Epidemiological Studies Of Malalignment, A Method For Computing Dental Arch Circumference*

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This report describes a mathematical method for computing the length of the outer circumference of a given dental arch by means of width and length measurements. This technique is best suited for: (1) population studies contrasting the size and shape of the jaws with the effects of such variables as ancestry, race, nutrition, climate, geographic location, or other environmental factors; (2) malocclusion studies which estimate the space available for teeth and the effects of faulty mouth habits on jaw size.

The primary purpose of this study is to evaluate two methods, mathematical and measured-wire, for determining the length of the outer circumference of the maxillary dental arch. Development of a satisfactory mathematical technique would eliminate the need for plaster casts of dental arches in epidemiological or genetic studies of populations.

MATERIALS AND METHODS

Over five hundred maxillary stone casts, made from alginate impressions, were obtained from the U.S. Naval Academy, Annapolis, Maryland. Three hundred and sixty-two of these were selected with a full complement of permanent dentition, mesial to M_1, for this study. The dental and other physical attributes of this all-male population have been described in a previous publication.[14]

Numerous investigators have described the general outline form of the maxilla as parabolic.[1-7] Other recognized forms, such as square and "V" shape, are present but do not occur too frequently in the general population.[4,5] The approximate formula, $2\sqrt{y^2+\frac{4x^2}{3}}$, for computing the length of an arc of a parabola was chosen to estimate the length of the outer circumference of the study casts. It is practical and easy to manipulate. The mathematical advantages of the parabola are: (1) all are essentially alike, and (2) by a proper choice of scales and axes any parabola can be made to coincide with any other.[8]

A program was designed for a small digital computer to solve this basic formula, where x represents arch length, and y represents arch width. From this program a master chart was produced commencing with an x axis (length) of 25.0 mm, and a y axis (width) of 30.0 mm, graduating to 38.5 mm and 64.0 mm, respectively, in 0.5 mm increments.* The estimated length of the outer circumference is the intersection of x and y.

The approximate sample size necessary to estimate the means, for each method, within a 95 per cent confidence interval was determined. On this random sample of 31 casts double determinations were made. The errors of measurement for each method were calculated at a .5 per cent confidence

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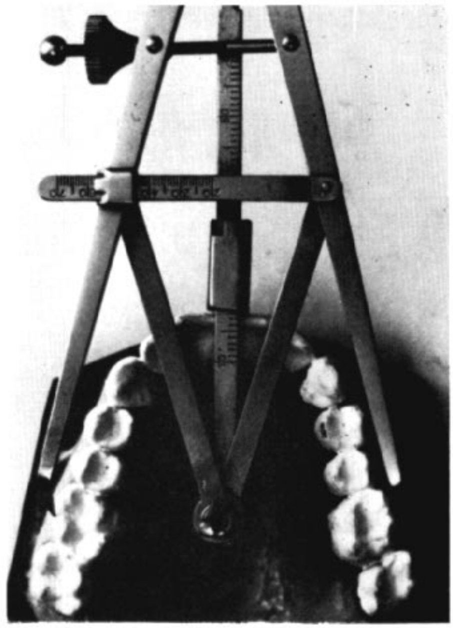
* Raw data may be obtained from the author.

interval as being measured-wire 0.57, mathematical 0.09 mm.

Landmarks for determining arch dimensions differ among investigators depending on the objective of their study.[9] The usual guide-lines for determining the length of the dental arch circumference are the central fossae of molars and the mesial and distal triangular fossae of premolars. The size of the dental arch is expressed in terms of the length of the curve extending from the distal surface of M_1 to the homologous area of its antimere, measured along an imaginary midline passing through the fossae of the row of teeth between these sites.[10] However, the exact location of fossae and proximal surfaces of restored or carious teeth can be deceptive and the axial inclination of the teeth can give a distorted picture of jaw size. The exactitude of the measurements also depends, in part, on the recognizability of the chosen points.[2] The ease to refer back to specific anatomical landmarks emphasizes the need for fixing certain stable sites. Therefore, a mark was inscribed on each cast with a finely tapered 3H pencil at the gingivocervical margin of M_1, at a point bisected by a line formed by the buccal fissure.

A Korkhaus #14 three dimensional orthodontic caliper was used to measure arch width from the pencil inscribed points, across the dental arch to the corresponding landmark on the homologous tooth. Arch length was obtained simultaneously from the midpoint on the axis established at M_1 to the top of the interdental papilla between the central incisors (Figure 1).

Naval Academy I.D. numbers were used for coding the stone casts and examination record cards. Arch length and width were measured and noted on these individually coded record cards. After measuring all of the casts with the caliper (the first method),



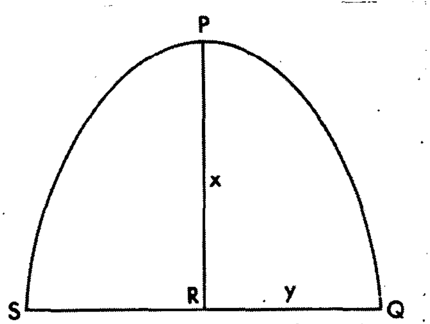


Fig. 1 The length of the arc of a parabola, as arc SPQ, where $x = PR$, and $y = QR$ $2\sqrt{y^2 + \frac{4x^2}{3}}$ (approx.)
y = arch width; x = arch length.

the length of the outer circumference for each arch was ascertained from the master chart and recorded on the individual's card.

The second method (measured-wire) used to determine the length of the outer arch circumference was a modification of the usual method.[9] The use of the buccal fissures as landmarks had

TABLE I

Means and variance for the two methods of estimating the length of the outer circumference of the dental arch.

Measured-Wire Technique (wire)	Mathematical Technique (formula)
$\bar{X} = 92.05$ mm	$\bar{X} = 91.22$ mm
$s^2 = 29.59$	$s^2 = 31.08$
$s = 5.44$	$s = 5.58$
$s_{\bar{X}} = 0.286$	$s_{\bar{X}} = 0.293$

$\bar{x}$ = means, s^2 = variance, s = standard deviation, $\frac{s}{\bar{x}}$ = standard error of means

TABLE II

Frequency of differences between the two methods for determining the length of the outer dental arch circumference.

Within the fixed interval of ±0.52 mm		Greater than the fixed interval of ±0.52 mm	
N	%	N	%
348	96.13	14	3.77

already been mentioned. Several pieces of .010 chrome-steel wire were formed into approximate arch shapes and heat treated at 900° F for 1 minute to prevent kinking. A preformed wire was placed around the circumference of the arch and the fixed sites at M_1 were marked on the wire with a sharp scratch-awl. The wire was straightened and the distance between the two points measured to the nearest 0.1 mm on a Helois millimeter ruler. For an objective evaluation, these measurements were noted on separate coded sheets. After each measuring the scratch marks on the wire were lightly sanded away with emory cloth. The preformed wire was replaced frequently throughout the experiment.

Results

The means and variance for the lengths of the outer circumference were determined for both measuring techniques and are shown in Table I. When the methods were tested as independent observations and the students "t" test applied, no significant difference between the two means could be detected.

Employing the mathematically determined lengths as the subtrahend and the measured-wire lengths as the minuend, a 95 per cent confidence interval for the absolute mean difference was computed. (A difference in length greater than ±0.52 mm would be significant at the 0.5 level of confidence.) The frequency of differences between the two techniques within the range of ±0.52 mm, as well as those exceeding this range, were tabulated and are shown in Table II.

Three hundred and forty-eight of the differences, 96.13%, were well within the 5% interval. Since this is characteristic of a normal distribution, one would then expect 5% of the casts to fall outside this interval. Fourteen, 3.87% of the differences, were greater than these limits. This means the discrepancy on an individual basis was within the confidence interval 24 out of 25 times. These 14 casts were either extremely square or "V" shaped as shown in Figure 2. The mathematical technique underestimated the square shaped arches by 1.20 mm and overestimated the "V" shaped arches by 1.10 mm. Frequency distributions of arch dimensions for the 326 models were plotted and an abbreviated table was prepared from that portion of the sample within ±2 standard deviations. Table III describes 95% of the sample.

Discussion and Summary

The mensuration formula for computing the length of a parabolic arc was utilized to determine dental arch size for 362 maxillary stone casts with a full complement of permanent teeth

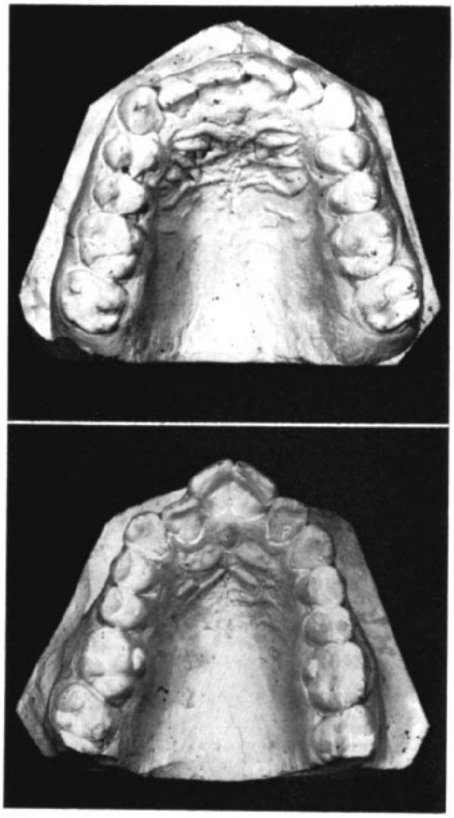


Fig. 2 Above, square-shaped arch underestimated by 1.20 mm by mathematical technique. Below, "V" shaped arch overestimated by 1.10 mm by mathematical technique.

mesial to M_1. The casts were also measured with an .010 orthodontic archwire. Remeasurements of arch size for each technique done on a random sample of 31 casts with a mean not statistically different from the parent groups (within an alpha level of 0.05) resulted in an error term for the measured-wire technique six times greater than the mathematical method. Since there was no difference between the means obtained by either method, it appears evident that the mathematical method is more efficient than the measured-wire technique.

There is a definite need for information on the size and shape of the jaws in different geographic locations and among different social and racial groups, which at present does not exist. Neither are there efficient techniques for measuring dental arch circumference lengths in large populations samples so that arch size can be contrasted with these variables.[11]

Numerous studies have shown a negative correlation between arch size and malalignment of teeth. More teeth become crowded as arch width diminishes.[10-14] As more data are accumulated and baselines become established, regression coefficients can be

TABLE III

Arch Length = x

Arch Width = y	26.00*	28.00	30.00	32.00	34.00	36.00
50.00*	78.06	81.66	85.36	89.14	93.00	96.92
52.00	79.36	82.90	86.54	90.28	94.08	97.96
54.00	80.68	84.18	87.76	91.44	95.20	99.04
56.00	82.04	85.48	89.00	92.64	96.36	100.14
58.00	83.24	86.80	90.28	93.86	97.52	101.28
60.00	84.82	88.14	91.58	95.10	98.74	102.44
62.00	86.24	89.52	92.90	96.38	99.96	103.00
64.00	87.70	90.92	94.24	97.68	101.22	104.82

* millimeters.

For other values use $2\sqrt{y^2 + \frac{4x^2}{3}}$ where x = arch length; y = ½ arch width applied to estimate the crowding of teeth from dental arch dimensions.[14] In order to facilitate the accumulation of this data, modifications are being made on the Korkhaus caliper to adapt this instrument for use directly in the oral cavity. To date one modified prototype has been completed and is being tested.

The development of an efficient technique to determine arch size would be useful in estimating changes in arch form following orthodontic treatment and to evaluate deviations of arch form in specific anomalies of jaw development such as cleft palate. The proposed method may partially fulfill this need.[15]

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