

CRANIAL FORM AND DENTAL STATUS OF A  
PREHISTORIC AMERINDIAN POPULATION

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Presented To

The Faculty of Graduate Studies and Research  
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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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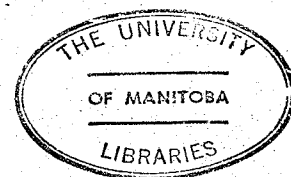
A dissertation submitted to the Faculty of Graduate Studies of  
the University of Manitoba in partial fulfillment of the requirements  
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MASTER OF SCIENCE

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## 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 southeastern 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 Sanguine, 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/Sanguine this triangle was equilateral; the Sanguine 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

distinction 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  $45^\circ$  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 buccally.

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 man, 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 Okay 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.