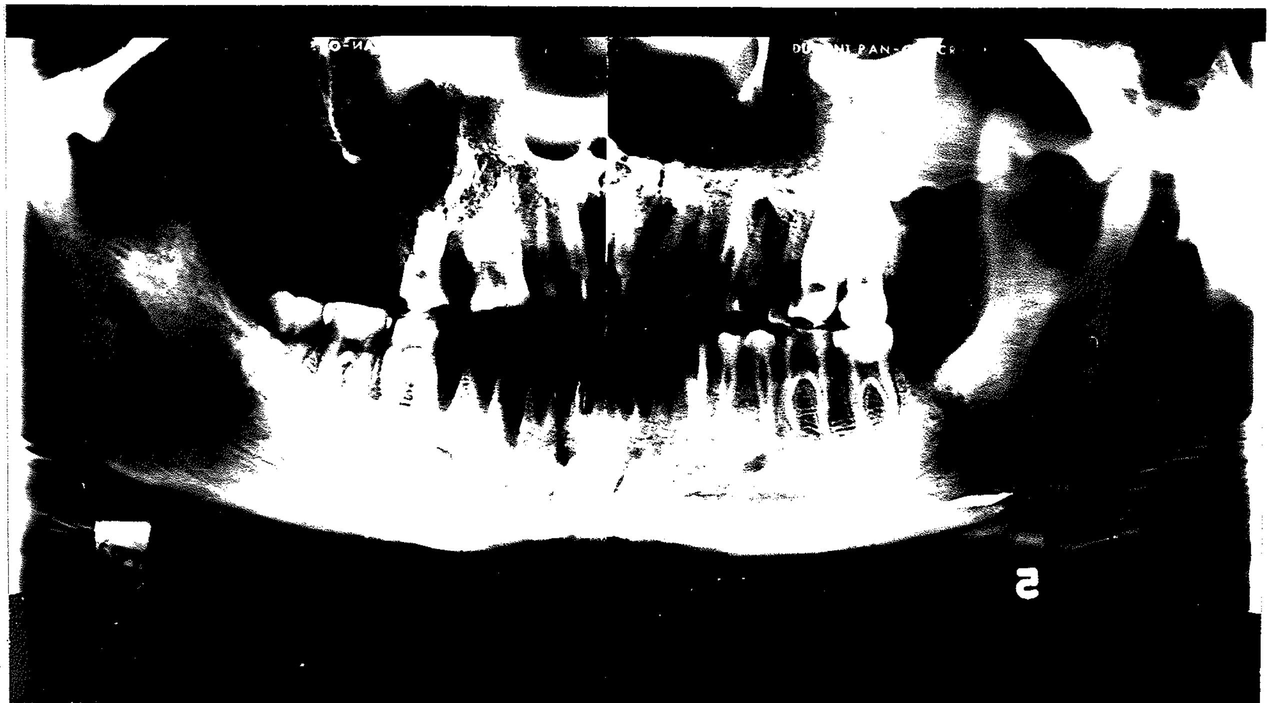
In the present study local films were taken of certain of the apparent abnormalities. Figure 13 shows a photograph of a panorex film in which the lower six-year molar appears taurodontic. As illustrated by the adjacent photograph this is not confirmed by the periapical radiograph. The value of the film, however, is seen in Figure 14 which shows apparent impaction of the canine tooth. This is verified by the local films.

In principle the panorex x-ray is an extra-oral product of curved surface laminography, a body sectioning

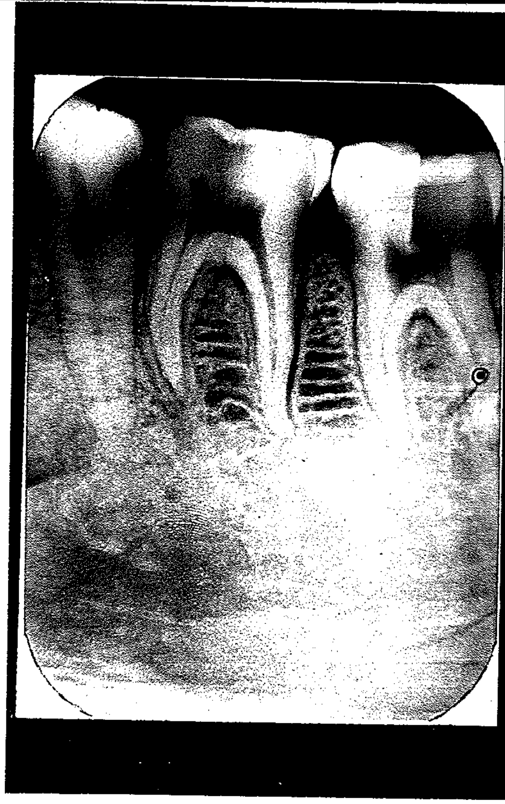
Figure 13

a. Photograph of Panorex radiograph with evidence of possible taurodontic mandibular molars

b. Photograph of the periapical radiograph of the same mandibular molars refuting evidence of taurodontism.



a

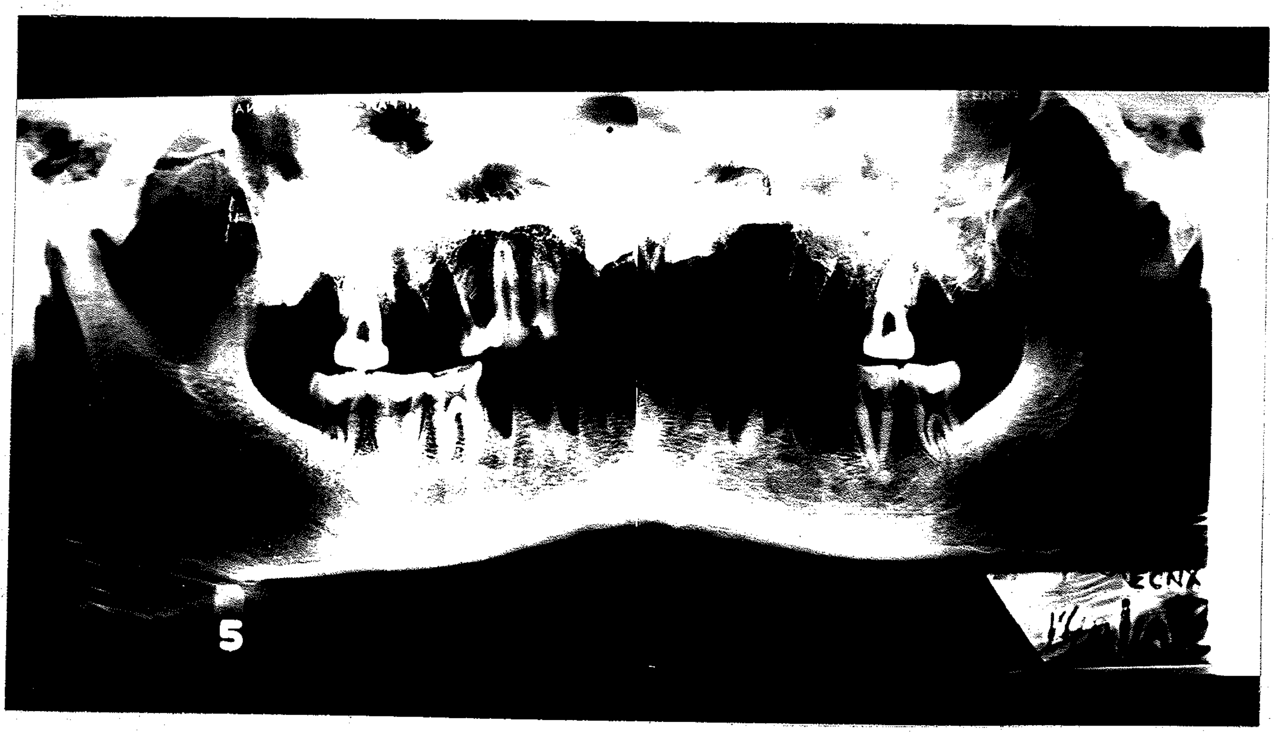


b

Figure 14

a. Photograph of Panorex radiograph illustrating evidence of impacted canine

b. Photograph of occlusal x-ray film confirming the impacted canine



a

b

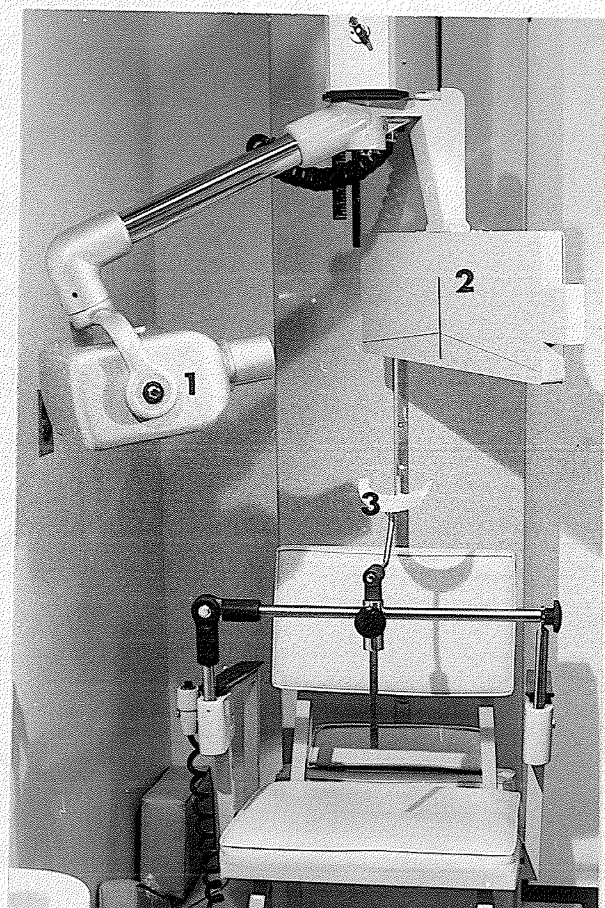
technique. The machine itself as pictured (Figure 15) consists of an x-ray source and an x-ray film which is held in a cassette holder. Both the x-ray source and the film rotate about the skull. The controls consist of a regulation of Milliamperage(MA) and Kilovoltage (KV); a pre-set timer and a switch which activates the x-ray source. In utilizing the panorex machine the patient sits in the chair and places his chin on the chin rest. The x-ray source and film cassette holder which are placed in a constant relationship are adjusted in height to approximate the level of the patient's dentition. This approximation is achieved via the hand and foot pedal switches. With the proper adjustments of MA and KV made, the machine is activated.

During this activation the patient's head is maintained stable on the chin rest while the tube head, (the x-ray source), as well as the cassette holder, with the x-ray film, move in a circular pattern. The first half of this rotation, the centre of which is located just inside the ramus opposite the x-ray source, will expose one-half of the mandible inclusive of the anterior teeth. At this time the x-ray beam is shut off and the chair traversing the patient will shift to the opposite side. The purpose of the shift is to establish a new centre of rotation. After the shift the x-ray source is activated again auto-

Figure 15

Photograph of the Panorex x-ray machine. (The controls are located away from the chair behind a lead shield).

1. Tube Head, x-ray source
2. Cassette holder
3. Chin rest


1
2
3

matically and defines another circle of rotation with the central point located inside the other ramus. During this procedure, which lasts a total of 20 seconds, the activating switch is continually on. The interrupted x-ray exposure, the turning of the tube head and x-ray cassette holder, and the shift of the chair are all automatic.

As stated above the panorex x-ray machine is based on curved surface laminography. The principle of this type of laminography is that the shadow or image of the object that passes through a beam of x-rays must fall on a film that is moving at the same velocity as is the image . This is achieved by rotating the x-ray source and the x-ray film in opposite directions. With the panorex the tube head and cassette holder are rotating in the same direction. It is during this rotation that the cassette holder as is seen in Figure 15 is equipped with cables on a pully system. It is via this pulley system that the x-ray film is moved in the opposite direction of the x-ray source. By this movement in opposite directions a selected layer of tissues can be isolated while structures or either side of the selected tissues are blurred near to extinction.

The film utilized for the panorex x-rays was Kodak film, 5" x 12" DF 85. Panorex R.P. panorex film was also utilized. These films were contained in a screened cassette. In principle the process of x-rays exposure consists of electrons liberated by high voltage from a cathode (Tungsten wire) belting on an anode (copper) which emits x-rays. The x-rays then travel in all directions off the anode controlled by filters and shields. Those that hit the x-ray film break up the precipitated Ag Br crystals, which are contained in an emulsion, to silver and bromide ions.

The x-ray films can, however, be affected by various other factors in addition to x-rays. These factors include chemical factors, temperature and light, as well as many others. In an attempt to decrease the radiation required to expose x-ray films some of these factors have been utilized. The use of intensifying screens decreases the amount of x-ray exposure substantially by increasing the effect of the given exposure. The intensifying screens utilize calcium tungstate or barium lead sulfate. These phosphers, as they are called, when acted upon by x-rays, fluoresce and the light impinges on the film thereby increasing the exposure of the film. After the exposure of the x-ray film it is 'developed'. In this process the silver ions are blackened. The film is then fixed whereby Ag Br salts are removed and the blackening of the developing solution is stopped.

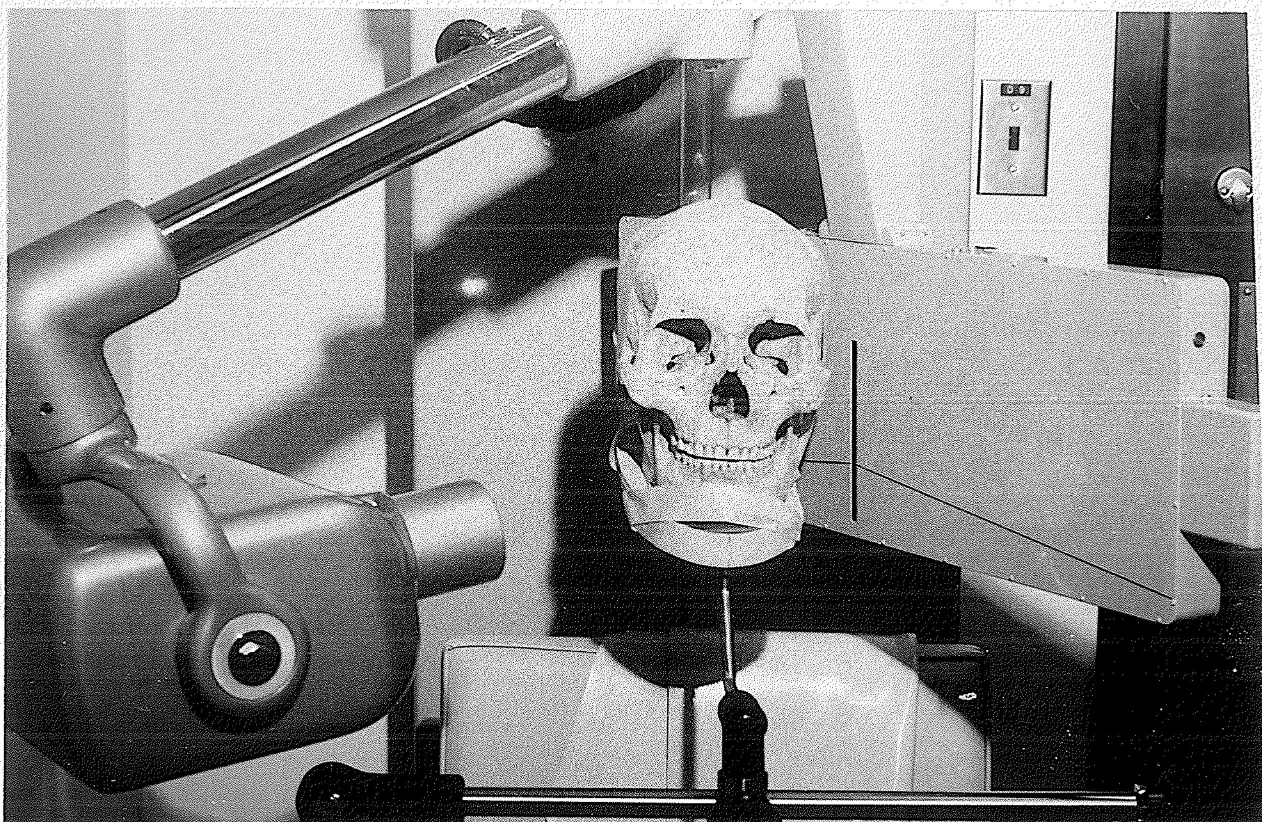
As mentioned earlier the KV and MA are controlled on the panorex machine while the time is constant. In normal clinical use the KV is varied between 64-90 KV while the MA is adjusted between 10-13 MA. These are adjusted according to the facial width of the patient. The purpose of the adjustment is to control the density, (ie. the blackness of the film), and the contrast, (ie. the greyness of the film). The density is controlled by both MA and KV while the contrast is controlled mainly by KV. In attempting to achieve an x-ray suitable for examination it was found that the clinical settings were unsuitable. Because of this, trials were run to determine the settings of MA and KV which would more closely approximate a routine clinical result. The settings determined were 50 KV and 7 MA. The problem of supporting the materials in proper orientation was overcome by utilizing a piece of wood taped firmly to the chin rest. The element of mobility of the chin rest was rectified by taping it to the cross bar of the chair. With the board in place the materials were taped to the board. In the placement an attempt was made to simulate the proper chin placement trying to prevent the materials from being off centre which would affect distortion on the film (as seen above in Figure 16). After the films were exposed they were developed and fixed in a Fischer Automatic DO 100* developer with the temperature adjusted to 89°F.

In the present study the following aspects were

* Fischer DO 100 Developer, Fischer Industries Inc., 2520 Kaniville Court, P.O. Box 570, Geneva, Illinois 60134 U.S.A.

Figure 16

Photograph of skull mounted on board adapted to the chin rest of the Panorex x-ray machine.



recorded from the panorex roentgenograms, on computer cards for each tooth. The values extended from 01 to 12 and were an attempt to describe the situation for a given tooth. Some of these areas are partly or could partly be observed clinically but this was the most accessable area for their recordings.

01 - Partially erupted tooth
(clinical or x-ray film)

02 - Apparent agenesis of a tooth

03 - Unerupted tooth

04 - Taurodontic tooth
(increased size of pulp chamber)

05 - Apparent fused roots of a tooth

06 - Apparent impaction of a tooth

07 - Radioopacity evident around the tooth

08 - Radiolucency around the tooth
(Some obvious clinically as bony perforations)

09 - The root and supporting bone appear within normal limits

(01 to 09 apply when the tooth is present in the arch; 11 and 12 apply in the absence of a tooth).

11 - The tooth socket is present

12 - No evidence of a tooth socket

APPENDIX III

ALVEOLAR BONE LEVEL EVALUATION

APPENDIX III

Alveolar Bone Level Evaluation

The level of the alveolar bone with reference to the dentition was sought in this analysis. As an indication of the periodontal condition in living patients, Russell (1956), has devised a soft tissue scale. Davies, Picton and Alexander (1969) in working with skulls utilized two measurements from the cemento-enamel junction to the alveolar bone. An average for the mouth was given by them as the 'cervical height index'. This was found to correlate highly with Russell's index above. Lavelle and Moore (1969), utilized an oblique x-ray to establish an index of the degree of alveolar bone resorption. All these methods are considered types of periodontal condition indicators.

The present survey utilized a Hu Freedy Periodontal probe (Figure 17) the tip of which is less than 1 mm in diameter. The probe has graded marks at 1, 2, 3, 5, 7, 8, 9 and 10 mm. The same probe was used throughout the survey. The measurements were taken at six positions around each tooth as indicated by Figure 18 . The areas from which the measurements were taken, are first the distal buccal, second, the mid buccal and third mesial buccal, then the distal lingual, mid lingual and mesial lingual.

From this evaluation of bone levels two groups were set up. One group had measurements done from the cemento-enamel junction to the bone level; this was group 0. The other group was designated group 9 and was considered separately due to the extensive attrition which partly eliminated evidence of the cemento-enamel junction. As a result of this, the measurements were taken from the most occlusal area on the tooth at the particular area of measurement--again to the level of the alveolar bone. These two groups were evaluated separately and as a result there are two group values for every position for every tooth.

As a test of the reproducibility of the measurements three pieces were evaluated five times on each of five separate occasions. Variation of these samples were at a maximum of ± 1 mm.

For evaluation, the teeth were numbered 1-32. The maxillary right 3rd molar was designated number 1 with the numbers increasing to the maxillary left 3rd molar which was designated number 16. The mandibular left 3rd molar was designated number 17 and the numbers continue to increase to number 32 at the mandibular right 3rd molar.

After the chartings were completed the information for each individual tooth was recorded on computer punch cards.

These cards were utilized by the computer to provide frequency of each measurement at each particular point for each tooth of group 0 and for group 9. (eg., the distal buccal point of number 30, group 0 had values from 0-9 mm and a value of 3 mm was recorded six times). After this, the computer provided the frequency of a certain value for each location for example, the mid buccal landmark, for all the teeth of each group, again separating group 0 and group 9. From this information it was hoped a general indication of the alveolar bone status could be obtained. See Figures 17, 18 and 19 for the probe, locations and the charts.

Figure 17

Photograph of the Hu Freedy Periodontal Probe (1) located at the mesio buccal point of tooth Number 30.

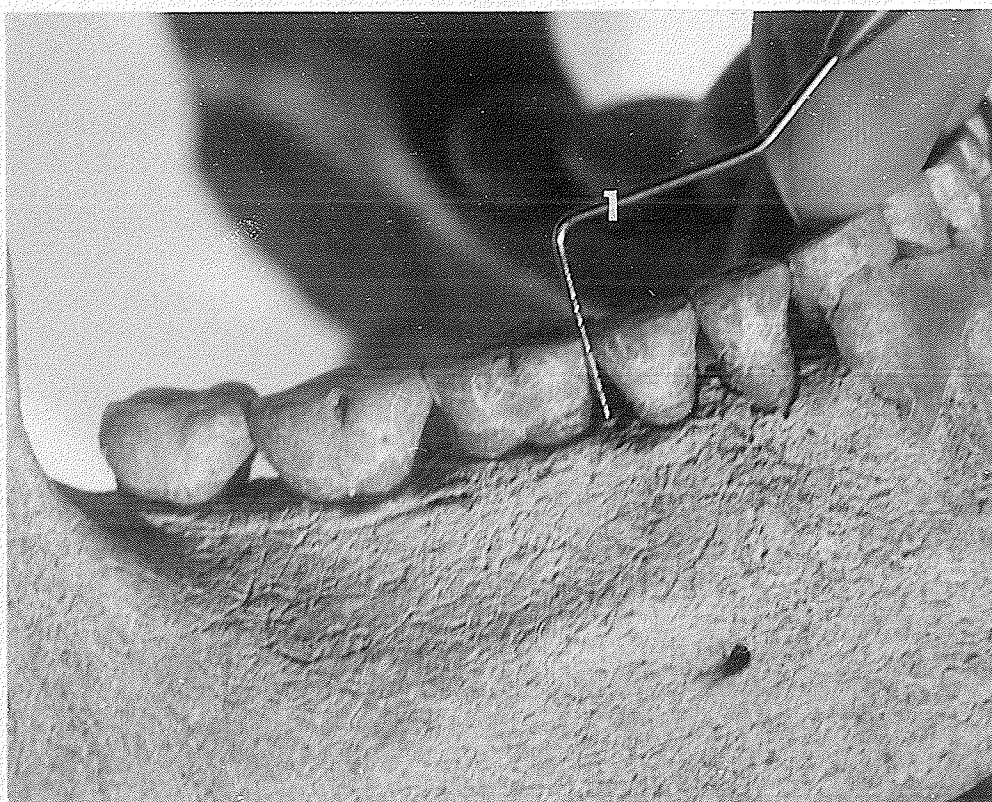

1

Figure 18

This composite photograph is of the one specimen orientated and photographed about the central (occlusal) view. This is to illustrate the location and order of recording the lingual and buccal measurements of the bone level in reference to the cemento-enamel junction.

1. Distal Buccal
2. Mid Buccal
3. Mesio Buccal
4. Distal Lingual
5. Mid Lingual
6. Mesio Lingual

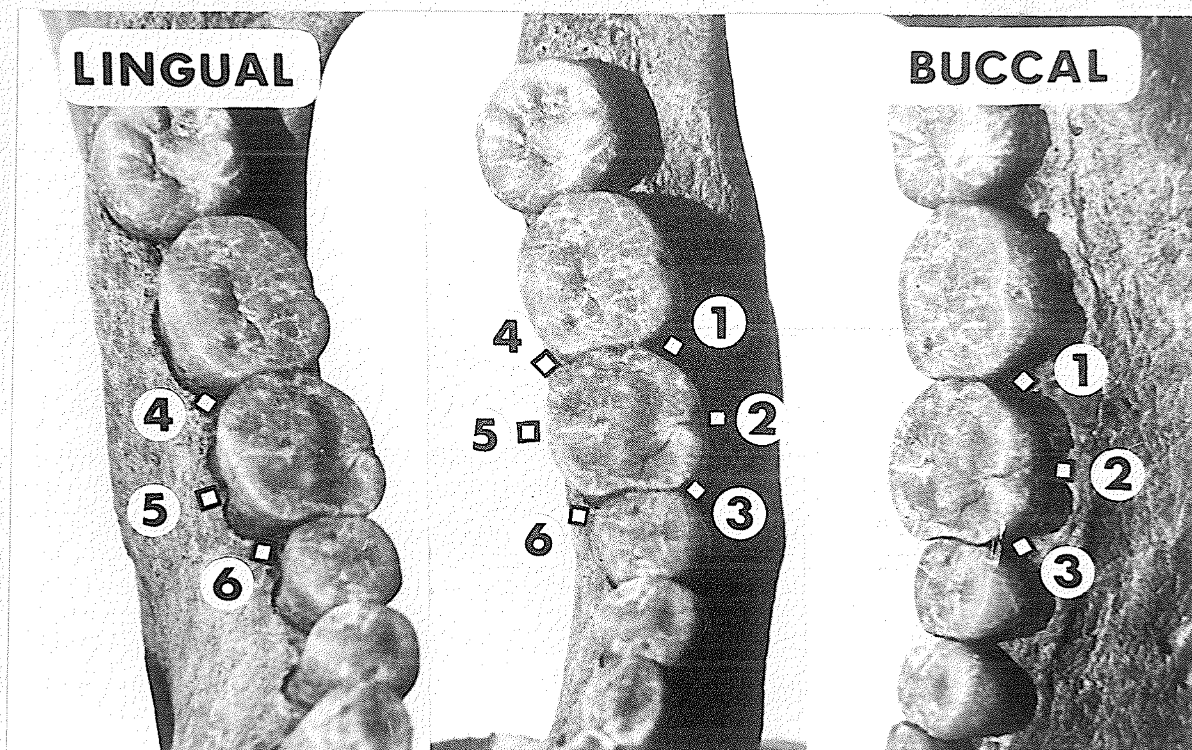
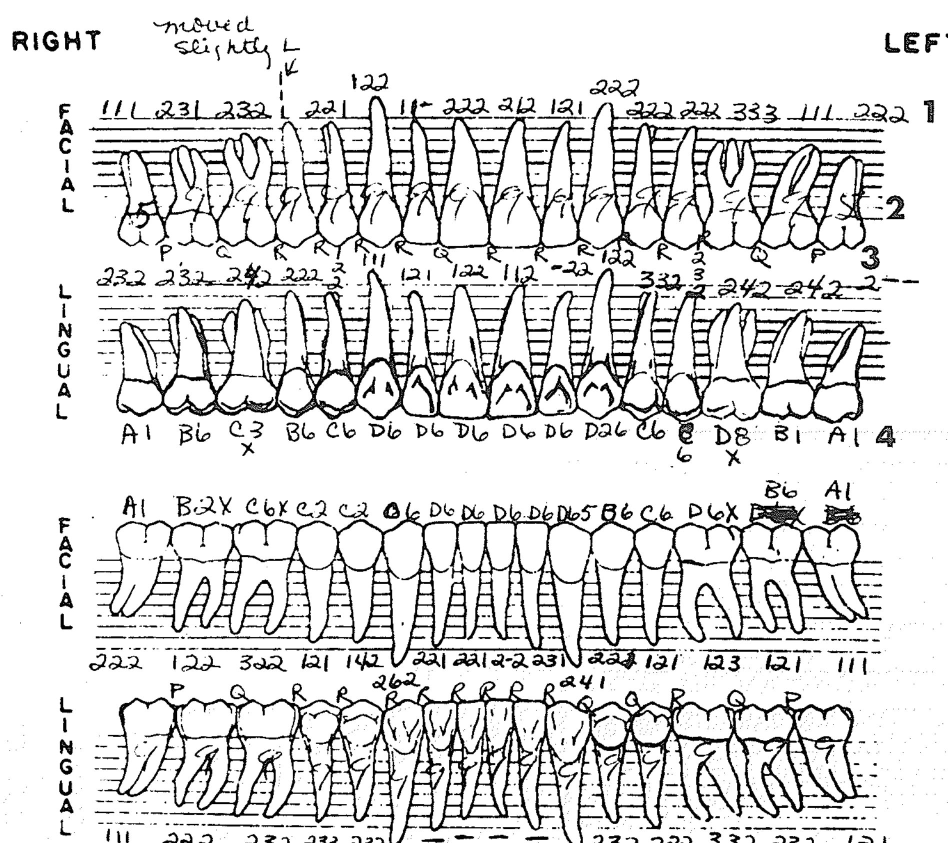

LINGUAL
BUCCAL
1
2
3
4
5
6
1
2
3
4
5
6
1
2
3

Figure 19

Photograph of a clinical charting record illustrating:

1. Bone level measurements
2. Pathology State (5's and 9's)
3. Interproximal wear scales (P,Q,R)
4. Occlusal wear scales (Eg. A1)


RIGHT
LEFT
moved slightly L
FACIAL
LINGUAL
FACIAL
LINGUAL
1
2
3
4

APPENDIX IV

WEAR OF THE DENTITION

APPENDIX IV

Wear of the Dentition

Attrition of the dentition has been studied for many years. The evaluation of it, however, has proven to be subjective and quite lacking in precise definition until quite recently. As far back as 1929 Leigh described four stages of attrition graded from no dentin exposed and extending to the point where the pulp was exposed with the other intermediate steps designated by varying degrees of dentin exposure. Klatsky in 1939 repeated these stages as did Davies and P. Penderson in 1955, and Begg in 1954. In 1959 Murphy described a more detailed evaluation of molar attrition graded according to dentin patches and extending to the manner of joining of the dentin patches.

In 1971 Molnar provided an in depth method for describing attrition. In it the three-dimensional aspect of attrition was contained. For the first time attrition was described in a manner in which the description made obvious that the tooth was not just sawed down. For these reasons the scale used to describe occlusal attrition was adapted from Molnar. His exact scale was not utilized in that it did not apply equally well to the posterior and anterior teeth as well as the fact that the classifications of the second scale did not necessarily exclude each other. For these reasons scale one has fewer stages (five instead of eight) and in the results, two digits are allowed for the second scale records. The second scale is, however, taken directly from Molnar's work. The last scale for occlusal attrition has also been reduced. Stages which were felt to be duplications of scale two were eliminated (for example natural form is stage one for scale two and scale four for Molnar).

In addition to the occlusal values, interproximal wear scores were given extending from pinpoint contacts to broad contacts. This scale was P,Q,R, but due to the lack of contact of numerous anterior teeth after extreme attrition a value of 0 was added.

This methodology was applied to both the anterior and posterior teeth alike. Obviously, this is subjective procedure and as a result, vulnerable to human interpretation and error. For this study one examiner was used and a method sample was performed to evaluate the reproducibility of the application of the scale. This method sample consisted of two mandibles and one crania each examined five times. The initial examination was performed on each at the beginning of the work. Three examinations were conducted during the course of the work and the final examination was performed at the conclusion of the examinations of the entire group. By spreading these test samples out in this manner it was felt a more accurate check could be established for the consistency of the method.

The first digit of the four-digit scale for the occlusal wear is as follows:

A. No dentin exposed

B. Cusps still remained but dentin was exposed

C. Cusps were absent, dentin exposed with flat occlusal surface

D. Excessive dentin was exposed presenting with loss of enamel rim at some aspect

E. Roots only remained

The second and third digits of the four-digit scale for the occlusal wear are as follows:

1. Natural form
2. The buccal aspect of the tooth is higher
3. The lingual aspect of the tooth is higher
4. The mesial aspect of the tooth is higher
5. The distal aspect of the tooth is higher
6. The tooth is flat
7. The tooth is rounded buccal lingually
8. The tooth is rounded mesial distally

The fourth place in the four-digit scale for occlusal wear is as follows:

X (1) Cupped a little

Y (2) Deeply cupped

Z (3) Notched

The interproximal attrition value occupied two spaces on the punch card. The first space listed the distal contact while the second gave the mesial contact description. Both the mesial and distal areas ranged from 0 to 3.

O (0) No contact

P (1) A pinpoint contact

Q (2) A broad contact point

R (3) A contact point extending from buccal to lingual

TABLES

Table 1

The mean angle values recorded for the mandibles of the population together with their standard deviations.

SMITH - MANDIBLE (FACTOR ANALYSIS)

N = 59 M = 34

MEANS AND STANDARD DEVIATIONS

VARIABLE	MEAN	STANDARD DEVIATION
1	18.47240	4.31120
2	18.40886	4.80441
3	139.78667	7.27678
4	140.00880	6.83472
5	101.40137	9.27243
6	138.49530	6.90694
7	67.18459	4.96958
8	72.65715	8.07059
9	73.06454	3.88673
10	53.76837	3.50524
11	61.91730	3.23828
12	43.54910	3.69267
13	86.85468	5.05145
14	63.81102	4.06390
15	70.17583	3.54377
16	49.78101	3.81483
17	111.72481	5.04572
18	35.73892	5.29930
19	87.07021	6.90066
20	76.06522	4.08862
21	51.03365	5.45484
22	113.83795	5.34756
23	39.12595	5.33652
24	90.12868	6.10049
25	75.08055	4.23406
26	51.34698	4.45601
27	27.91026	4.91586
28	25.58031	4.22278
29	45.26720	6.33013
30	43.11542	6.27769
31	140.18459	11.98494
32	92.32681	7.75765
33	131.54285	10.83070
34	92.13577	7.79505

Table 2

The mean angle values recorded for the craniae of the population together with their standard deviations.

SMITH - CRANIA (FACTOR ANALYSIS)

N = 28 M = 27

MEANS AND STANDARD DEVIATIONS

VARIABLE	MEAN	STANDARD DEVIATION
1	17.00267	3.61069
2	16.68449	3.47590
3	135.93198	6.29475
4	136.90053	6.53098
5	95.72382	7.33860
6	129.24408	7.77269
7	57.65115	2.89644
8	22.48282	2.16099
9	51.60638	5.58813
10	39.62909	4.28823
11	92.70442	4.28975
12	93.01369	2.81190
13	119.34164	4.40588
14	137.03545	4.67290
15	91.75162	2.60247
16	118.92355	3.17685
17	137.46040	4.21468
18	42.86896	2.52217
19	24.30214	1.01161
20	153.02283	7.95726
21	26.04312	1.49757
22	23.67987	1.21095
23	77.96147	6.62828
24	12.34985	0.67269
25	12.61660	0.86796
26	11.31629	0.75532
27	13.35420	0.95281

Table 3

Correlation data of the angles of the mandibles.

SIMPLE CORRELATION COEFFICIENTS

VARIABLE	1 12 23 34	2 13 24	3 14 25	4 15 26	5 16 27	6 17 28	7 18 29	8 19 30	9 20 31	10 21 32	11 22 33
1	1.000										
2	0.603	1.000									
3	-0.855	-0.441	1.000								
4	-0.529	-0.841	0.545	1.000							
5	-0.630	-0.626	0.385	0.403	1.000						
6	0.123	0.264	-0.255	-0.380	0.540	1.000					
7	-0.298	-0.248	0.273	0.231	0.558	0.434	1.000				
8	0.514	0.534	-0.433	-0.452	-0.330	0.231	0.496	1.000			
9	0.217	0.139	-0.068	-0.139	-0.207	0.008	0.120	0.319	1.000		
10	0.282	0.232	0.005	-0.013	-0.407	-0.133	0.142	0.379	0.644	1.000	
11	-0.019	0.283	0.394	0.036	-0.401	-0.292	0.094	0.255	0.291	0.803	1.000
12	0.157	0.438	0.227	-0.193	-0.567	-0.302	0.068	0.447	0.498	0.843	0.880
	1.000										
13	0.071	-0.057	-0.042	-0.034	0.034	0.099	-0.118	-0.113	0.859	0.403	0.083
	0.185	1.000									
14	0.153	0.039	0.076	0.100	-0.212	-0.031	-0.003	-0.003	0.646	0.889	0.574
	0.533	0.631	1.000								
15	-0.105	0.089	0.357	0.146	-0.181	-0.133	-0.123	-0.164	0.308	0.714	0.882
	0.657	0.365	0.768	1.000							
16	0.095	0.328	0.242	-0.097	-0.464	-0.210	-0.081	0.179	0.561	0.856	0.874
	0.942	0.415	0.731	0.819	1.000						
17	0.211	0.534	-0.050	-0.479	-0.522	-0.123	-0.104	0.341	0.108	0.324	0.337
	0.532	-0.075	0.144	0.110	0.409	1.000					
18	0.112	0.331	-0.079	-0.242	-0.275	-0.045	0.257	0.459	-0.098	0.296	0.398
	0.462	-0.366	0.012	0.126	0.277	0.692	1.000				
19	-0.324	0.147	0.254	-0.191	-0.069	0.063	0.034	0.005	-0.038	0.184	0.236
	0.300	-0.071	0.193	0.175	0.272	0.699	0.604	1.000			
20	-0.030	0.318	0.160	-0.377	-0.218	-0.009	-0.229	-0.010	0.360	0.166	0.022
	0.237	0.372	0.229	0.038	0.293	0.323	-0.459	0.046	1.000		
21	-0.572	-0.133	0.454	-0.008	0.215	0.070	-0.150	-0.364	0.094	0.032	-0.002
	0.026	0.228	0.237	0.155	0.154	0.195	-0.186	0.671	0.492	1.000	
22	0.291	0.436	-0.152	-0.363	-0.559	-0.210	0.040	0.442	0.198	0.312	0.230
	0.375	-0.028	0.179	0.066	0.269	0.863	0.626	0.547	0.184	0.095	1.000
23	0.001	0.101	0.048	-0.086	-0.205	-0.244	0.248	0.320	-0.156	0.140	0.295
	0.278	-0.371	-0.006	0.093	0.138	0.621	0.843	0.670	-0.429	-0.206	0.658
	1.000										
24	-0.076	0.270	0.016	-0.395	-0.324	-0.168	0.004	0.124	-0.197	0.019	0.162
	0.268	-0.361	-0.067	0.006	0.155	0.758	0.671	0.786	-0.036	0.399	0.684
	0.742	1.000									
25	0.263	0.322	-0.128	-0.234	-0.397	-0.069	-0.337	0.036	0.397	0.229	-0.058
	0.139	0.433	0.333	0.045	0.242	0.256	-0.396	0.056	0.740	0.469	0.424
	-0.403	-0.048	1.000								
26	-0.181	0.104	0.099	-0.237	-0.071	-0.110	-0.383	-0.344	-0.088	-0.210	-0.225
	-0.041	0.006	-0.093	-0.207	-0.027	0.352	-0.147	0.533	0.511	0.791	0.176
	-0.199	0.509	0.522	1.000							
27	-0.095	-0.293	0.016	0.075	0.368	0.177	0.074	-0.105	-0.349	-0.500	-0.512
	-0.531	-0.244	-0.513	-0.535	-0.598	-0.263	-0.197	-0.329	-0.116	-0.262	-0.517
	-0.425	-0.542	-0.165	-0.142	1.000						
28	-0.115	-0.166	-0.305	0.038	0.206	-0.009	-0.248	-0.282	-0.426	-0.527	-0.537
	-0.599	-0.272	-0.437	-0.434	-0.586	-0.616	-0.416	-0.526	-0.253	-0.315	-0.620
	-0.376	-0.483	-0.384	-0.297	0.613	1.000					
29	-0.177	-0.414	-0.029	0.193	0.673	0.481	0.148	-0.325	-0.361	-0.637	-0.578
	-0.720	-0.680	-0.454	-0.401	-0.645	-0.679	-0.503	-0.433	-0.185	-0.067	-0.791
	-0.610	-0.644	-0.248	-0.253	0.774	0.681	1.000				
30	-0.207	-0.366	-0.006	0.277	0.344	0.050	-0.243	-0.432	-0.311	-0.460	-0.487
	-0.516	-0.431	-0.232	-0.257	-0.499	-0.831	-0.647	-0.581	-0.174	-0.095	-0.743
	[illegible]	-0.667	-0.221	-0.306	0.297	0.833	0.711	1.000			

Table 4

Correlation data of the angles of the craniae.

MPLE CORRELATION COEFFICIENTS

RIABLE	1 12 23	2 13 24	3 14 25	4 15 26	5 16 27	6 17	7 18	8 19	9 20	10 21	11 22
1	1.000										
2	0.778	1.000									
3	-0.782	-0.440	1.000								
4	-0.655	-0.827	0.540	1.000							
5	-0.421	-0.356	0.186	0.277	1.000						
6	0.440	0.476	-0.381	-0.416	0.606	1.000					
7	-0.463	-0.245	0.270	0.491	0.363	-0.111	1.000				
8	-0.013	0.144	-0.006	0.014	0.145	0.165	0.472	1.000			
9	0.388	0.468	-0.329	-0.394	0.173	0.574	0.351	-0.077	1.000		
10	0.321	0.530	-0.260	-0.520	0.383	0.760	0.304	0.026	0.865	1.000	
11	0.020	-0.018	-0.050	-0.020	0.020	-0.025	0.283	0.467	0.217	0.136	1.000
12	0.298	0.330	-0.281	-0.477	0.127	0.347	-0.545	-0.009	0.556	0.520	0.227
	1.000										
13	-0.325	-0.334	0.281	0.288	-0.105	-0.402	0.191	-0.101	-0.088	-0.211	-0.089
	0.002	1.000									
14	-0.097	-0.071	0.192	0.173	-0.255	-0.287	0.023	-0.357	0.027	-0.122	-0.209
	-0.123	0.868	1.000								
15	0.240	0.164	-0.224	-0.353	0.199	0.329	-0.514	-0.323	0.589	0.558	0.276
	0.893	0.074	-0.071	1.000							
16	-0.124	-0.361	0.079	0.343	0.549	0.231	0.094	-0.259	0.062	0.047	-0.150
	0.101	0.777	0.680	0.282	1.000						
17	-0.047	-0.042	0.218	0.034	-0.206	-0.224	-0.296	-0.458	0.109	-0.069	-0.000
	0.165	0.851	0.952	0.177	0.735	1.000					
18	0.174	0.206	-0.161	-0.185	0.182	0.355	0.232	0.425	-0.015	0.051	0.660
	-0.072	-0.217	-0.208	-0.082	0.147	-0.103	1.000				
19	-0.123	0.090	-0.123	-0.341	0.375	0.394	-0.204	-0.186	0.502	0.649	0.056
	0.637	-0.171	-0.037	0.492	0.045	0.126	-0.145	1.000			
20	-0.169	-0.050	0.158	0.043	0.356	0.264	0.496	-0.012	0.622	0.637	0.197
	0.451	0.296	0.135	0.552	0.479	0.186	-0.273	0.271	1.000		
21	-0.249	-0.231	0.043	0.058	0.666	0.400	0.505	0.093	0.348	0.526	-0.025
	0.280	0.027	-0.099	0.342	0.566	-0.027	0.144	0.542	0.520	1.000	
22	-0.063	0.145	-0.080	-0.351	0.398	0.459	-0.398	-0.265	0.354	0.529	-0.295
	0.261	-0.274	-0.091	0.157	-0.196	-0.028	-0.077	0.846	0.198	0.360	1.000
23	0.456	0.477	-0.022	-0.122	-0.160	0.287	0.376	0.223	0.184	0.224	-0.242
	-0.035	0.074	0.246	-0.048	0.206	0.272	0.077	-0.392	0.213	0.048	-0.249
	1.000										
24	-0.188	0.048	0.140	-0.230	0.376	0.361	-0.381	-0.206	0.141	0.339	-0.107
	0.070	-0.293	-0.109	-0.058	-0.226	0.053	-0.032	0.616	-0.019	0.102	0.813
	-0.306	1.000									
25	-0.431	-0.350	0.341	0.158	0.605	0.205	0.108	-0.040	0.163	0.420	0.386
	0.229	0.044	-0.033	0.317	0.489	0.140	0.047	0.504	0.542	0.849	0.303
	-0.015	0.259	1.000								
26	0.063	0.203	-0.263	-0.389	0.304	0.429	-0.357	-0.240	0.437	0.600	-0.428
	0.332	-0.137	-0.041	0.282	-0.092	-0.080	-0.101	0.738	0.338	0.406	0.853
	-0.127	0.388	0.184	1.000							
27	0.015	-0.070	-0.245	-0.012	0.593	0.537	0.439	0.191	0.410	0.468	-0.297
	0.230	0.082	-0.035	0.216	0.556	-0.029	0.301	0.374	0.297	0.856	0.282
	0.046	0.026	0.453	0.385	1.000						

Table 5

Data relating to method study of mandibles

) SUBJECTS

4 POINTS

ORIGINAL XY	9.66	0.33	9.66	1.76	8.39	2.06	7.86	2.89	4.98	6.60	5.89	7.05
	4.14	9.04	5.97	9.38	12.82	9.77	14.85	9.40	13.33	7.46	14.24	6.21
	11.41	3.02	10.84	2.15								
ANSFORMED XY	0.0	0.0	1.43	0.0	1.73	1.27	2.56	1.80	6.27	4.68	6.72	3.77
	8.71	5.52	9.05	3.69	9.44	-3.16	9.07	-5.19	7.13	-3.67	5.88	-4.58
	2.69	-1.75	1.82	-1.18								
ORIGINAL XY	9.66	0.34	9.61	1.73	8.34	2.04	7.82	2.87	4.97	6.61	5.90	7.04
	4.15	9.04	6.13	9.36	13.01	9.76	15.02	9.38	13.46	7.43	14.39	6.15
	11.57	2.98	11.00	2.11								
ANSFORMED XY	0.0	0.0	1.39	0.0	1.75	1.26	2.59	1.75	6.43	4.46	6.63	3.52
	8.89	5.19	9.14	3.20	9.29	-3.69	8.84	-5.68	6.95	-4.05	5.64	-4.94
	2.57	-2.00	1.72	-1.40								
ORIGINAL XY	9.69	0.33	9.61	1.73	8.32	2.03	7.77	2.85	4.90	6.57	5.89	7.01
	4.05	8.98	5.96	9.32	12.78	9.78	14.80	9.41	13.30	7.47	14.22	6.11
	11.49	3.00	10.84	2.04								
ANSFORMED XY	0.0	0.0	1.40	0.0	1.78	1.27	2.63	1.77	6.50	4.43	6.89	3.41
	8.96	5.14	9.19	3.21	9.26	-3.62	8.77	-5.62	6.92	-4.01	5.51	-4.85
	2.56	-1.95	1.64	-1.25								

MITH CEPH ANALYSIS VIEW 11 METHOD

DINATES

	NO. OF.	MEANS		STDRD DEV.	
OINT	SAMPLES	X	Y	X	Y
1	3	0.0	0.0	0.0	0.0
2	3	1.408	0.0	0.020	0.0
3	3	1.751	1.266	0.023	0.007
4	3	2.593	1.774	0.033	0.026
5	3	6.403	4.523	0.120	0.137
6	3	6.812	3.566	0.085	0.184
7	3	8.853	5.284	0.129	0.207
8	3	9.126	3.368	0.071	0.279
9	3	9.331	-3.490	0.098	0.288
10	3	8.895	-5.497	0.156	0.268
11	3	7.000	-3.911	0.113	0.210
12	3	5.676	-4.789	0.187	0.186
13	3	2.608	-1.901	0.071	0.134
14	3	1.727	-1.276	0.089	0.114

ES	13- 2-14- 2	3- 2- 4- 2	2-14-13-14	4- 3- 2- 3	4- 2-13- 2	3- 2-14- 2	4- 1-13- 1	3- 1-14- 1	5- 1-12- 1
LE 1	17.465	18.829	141.521	135.851	112.126	148.420	68.158	69.240	74.654
LE 2	17.238	18.775	138.522	135.785	114.980	150.993	71.913	74.956	75.946
LE 3	19.894	18.237	138.247	136.943	114.631	152.762	71.290	72.786	75.598
ER OF SAMPLES	3	3	3	3	3	3	3	3	3
S	18.199	18.613	139.430	136.193	113.912	150.725	70.454	72.327	75.399
DARD DEVIATIONS	1.473	0.327	1.824	0.676	1.559	2.194	2.011	2.885	0.667
THE MEANS	18.193	18.610	139.439	136.201	113.982	150.785	70.463	72.335	75.393

ES	6- 1-11- 1	7- 1-10- 1	8- 1- 9- 1	5- 2-12- 2	6- 2-11- 2	7- 2-10- 2	8- 2- 9- 2
LE 1	56.529	62.144	40.690	89.862	68.252	71.360	47.368
LE 2	57.491	63.012	40.950	90.797	68.978	72.024	47.466
LE 3	56.455	62.475	40.641	90.686	67.902	71.535	47.177
ER OF SAMPLES	3	3	3	3	3	3	3
S	56.825	62.544	40.760	90.448	68.377	71.640	47.337
DARD DEVIATIONS	0.576	0.438	0.165	0.523	0.545	0.345	0.140
THE MEANS	56.827	62.544	40.766	90.451	68.388	71.646	47.349

Table 6

Data relating to method study of craniae

3 SUBJECTS

5 POINTS

ORIGINAL XY	[illegible]	1.54	13.15	17.08	13.20	18.67	14.88	17.25	15.43	16.21	14.37	14.43
	18.92	12.76	15.76	11.37	14.72	8.84	13.40	6.53	12.20	8.36	10.57	11.21
	7.20	12.47	11.81	14.25	11.29	15.99	11.56	17.11				
INSFORMED XY	0.0	0.0	15.54	0.0	16.53	-0.04	15.73	-1.73	14.69	-2.29	12.90	-1.24
	11.27	-5.81	9.85	-2.66	7.31	-1.64	4.99	-0.34	6.81	0.88	9.65	2.53
	10.88	5.91	12.70	1.32	14.44	1.85	15.56	1.59				
ORIGINAL XY	13.56	1.57	13.67	17.08	13.69	18.10	15.35	17.24	15.95	16.22	14.91	14.41
	19.45	12.70	16.27	11.43	15.26	8.80	13.95	6.49	12.75	8.35	11.11	11.21
	7.73	12.52	12.42	14.23	11.68	15.99	11.98	17.12				
INSFORMED XY	0.0	0.0	15.51	0.0	16.53	-0.01	15.68	-1.68	14.67	-2.29	12.85	-1.26
	11.17	-5.81	9.88	-2.64	7.24	-1.65	4.92	-0.36	6.77	0.86	9.62	2.52
	10.91	5.91	12.65	1.23	14.41	1.98	15.54	1.69				
ORIGINAL XY	13.43	1.61	13.47	17.09	13.55	18.16	15.20	17.24	15.81	16.25	14.76	14.41
	19.30	12.77	16.11	11.49	15.10	8.81	13.78	6.51	12.58	8.32	10.90	11.24
	7.56	12.44	12.21	14.24	11.64	16.01	11.91	17.16				
INSFORMED XY	0.0	0.0	15.48	-0.00	16.55	-0.08	15.63	-1.73	14.65	-2.34	12.80	-1.30
	11.18	-5.84	9.89	-2.65	7.20	-1.65	4.90	-0.34	6.71	0.87	9.62	2.55
	10.81	5.90	12.63	1.25	14.40	1.83	15.55	1.56				

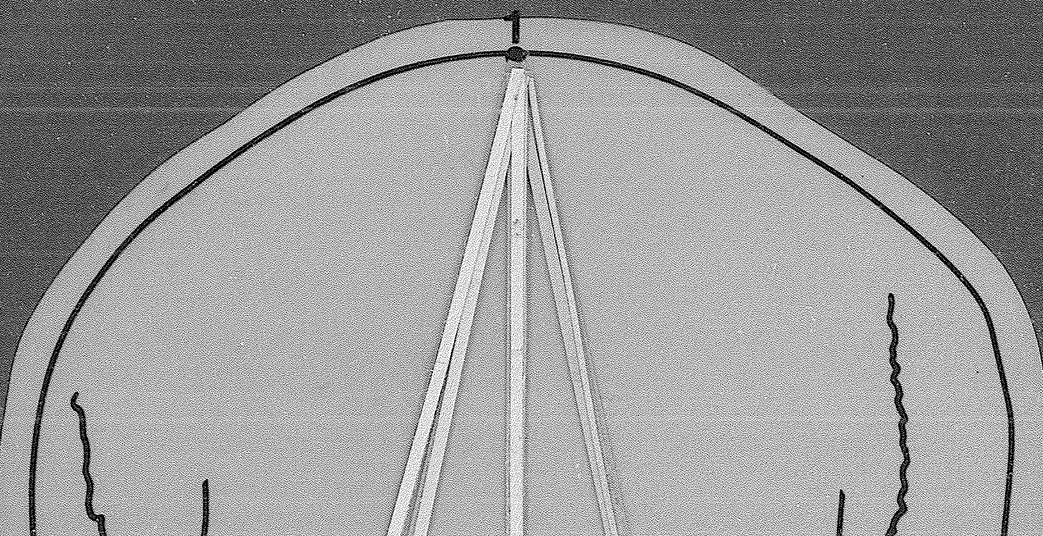
ITH CEPH ANALYSIS VIEW 21 METHOD

INATES

INT	NO. OF. SAMPLES	MEANS X	MEANS Y	STDRD DEV. X	STDRD DEV. Y
1	3	0.0	0.0	0.0	0.0
2	3	15.510	-0.000	0.031	0.000
3	3	16.537	-0.044	0.0	0.032
4	3	15.681	-1.712	0.047	0.029
5	3	14.667	-2.305	0.025	0.032
6	3	12.851	-1.266	0.049	0.028
7	3	11.205	-5.819	0.056	0.020
8	3	9.873	-2.651	0.019	0.010
9	3	7.253	-1.646	0.057	0.007
0	3	4.939	-0.344	0.048	0.010
1	3	6.765	0.867	0.054	0.010
2	3	9.632	2.535	0.016	0.019
3	3	10.368	5.906	0.048	0.010
4	3	12.659	1.266	0.037	0.045
5	3	14.412	1.887	0.025	0.084
6	3	15.547	1.614	0.016	0.068

S	15- 3-16- 3	4- 3- 5- 3	3-16-15-16	5- 4- 3- 4	5- 3-15- 3	4- 3-16- 3	13- 1- 7- 1	11- 1- 9- 1	6- 2-14- 2
E 1	17.096	13.814	133.897	143.888	92.730	123.641	55.772	19.965	50.058
E 2	16.574	12.369	134.685	147.852	93.855	122.797	55.920	20.044	48.594
E 3	17.010	11.059	134.586	150.783	91.416	119.484	56.202	20.278	49.554
R OF SAMPLES	3	3	3	3	3	3	3	3	3
	16.893	12.414	134.389	147.508	92.667	121.974	55.964	20.096	49.402
ARD DEVIATIONS	0.280	1.378	0.472	3.466	1.222	2.203	0.217	0.162	0.743
HE MEANS	16.893	12.410	134.385	147.510	92.670	121.973	55.964	20.095	49.406

S	6- 3-14- 3	7- 3-13- 3
E 1	37.814	94.104
E 2	36.464	93.734
E 3	36.756	93.172
R OF SAMPLES	3	3
	37.011	93.670
ARD DEVIATIONS	0.711	0.470
HE MEANS	37.010	93.668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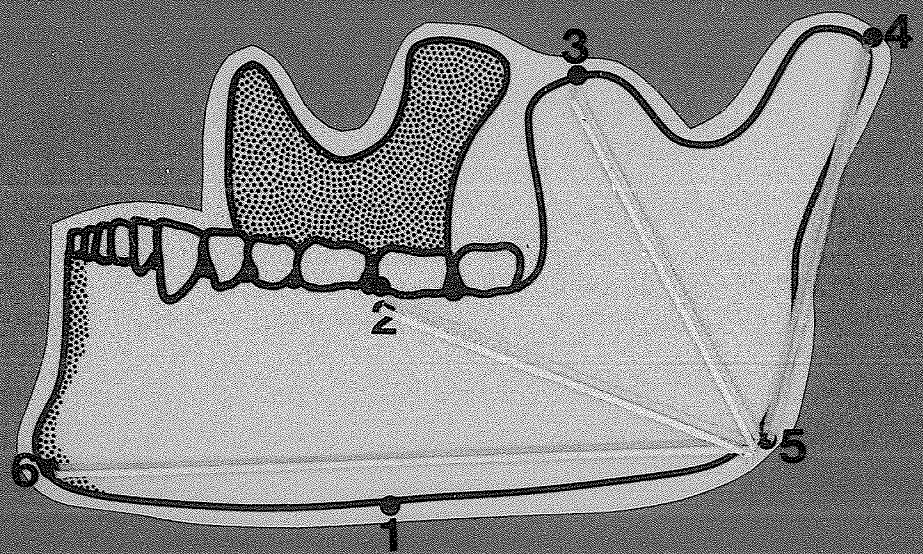
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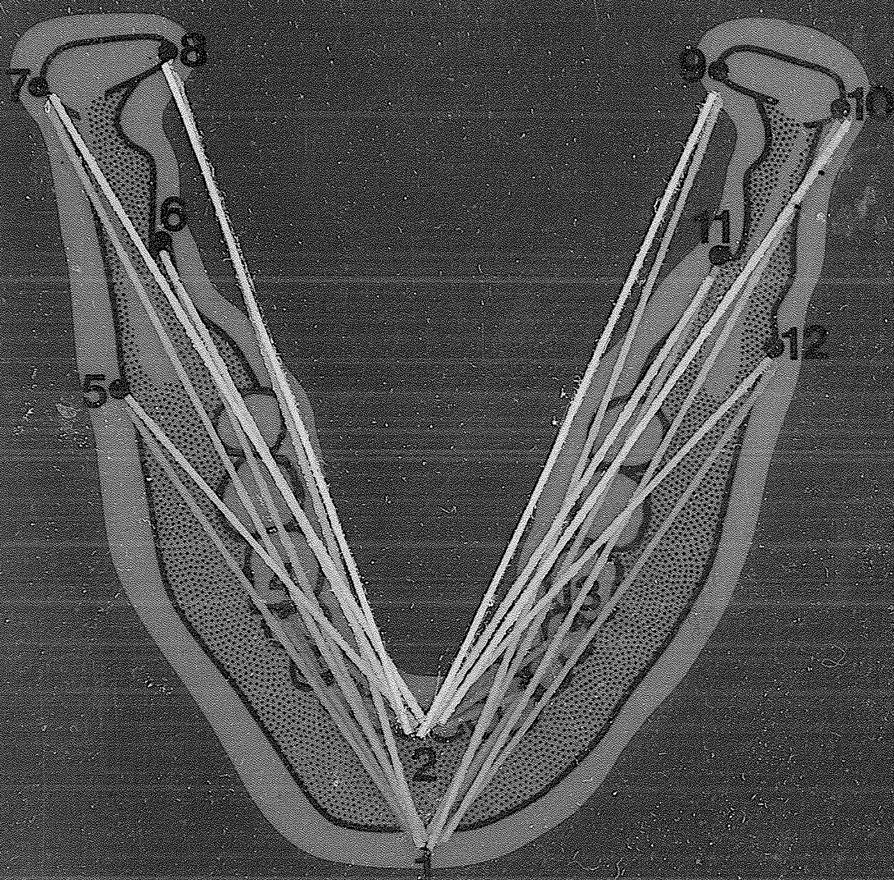

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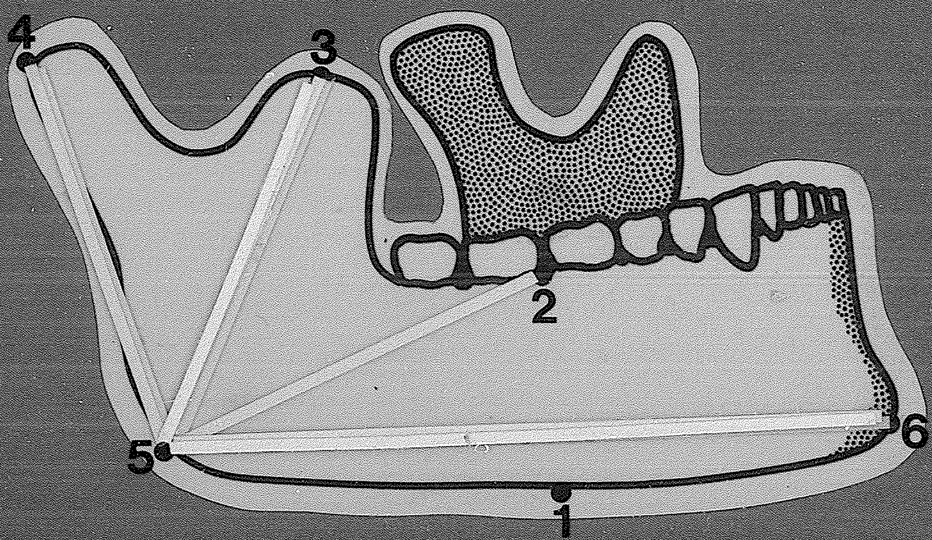
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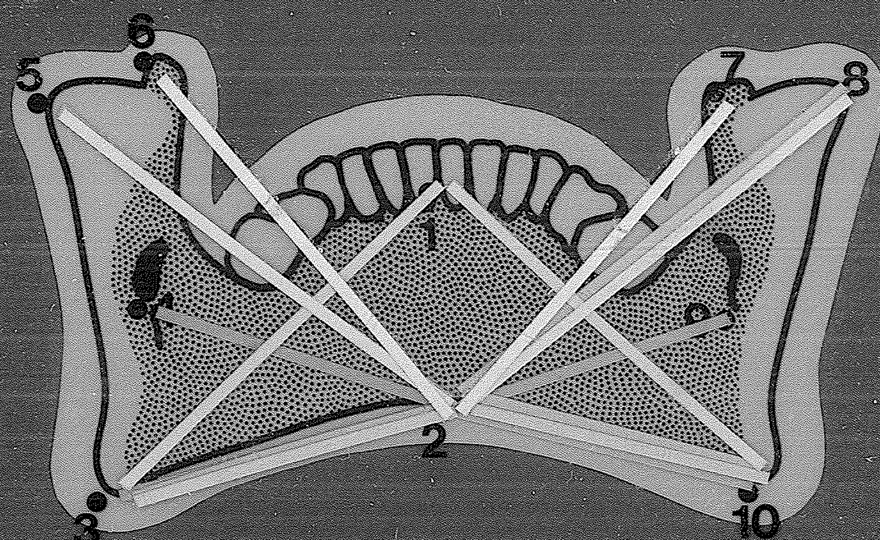
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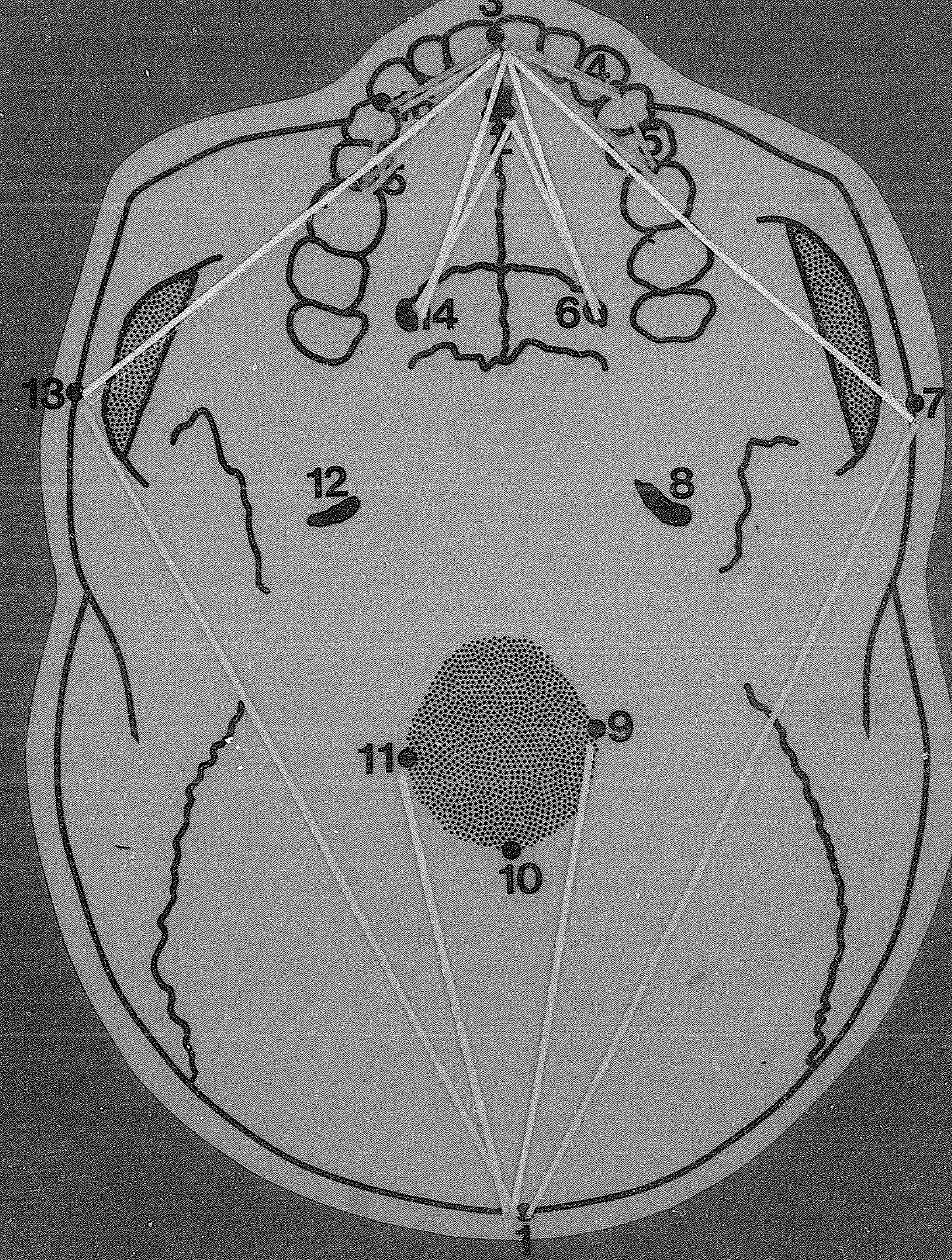
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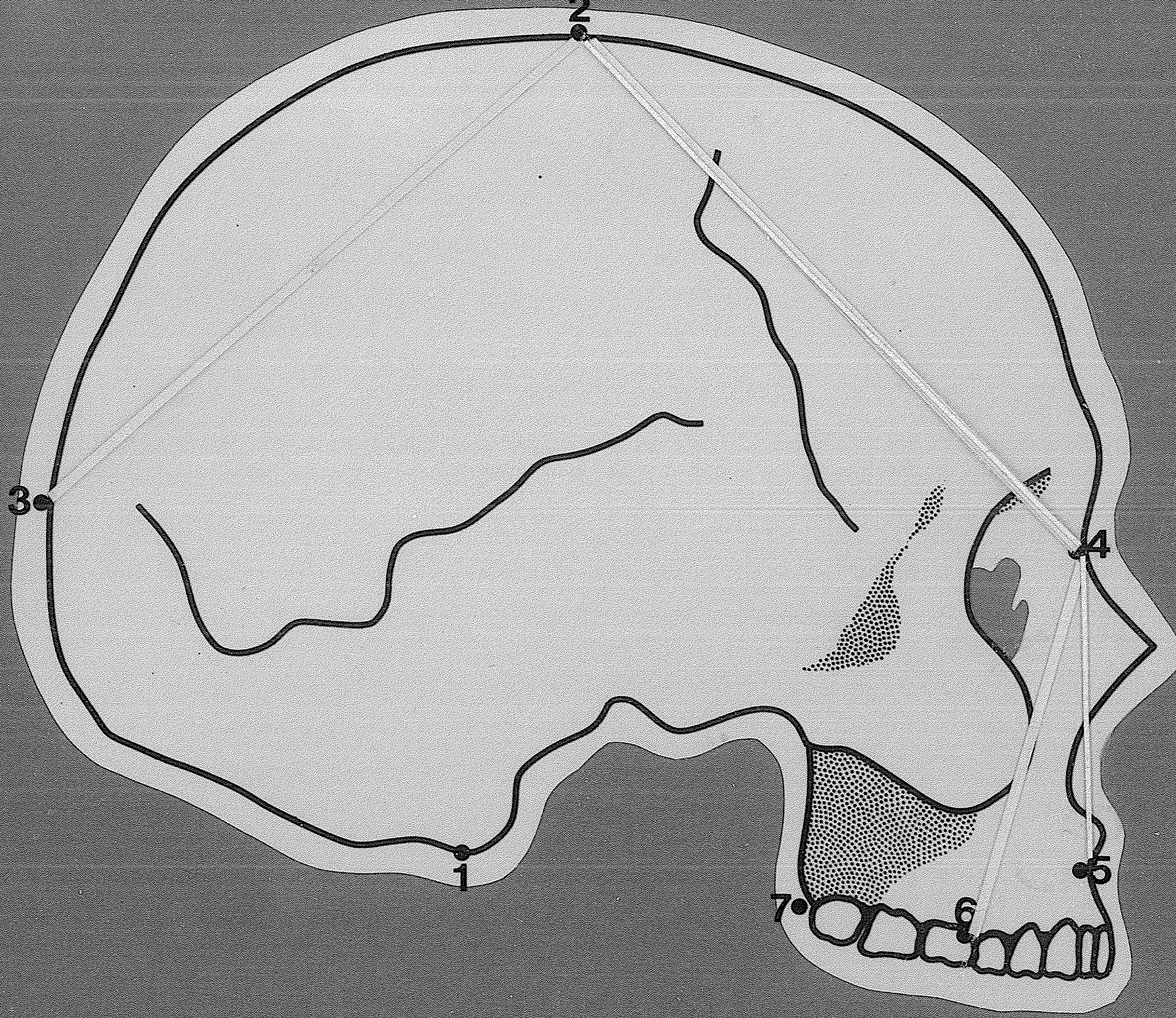

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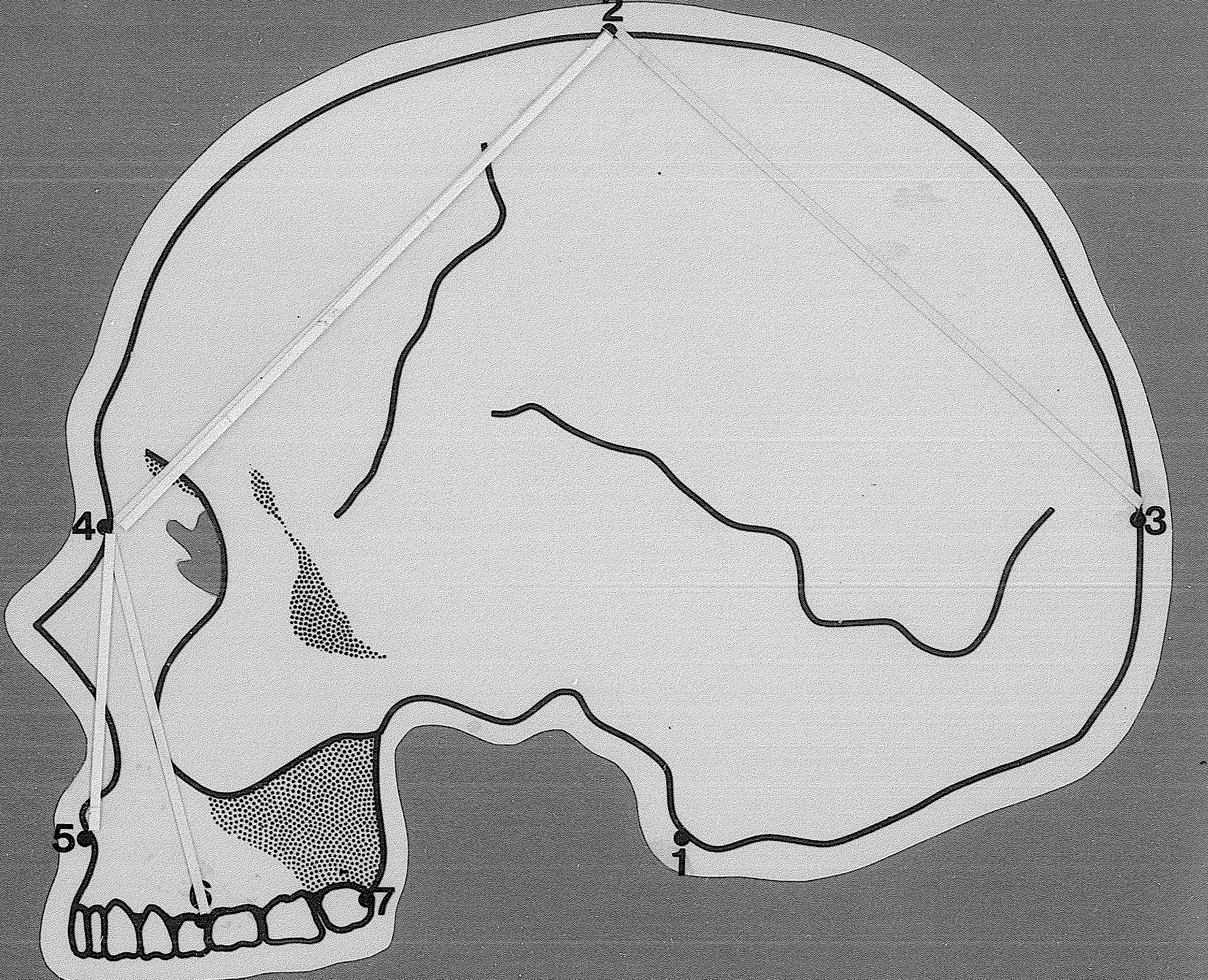
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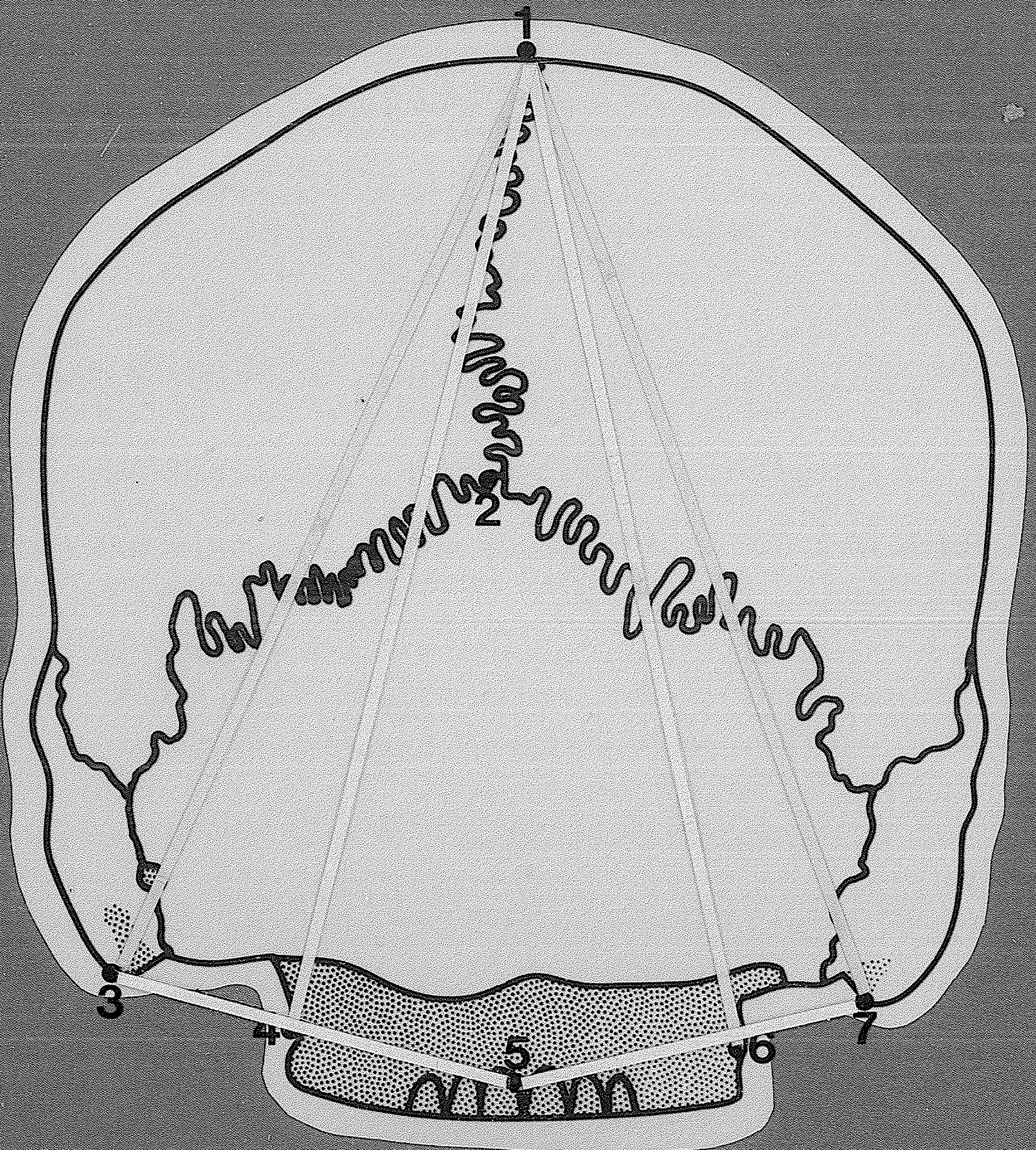

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