Maxil006Cary Anterior Alveolar Arch (AA) Shape Analysis: A Cone Beam Computed Tomography Study

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Abstarct

Objetivo: The aim of this study is classified the shapes of the alveolar arches in the anterior aesthetic region using cone beam computed tomography images.

Methods: The sample consisted of 40 young adults, the age of the subjects ranged between 23 and 33 years, with a mean of 25.90 years. All subjects performed cone-beam computed tomography (CBCT), evaluating the axial view. Statistical software (SPSS version 20.0; IBM Corp., Armonk, NY, USA) was used to analyze the data for inter-examiner calibration, an intraclass correlation coefficient test was performed with a confidence level of 95%.

Results: The predominant form of the AA arch is the short medium with a percentage of 60% equivalent to 24 subjects in the sample, and with the lowest percentage the form of the AA arch is long narrow arch with a 7 .5% equivalent to 3 of the 40 total subjects of the sample.

Conclusion: The shape of the anterior alveolar arch, using the formula of the fourth-degree polynomial that has been shown to be the most suitable to represent a smooth and natural curve of the arch, can be classified into long narrow, short medium, long medium and long wide arches. Further studies on this are recommended.

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Introduction

With the new era of technology, cone beam computed tomography (CBCT) is gaining great popularity as a promising modality within dental practice as it provides detail through three-dimensional information of the life-size craniofacial complex without distortion or overlapping of the craniofacial anatomical structures (1). This is a highly accurate method that has been used for the evaluation, visualization, quantification, and linear measurement of dental and bone structures with high sensitivity and reliability for orthodontic research (2) compared to physical measurements where general submillimeter inaccuracies have been found (3), with measurements on lateral cephalograms that can be inaccurate up to almost 1 mm from the actual measurement and may be questionable in terms of their diagnostic value (4). Therefore, a 3D evaluation of the shape of the anterior alveolar arch (AA) better illustrates its real morphology, becoming the preferred measurement technique for specialists in the area (1).

The transverse dimensions of dental arches have significant effects on orthodontic diagnosis and treatment planning. These have an influence on the amount of space available for dental alignment, the stability of the dental movements produced and the final aesthetic result. (5) Therefore, making an accurate diagnosis of the shape of the alveolar arch is essential.

The shapes of the alveolar arches differ from person to person and their complexity has made them the subject of several morphological studies, so different researchers are investigating various elements that influence the shape of the alveolar arch since these factors, It is expected that they may allow proposing new treatments for their identification and orthodontic treatment. (6)

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The shape of the alveolar arch influences function, esthetics, and as well as occlusion. It is initially formed by the configuration of the supporting bone. After tooth eruption, it is further modified by musculature and functional forces. Furthermore, the shape of the alveolar arch tends to differ among various age and ethnic groups. (7.8)

Conventionally, orthodontists determine the alveolar arch shape of their patients visually or by measuring intercanine and molar distances. However, this is associated with errors and biases when reproducing evaluations already carried out by the same professional at different times or by another orthodontist. (9)

For years, researchers have been trying to define the shape of the "ideal" alveolar arch. It is a common assumption that the alveolar arch is symmetrical in nature and can be represented by an algebraic or geometric formula. (10)

Although other authors have described the classification of the alveolar arch shape as geometric figures such as ellipse, parabola and hyperbola, classifications have also been made using mathematical equations such as polynomial equations, cubic spline function, Euclidean distances or Fourier series. (11) Within which polynomial equations have been used extensively to determine the shape of the alveolar arch, particularly the fourth degree equation has proven to be the most suitable for smoothing the curve of the anterior alveolar arch. (12)

Bulyalert et al. (12) based on the study carried out by Ferrario (1994) used the fourth degree polynomial equation for the "curve correction" that showed the closest correlation with the current shape of the alveolar arch, in addition, the reference points used and obtained from a CBCT analysis proved to be more advantageous than others located in hard tissue. However, those measurements were made in adult Class I patients.

The objective of this study is to determine the various shapes of the maxillary anterior alveolar arch using the methodology carried out by Bulyalert et al. (12), in a sample consisting of different skeletal and dental patterns in the students of the University of Cuenca enrolled in the subject of orthodontics I during the academic period September 2021-February 2022.

Materials and methods

Sample taking

The sample consisted of 40 young adults (13 men and 27 women) (table 1) (Fig. 1), students of the Faculty of Dentistry of the University of Cuenca, the age of the subjects ranged between 23 and 33 years, with a mean of 25.90 years (table 2). A total of 40 sets of CBCT images without technical errors or artifacts that affect the quality of diagnosis were selected, and all of these were obtained using an Accuitomo 170 3D scanner, with a 170 x 120 mm diameter uptake volume, which gives as a result a voxel size 250 µm. The software used to perform the scans is the one provided by the scanner itself, the "i-Dixel Software". The CBCT images were taken by the same operator to maintain homogeneity. The exclusion criteria were the following: cleft palate; missing or supernumerary anterior teeth; rotated, tilted or clenched teeth; deciduous anterior teeth; presence of intracanal material; root resorption and other pathological manifestations of anterior teeth. The following were considered as inclusion criteria: Permanent dentition and patients of legal age.

Imagemeasurements

Based on the methodology of Bulyalert (12). CBCT images were measured using Sidexis 4 software (Dentsply Sirona) from the axial point of view 3mm below the cement enamel junction (CEJ) of the maxillary canines. The central root points of the maxillary central incisors (a and a'), canines (b and b') and first premolars (c and c') were taken into account as reference points. Measurements were made using three horizontal lines between incisors (aa' line) creating the interincisal width, canines (bb' line) creating the intercanine width, and first premolars (cc' line) creating the interpremolar width. Two measurements were also created vertically, for this, a perpendicular line is made starting from the midpoint of aa' line (am) to the midpoint of cc' line (cm) and marking an additional point just at the middle of the bb' line (bm). With these three points, first a measurement was marked that goes from am to bm (ambm line) which was called intercanine depth, then a second measurement was marked that goes from am to cm (amcm line) which was called interpremolar depth. (Fig.2)

To perform the classification of the anterior alveolar arch, the calculation of the intercanine width to depth ratio was taken as a parameter, together with the intercanine width and the interpremolar width. The intercanine width to depth ratio represented the shape of the anterior alveolar arch while the intercanine width and interpremolar width provided information on the anterior and posterior dimensions of the esthetic zone. With the data obtained, the patients were classified into several groups, which were determined by the width of the average silhouette obtained from the analyses; this made it possible to identify differences between patients in the same group and between other groups.

For the identification of the type of AA arch shape, the fourth degree polynomial function was used according to previous studies with slight modifications. To simplify the equations, fourth-degree smooth curves were created that roughly fit the X and Y coordinates. The latter curve was named the midpoint between the incisors after a translation of the X and Y axes of each CBCT image. The Y axis was created parallel to the midpalatal suture. The X axis was a line perpendicular to the Y axis at the level of the central incisors in the aa' plane. All X and Y coordinates of teeth in the anterior esthetic zone (first premolars from right to left) were digitally located at the root center point of each tooth. 1776

The mean coordinates of each group were exported to a mathematical software (Microsoft Excel), a dynamic table was created with the coordinates of each patient and it is graphed applying the curve fit by means of the fourth degree polynomial equation:

$f(x) = ax^4 + bx^3 + cx^2 + dx + e$

Data analysis

The shapes of the maxillary anterior alveolar arch were classified by group analysis using the values obtained in mm from the corresponding measurements of width and depth to intercanine width, interpremolar width, intercanine depth and interpremolar depth, the means were compared with the individual value corresponding to each patient and this value, together with the curve of the silhouette from the values and graphs obtained from the mathematical program (Microsoft Excel) resulted in the classification in four variants: long narrow, short medium, long medium and long wide. Statistical software (SPSS version 20.0; IBM Corp., Armonk, NY, USA) was used to analyze the data for inter-examiner calibration and to determine means for intercanine and interpremolar width to depth relationship.

Reliability test

An inter-examiner calibration was performed in which a certain number of patients were randomly assigned to five of the examiners and they performed the corresponding measurement, then seven days later other patients were randomly assigned to the same examiners for a second measurement. An intraclass correlation coefficient test was performed with a confidence level of 95%, which did not show significant differences.

Results

Once the data was analyzed, the demographic description of the participants was made; the sample included 40 subjects (13 men, 27 women) (Table 1). Their ages ranged between 23 and 33 years (mean age 25.90 years with a standard deviation of 2 years) (Table 2). The intra-examiner calibration precision was 0.997, which on the intraclass correlation coefficient scale indicates very high. The mean coordinates of the participants in each group were fitted to the curves of the fourth degree polynomial equation that best fit to determine the shape of the AA arch.

Based on author Bulyalert's classification of AA maxillary arch shapes (12), the mean values and standard deviation of the sample coordinates were used to determine the names corresponding to the depth and width of the curves. , as follows: Long narrow (Fig. 3.), Short medium (Fig. 4.), Long medium (Fig. 5.) and Long wide (Fig. 6.). In (Fig. 7) you can analyze and compare the graphs with the four mentioned AA arch shapes.

The number of subjects, mean values, standard deviations, and lower and upper limits of all variables in each group are presented in Table 3.

The 4 groups showed significant differences between the groups, the intercanine width and the interpremolar width of the long narrow arch group (27.37 + 1.95 mm and 32.76 + 2.16 mm, respectively) being the narrowest transverse dimensions among all groups. The intercanine and interpremolar widths of the short medium arch group (30.14 + 1.61 mm and 36.52 + 1.80 mm, respectively) as well as those of the long medium group (31.00 + 1.22 mm and 37.25 + 1.51 mm, respectively) did not showed significant differences; In contrast, the long wide group exhibited the widest transverse dimensions (33.21 + 1.70 mm and 39.95 + 0.72 mm, respectively). Intercanine depth and interpremolar depth were not significantly different between the long narrow arch group (7.15 + 0.97 mm and 12.84 + 0.24 mm, respectively), the long medium arch group (7.40 + 0.82 mm and 14.68 + 1.42 mm, respectively), and the long narrow group. (7.84 + 0.97 mm and 15.04 + 0.91 mm, respectively); however, these 3 groups were significantly longer in the anteroposterior dimension than the short medium arch group (6.02 + 0.75 mm and 11.51 + 1.05 mm, respectively).

In table 4 it can be seen how the predominant form of the AA arch is the short medium with a percentage of 60% equivalent to 24 subjects in the sample, and with the lowest percentage the form of the AA arch is long narrow arch with a 7 .5% equivalent to 3 of the 40 total subjects of the sample.

Discussion

Many professionals at the time of making a diagnosis are limited to using plaster dental models which have limitations such as: the space they occupy, the risk of falls and fractures that could modify the model, thus affecting its level of accuracy with respect to the patient's mouth and the difficulty in sharing information with other professionals.(13). These limitations can be resolved by using a 3D model, however in this study it was decided to use a CBCT to perform the measurement, the determination of the shape of the anterior arch and to analyze the classification of the shapes of the anterior alveolar arch (AA). since this allowed us more precise data.(12)

These data are verified when determining the reference points used for this study. Bulyalert et al. (12) took as reference the center of the root of the incisors, canines, and premolars at a height of 3 mm below the CEJ of the maxillary canines, since these points were on hard tissue, which is a more stable tissue. The reason it was decided at this height is because 3 to 4 mm apically from the marginal free gingiva is the proper distance to place an implant platform when using the well-known points determined by the Andrews and Andrews study such as the WALA ridge, reference points that serve as an anatomical guide for the position of the teeth in the transverse direction of the mandible (14). The height of 3 mm below the CEJ corresponds to the vertical axis towards the maxilla of the WALA ridge (12).

Recent studies have presented classifications of arch form based on transverse dimensions and the arch width to depth relationship (11,5,10). Our study used the intercanine width and interpremolar width, which represented the transverse dimensions of the anterior and posterior parts of the anterior esthetic arch, respectively, and the intercanine width-depth ratio, which describes the shape of the anterior arch, as the parameters for the AA arch form classification. (12).

Previously, arch shape was described in simple qualitative terms such as elliptical, parabolic, U-shaped, square, square-round, round, and V-shaped round based on Thompson's descriptive morphological study (15). Su-Jung Park et al. presented the shape of the arc as a parabola using a second-degree polynomial, with arc shapes at U, V, and O (16). Such descriptions were inadequate to precisely define the dental arch. The shapes of the anterior alveolar arches (AA) can currently be classified into 4 groups: long narrow arches, short medium arches, long medium arches and long wide arches, according to intercanine width, interpremolar width, intercanine depth and interpremolar depth (12).

To choose the arch form objectively, a mathematical method that describes the shape of the arch is required. Methods such as the cubic spline function, beta function, parabola and fourth order polynomial functions have been used (17). AlHarbi et al. compared these methods and revealed that the fourth-order polynomial equation represented the most appropriate function to describe the shape of the arch due to its naturally smooth curvature, and the curve produced by the proposed mathematical function fits dental landmarks believed to be that reliably define the dental arch (18).

Many authors have used the cusp tips to delineate arch shapes, while others used medial crown landmarks from a buccal perspective on anterior and posterior teeth as reference points, as well as lingual and occlusal landmarks or in the long axial axis of the teeth. In addition, other investigators used landmarks on the lingual surfaces closest to the gingival third because this site showed the smallest difference between the lingual surfaces of canines and premolars (19); another study analyzed dental arch shape morphometrically on best fit arch curves generated from collected landmarks providing intuitive visualization of shape and spatial location of shape variation easily with graphical representation. (20, 21). The fourth order polynomial showed a better approximation of the data points than the splines and the beta function. The approximation is uniform throughout the data set, which produces a more natural curvature. Also, the fourth-degree polynomial that included the odd power terms tracks the asymmetry of the arc. The choice of the degree of the polynomial depends on the number of points selected. For the normal arc, although the 6th order polynomial may offer some error reduction, both the 4th and 6th order polynomials are almost equally descriptive, while for an irregular arc, the 6th order will theoretically yield a greater error reduction. This reduction is undesirable as it is only an expression of the irregularity of the tooth as opposed to defining the shape of the arch. That makes the fourth order polynomial universal for use in both cases, i.e. regular and irregular arcs. Therefore, when the purpose is to produce a natural smooth curvature of the arc, the fourth order polynomial function is the most feasible function (18).

Within our study, a discrepancy has been observed between the results found and those presented by Bulyalert et al, due to the fact that the arches in their study present: short medium arch 16%, Long narrow arch 29%, medium long 32% and wide long 24% of subjects of analysis, while in our study we present: short medium arch 24%, long narrow 3%, long medium 9% and long wide 4%, analyzing how there is a higher prevalence of the medium long arch (32%) and in our case is the short medium arch (24%), thus a great discrepancy can be seen in the predominance of the type of arch according to each study, this could be explained due to the number of subjects analyzed and by different racial groups since Bulyalert et al, used 113 subjects of Thai origin while we used 40 subjects of Latin American origin, thus presenting different morphogenic and numerical characteristics.

Therefore, it is recommended to address this topic of study and encourage it to be replicated in different areas and regions with a larger number of participants to improve its reliability and have data about the variations that the shape of the arches can have depending on the demographic area.

Conclusion

The shape of the anterior alveolar arch, using the formula of the fourth-degree polynomial that has been shown to be the most suitable to represent a smooth and natural curve of the arch, can be classified into long narrow, short medium, long medium and long wide arches. Further studies on this are recommended.

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Tables:

Table 1. Frequency according to patient sex

	Frequency (N)	Percent (%)
Male	13	32,5
Female	27	67,5
Total	40	100,0

Table 2. Mean (X) and standard deviation (SD) according to patient age

N	**40**
Mean	**25,90**
Std. Deviation	**2,048**
Minimum	**23**
Maximum	**33**

Table 3. Dimensions according to the shape of the alveolar arch (Unit: mm)

GROUPS OF ARCH FORMS	SUBJECTS	VARIABLES	MEAN + SD	LOWER BOUND	UPPER BOUND
LONG NARROW	3	Intercanine width	27.37 + 1.95	25.12	28.58
		Interpremolar width	32.76 + 2.16	30.26	34.03
		Intercanine depth	7.15 + 0.97	6.08	7.97
		Interpremolardepth	12.84 + 0.24	12.58	13.06

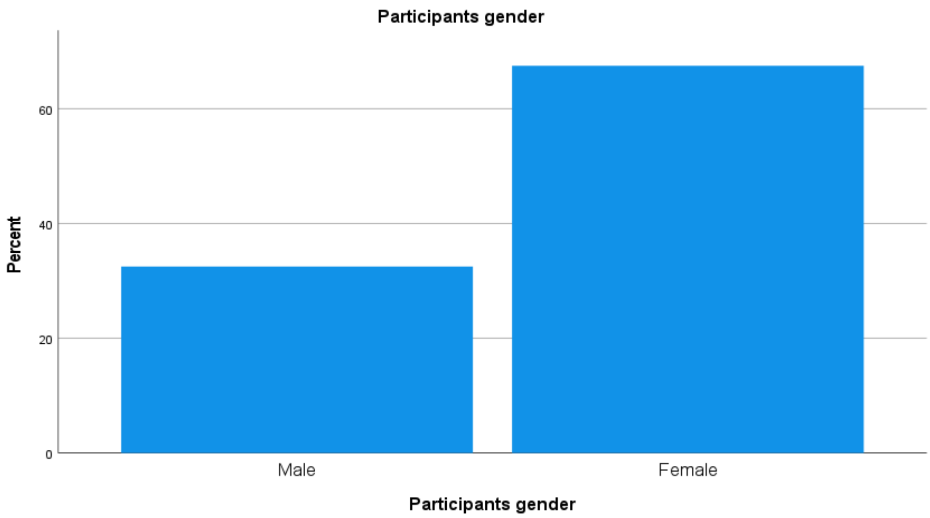
SHORT MEDIUM	24	Intercanine width Interpremolar width Intercanine depth Interpremolardepth	30.14 + 1.61 36.52 + 1.80 6.02 + 0.75 11.51 + 1.05	27.04 33.07 4.35 9.10	33.81 40.01 7.19 12.91
LONG MEDIUM	9	Intercanine width Interpremolar width Intercanine depth Interpremolardepth	31.00 + 1.22 37.25 + 1.51 7.40 + 0.82 14.68 + 1.42	28.88 34.58 6.05 11.61	32.68 38.83 8.54 15.60
LONG WIDE	4	Intercanine width Interpremolar width Intercanine depth Interpremolardepth	33.21 + 1.70 39.95 + 0.72 7.84 + 0.97 15.04 + 0.91	31.27 39.04 6.97 14.36	35.18 40.81 9.24 16.34

Table 4. Frequency of dental arch shapes

	Frequency	Percent
Short medium	24	60,0
Long narrow	3	7,5
Long medium	9	22,5
Long wide	4	10,0
Total	40	100,0

Figures:

Figure 1. Graph of the percentage according to the patient's gender



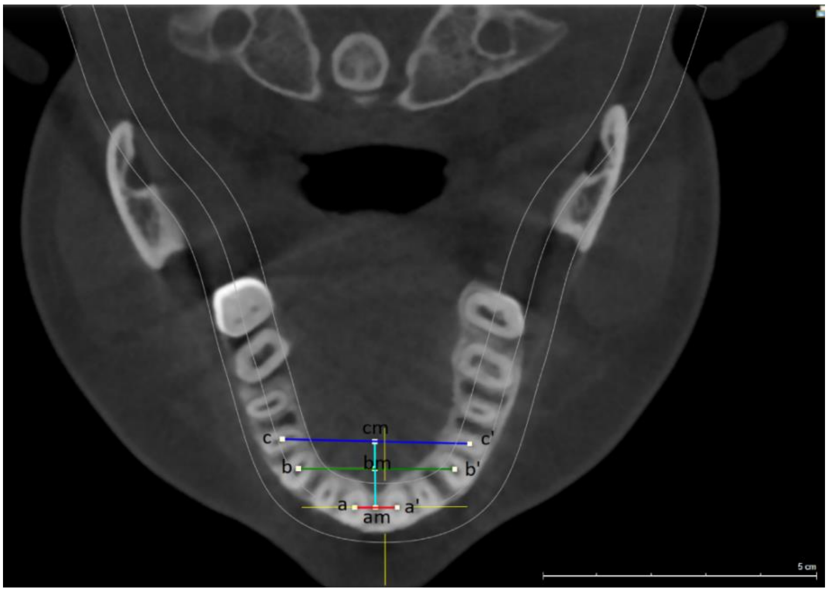


Figure 2. Points a and a' are located in the root center of the maxillary central incisors and form the aa' line. Points b and b' are located in the root center of the upper canines and form the bb' line. Points c and c' are located in the root center of the maxillary first premolars and form the cc' line. The point am is the midpoint of the aa' line. bm is a perpendicular extension of the am point and the termination of this extension is the cm point. The distance ambm is the intercanine depth and the distance amcm is the interpremolar depth.

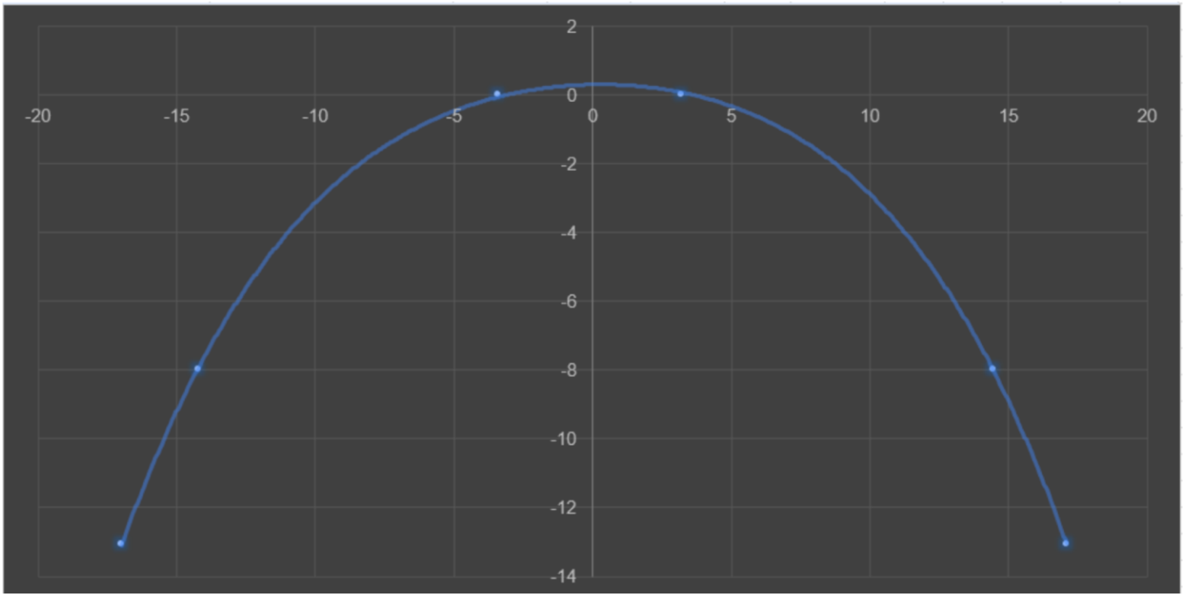


Figure 3. Arch Shape: Long Narrow

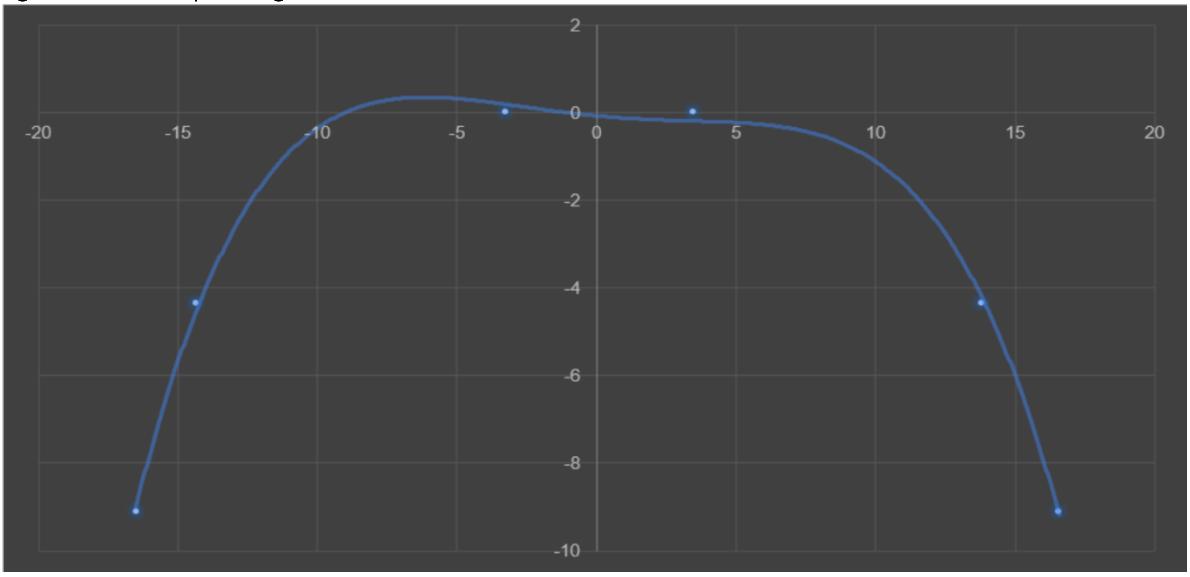


Figure 4. Arch Shape: Short medium

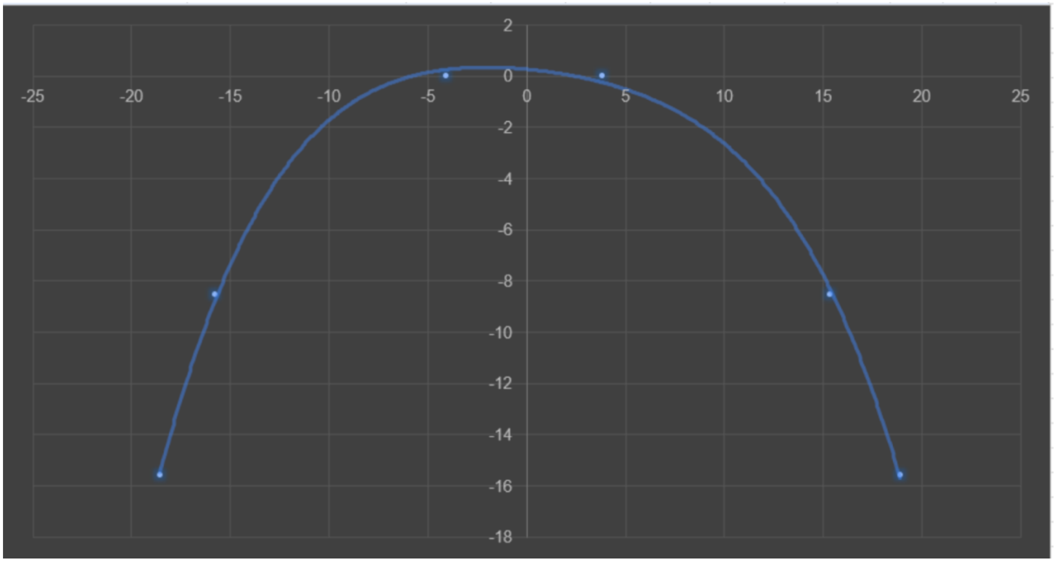


Figure 5. Arch Shape: Long medium

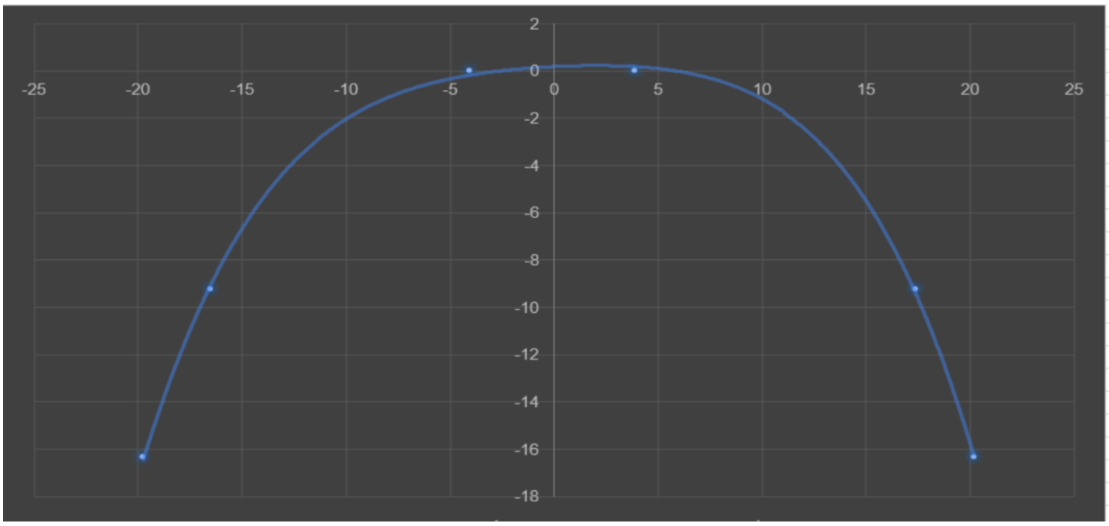


Figure 6. Arch Shape: Long wide

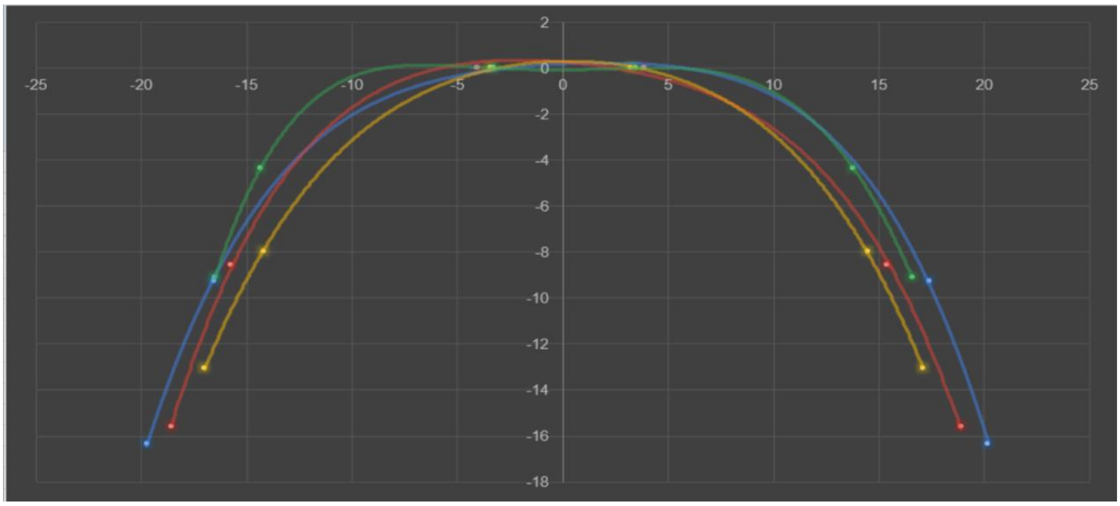


Figure 7. Comparison of the curves of the maxillary anterior arch in its various forms: a) Long narrow (yellow); b) Short medium(green); c) Long medium (red); and d) Long wide (blue).