Maxillary and mandibular dental arch forms in a Jordanian population with normal occlusion

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Abstract

Background

Ethnic background had been claimed to affect arch form. The purpose of this study was to describe the maxillary and mandibular arch forms in Jordanian population and to develop a classification of these forms which could be used to construct orthodontic archwires accordingly.

Methods

The sample comprised the study casts of five hundred and twenty subjects (231 males and 289 females with mean age 15.4 ± 1.02 years). All subjects had permanent dentition with normal occlusion. A mathematical method associated with a polynomial function of 6th degree was used to evaluate the dental arch forms. The resulting arch forms were organized into 5 groups for both the maxilla and the mandible utilizing computer software with special code designed for this study. Each group was subdivided into 3 subgroups: small, medium, and large sizes.

Results

Catenary arch form was found in 47% and 41.2% (P□0.01) in maxilla and mandible, respectively. Form 2 (between half ellipse and U-shaped arch form) was found in 27.7% and 26.7%. Medium size arch form was found in 55.4% in the maxilla and 65.6% in the mandible.

Conclusions

Catenary arch form was the most common arch form, followed by wide elliptical form. The other forms; tudor arch, tapered equilateral and quadroangular forms were less frequent. With respect to size, the medium size was the most common one in the studied sample.

Background

Several attempts have been made to define the “ideal” arch form considering that the dental arch is symmetric in nature and can be represented by an algebraic or geometric formula [1].

The ideal lower arch form has been described as a slightly modified equilateral triangle with the base representing the intercondylar width, and the six anterior teeth arranged on the arc of a circle, the radius of which equals the widths of canines and incisors combined [2–3]. Other suggested arch forms were semi-ellipse [4], parable [5], and catenary form [6–8]. Other authors suggested different forms for upper and lower arches; upper arch took the form of an ellipse, and the lower arch a parabola [9].

It has been suggested that there is no particular form present to describe dental arch form and that customizing arch forms seemed to be necessary in many cases to obtain optimum long term stability [1, 10].

Several factors have been claimed to affect arch size and form such as ethnic background, type of malocclusion, variability in eruptive paths of the teeth, growth of the supporting bones, and the movement of the teeth after emergence due to habits and unbalanced muscular pressures [11–13]

Dental arch form has been evaluated for different populations [14–17]. However, no studies have been conducted in Jordan. Accordingly, the aims of this study were to determine the maxillary and the mandibular arch forms in Jordanian population and to report on the mean of dental arch dimensions for Jordanians.

Methods

Collection of Data

A total of 6023 school students (2365 males and 3658 females), with an age range of 15 - 17 years, were examined at randomly selected schools from different districts in Jordan. The schools were selected from a list obtained from the directorate of education in the North, Center and South of the country. Four schools were selected from each city by selecting every third school in the list. Sample size calculation was made for cross sectional survey studies on the sample size chart with the power 0.90. The minimum number of subject to be included in this study was 430.

A full clinical examination was carried out in the school premises using a mouth mirror under natural lighting by one examiner (MJ). Five hundred and twenty students (231 males and 289 females with mean age 15.4 ± 1.02 years) fulfilled the following inclusion criteria and were invited to participate in the study; class I incisor and molar relationships, minimal crowding or spacing (≤ 2 mm), no or minor tooth rotations, no crossbite or scissors bite, all permanent teeth erupted except third molars, no missing or supernumerary teeth, no abnormality in size or shape of teeth, and no history of orthodontic treatment.

Upper and lower alginate impressions (Kromopan, Lascod s.p.a, Italy) and wax bite were taken. Impressions were kept according to the manufacturer recommendation and poured on the same day with hard dental stone (Zhermack Elite Ortho Stone, KAB Dental Inc, U.S.A) and orthodontic study models were constructed.

Measurements

The dental casts were scanned using HP scanjet G4050 (Hewlett-Packard Company, Palo Alto, CA, USA) and images with 300 dpi resolution were obtained. The position of the dental casts on the scanner was established with a millimeter translucent paper especially designed for this purpose; it was made by photocopying a sheet of millimeter paper on a transparent sheet.

The customized transparent sheet was placed between the scanner glass surface and the occlusal plane of the dental cast, so that the posterior edge of the dental cast would coincide with the abscissa axis (x) and the dental midline with the ordinate axis (y), creating a Cartesian system.

For each cast image, 14 points were determined on the dental arch representing the center of the clinical crown of the incisors, canines, the buccal cusps of premolars, and the mesiobuccal cusps of the first and second molars. The perpendicular distance to the midline from each point was analyzed to an x and y component and measured in millimeters.

Measurements of x and y coordinates of the 14 points of each dental cast image were plotted on a computer software (Curve Expert version 1.4, Hyams Development. U.S.A) to obtain the polynomial function that best describes the curve corresponding to the dental arch form (Figure 1).

When all the dental casts were scanned and analyzed, they were allocated into different arch forms according to the following procedure: each photo was converted to a “DAT format” file, using the Curve Expert program. The photo then appeared as a set of points (indices x and y) which was determined by the original photo. An interpolation was done to these sets of points using MATLAB (version 7.4.0.287 (R2007a), The mathworks, Inc, Natick, Massachusetts, U.S.A.) to form a polynomial function of the sixth order. Each set of points contained 14 points. Using the function generated by the interpolation process, a curve containing 100 points was generated. In order to cover 100 steps on the x-axis, a type of scaling was done on each set of points, then shifting all curves to start from the same point, which was zero. The slope of each point relative to its neighbors was calculated. The slope of each point in each curve was compared to the slope of the points which shared the same x value, x+1 or x-1 in all other curves. The curves were then allocated into different groups based on the slopes of the points on each curve. The biggest five groups (groups that contained most frequent types of curves) were made the main groups.

Each of the maxillary and mandibular curves were also divided into three sizes within each arch form according to the transverse distance between the tips of the mesiobuccal cusps of the right and left second molars. The minimum distance was subtracted from the maximum distance; the difference was divided into three ranges. Each cast was allocated into one of these 3 groups according to its width. The 3 ranges of distances between the second molars within each arch form in the maxilla and the mandible are shown in Table 1.

Intercanine width (from cusp tip to cusp tip), intermolar width (from the mesiobuccal cusp of the right first molar to the mesiobuccal cusp of the left first molar) and arch depth (the perpendicular line connecting the mid-point between the incisal edges and the transverse line passing through the distal surfaces of the first molars) were measured.

Error of the method

Twenty (10 upper and 10 lower) randomly selected casts were re-analyzed and the arch parameters were re-measured after one-month interval. Dahlberg’s formula was used to calculate the standard error of the method [18]. Houston’s coefficient of reliability was calculated [19].

The error in measurement for the intercanine width, the intermolar width and the arch depth was 0.34 mm, 0.39 mm and 0.37 mm respectively. Houston’s coefficient of reliability was above 92% for all the

measured variables.

Statistical analysis

Data analysis was carried out using the Statistical Package for Social Science (SPSS) software (SPSS 18.0, SPSS Inc., Chicago, USA). Means and Standard deviations were calculated for all the measured variables. Chi square test was employed to investigate if there are differences between the frequency of different arch forms and sizes in each of the maxilla and the mandible. T-test was used to compare between males and females for the intercanine and intermolar widths and arch depth. Analysis of variance (ANOVA) was used to compare between the arch parameters in the different arch forms. The P value was predetermined to 0.05 as the level of significance

Results

Arch forms

Five different arch forms were found for each of the maxilla and mandible as shown in Figure 2. Form 1 was a catenary arch, form 2 was between a half ellipse and a U-shaped arch, form 3 was a tudor arch form, from 4 was a tapered equilateral arch and form 5 was quadroangular form. The distribution of subjects in each arch form in the maxilla and mandible are shown in Figure 3 and Figure 4, respectively. Arch form 1 was the most common form observed in 47% and 41.2% for the maxilla and the mandible (Table 2), respectively (P 0.01). Form 4 was the least common in both maxilla and mandible with frequency of 6.2% and 6.9%, respectively (P 0.01).

Maxillary arch form 1 and 3 were more frequent in females than males with P 0.01. In the mandible, arch form 1 was more common in females than in males (P 0.01).

Arch size

The arch sizes were divided into small, medium and large within each arch form. Figure 5 shows the three sizes of arch forms. The distribution of subjects in each arch form according to size is shown in Figure 6 for the maxilla and Figure 7 for the mandible.

The mean for maxillary arch size was 56.26 ± 2.74 mm for females and 58.32 ± 2.89 mm for males ($P<0.001$). The mean size of mandibular arch was 52.02 ± 2.87 and 53.19 ± 3.11 for females and males respectively ($P<0.001$).

Size 2 (medium) arch was the most common size in both males and females and both mandible and maxilla ($P<0.001$).

Arch parameters

The mean and standard deviation of inter-canine and inter-molar widths and arch depth for each arch form in the mandible and the maxilla are shown in Table 3.

Discussion

The identification of a suitable arch form for treating each malocclusion is key for achieving a stable, functional, and esthetic occlusion. Clinically, it would be appropriate to have several preformed arch forms to choose from for individual patients after identification of patient's pretreatment arch form [14].

Several factors have been claimed to affect arch size and form such as ethnic background, type of malocclusion, variability in eruptive paths of the teeth, growth of the supporting bones and the movement of the teeth after emergence due to habits and unbalanced muscular pressures [11–12, 20].

It was intended in this study to identify the forms of maxillary and mandibular arches in a Jordanian population. Several studies have been conducted on different populations [10, 13, 21–23]. Most of the conducted studies were describing the mandibular arch form because the mandible is considered as the reference element of diagnosis and treatment in orthodontics [24]. According to several authors, the stability of the form and dimension of the mandibular dental arch is a factor of stability of the results [25]. Only few studies dealt with maxillary arch [22, 26].

Sixth polynomial function was used in this study to determine the arch form from the digitized points of tooth positions on the dental arch. It has been reported that the sixth-degree polynomial equation was the function that best described dental arch configuration. Polynomial functions with lower degrees compromised the descriptions of some important dental arch regions, such as anterior curvature of the mandibular arch and posterior tooth alignment [27].

Five arch forms were identified in each of the maxilla and the mandible in this study. Some previous studies reported three arch forms for their studied populations, others reported 5 different arch forms and some others reported eight arch forms [10, 24, 27–28].

The method used to determine the arch form in this study ensured high accuracy and objectivity since allocation of the curves into their corresponding arch form and size was constructed by a computer software. Other studies allocated them manually, by visual observation or by simple calculations [10, 22, 24].

The results of this study showed that there are at least five arch forms describing dental arches for untreated young Jordanian adults with normal occlusion. However, arch form 1 (Catenary) was the most common form representing almost half of the studied sample with a slightly higher frequency in the maxilla than in the mandible.

Telles [28] reported an elliptical mandibular arch form for the majority of their sample representing almost two thirds of the subjects.

The second most common arch form was form 2, a form between elliptical and U-shaped arch, with a relatively large intercanine distance. About one quarter of the curves fell under this category. Ricketts [29]

reported that one third of his sample exhibited this arch form while Triviño et al. [10] reported only 9 per cent of the studied mandibular arches belonged to this category.

Form 3 was not commonly observed in previous studies. This form has a morphology of projecting central incisors with a widening in the posterior region. It was described as "tudor" curve by architects. It was found in about 10% of our sample in both the maxilla and the mandible. Triviño et al. [10] reported a higher percentage (18%) of this form in their sample.

Form 4 was observed in a small number of our sample (around 7%). This form has a pointed anterior region. It was described in other studies with different frequencies. Raberin et al.[25] found this form in 19.4% of his sample while Triviño et al. [10] found it in only 2% of his studied sample.

In form 5, the incisors are arranged in a straight line with the initiation of the curvature at the distal region of the lateral incisors, it was described as a quadrangular. This arch form occurred in a low frequency generally with a lower frequency in the maxilla than in the mandible. Triviño et al. [10] reported a similar figure in the mandible. On the other hand, Triviño and Vilella [30] reported a higher percentage of this arch form which was the predominant form in that study.

The differences in arch forms between our study and other studies could be attributed to different ethnic backgrounds, sample characteristics and study methodology.

Size 2 (medium) was the predominant size in the maxilla and the mandible, in almost all the forms, a finding that has been reported by other authors [29–30].

Comparing arch forms between females and males, there were differences in arch forms 1 and 3 in the maxilla and arch form 1 in the mandible contrary to the findings of other studies who reported similar forms but different sizes in both genders [24, 30].

Differences in the results could be explained by different ethnic backgrounds and reference points used for measurements.

The transverse measurements carried out in this study were intercanine and intermolar widths. The mean of these parameters were close to the values found in other studies conducted on samples with similar criteria to our sample (Staley et al., 1985). Other studies reported smaller intercanine widths but larger intermolar widths [32–33].

Out of the 5 arch forms that were found for the Jordanian population, two constituted the majority of all arch forms. The rest were less frequent. It is recommended that clinicians keep the most common arch forms in their armamentarium. However, if a patient presented with one of the less common arch forms, it is of paramount importance for the clinician to respect the original arch form of this patient. Therefore, with less common arch forms, clinicians should make adjustments to the archwires according to the patient’s arch form to reduce the chances of relapse especially in the intercanine width; since changes in intercanine width is associated with high risk of relapse [25].

Conclusions

1. The catenary arch form was the most common form in both the maxilla and the mandible; it was more common in females than in males.
2. The catenary and the tudor arch forms were more frequent in females than in males for the maxillary arch.
3. The medium arch size was the most frequent size for the maxilla and the mandible.
4. Males exhibited larger arch size than females.

Abbreviations

Not applicable

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Institutional Research Board at Jordan University of Science and Technology (IRB/12/317). A written consent was obtained from the Ministry of Education. Approval was also obtained from individual head of each school and a negative consent letter was sent to students' parents or guardians.

Consent for Publication

All the authors agree on publication of this paper in case of acceptance and give all the publication rights to the Journal BMC Oral Health

Availability of data and material

All the data and the material is available in case the authors have been asked to provide

Competing interests

The authors have no competing or conflict of interest what so ever.

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Authors' contributions

Aljayousi M: (He was master student) Data collection, data analysis, writing up of the manuscript

Al-Khateeb S: (Main supervisor) Study design, statistical analysis, supervised data collection and analysis, and manuscript writing

Badran S: (Co-supervisor) Helped in data collection and data analysis, and manuscript writing

Abu Alhaija E: Helped in study design, data collection and statistical analysis

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Tables

Table 1: The range of inter-second-molar distances that determined arch size of each form

		Mandible			Maxilla		
	Arch Size (mm)	Small	Medium	Large	Small	Medium	Large
Arch Form	1	44-49	50-54	55-60	51-55	56-60	61-66
	2	44-49	50-54	55-60	50-54	55-59	60-64
	3	46-50	51-54	55-60	51-55	56-59	60-64
	4	45-50	51-56	57-62	50-53	54-58	59-62
	5	43-48	49-55	56-60	48-52	53-57	58-62

Table 2: The frequency of each arch form as a percentage in females, males and total sample

	Gender		Total (%)	*P-Value*
	Female Number (%)	Male Number (%)		
Mandibular arch form				
1	127 (43.9)	87 (37.7)	214 (41.2)	0.006*
2	77 (26.6)	62 (26.8)	139 (26.7)	0.358
3	29 (10.0)	19 (8.2)	48 (9.2)	0.149
4	17 (5.9)	19 (8.2)	36 (6.9)	0.739
5	39 (13.9)	44 (19.1)	83 (16.0)	0.583
Total	**289**	**231**	**520**	
Maxillary arch form				
1	141 (49.5)	100 (43.9)	241 (47.0)	0.008*
2	63 (22.1)	79 (34.7)	142 (27.7)	0.179
3	39 (13.7)	18 (7.9)	57 (11.1)	0.005*
4	19 (6.7)	13 (5.7)	32 (6.2)	0.289
5	23 (8.1)	18 (7.9)	41 (8.0)	0.435
Total	**285**	**228**	**513**	

Table 3: Mean and SD of inter-canine and inter-molar widths and arch depth of the maxilla and the mandible

Arch form	Inter-canine width	Inter-molar width	Arch depth
Mandible			
1	28.0 ±	48.1 ±	30.5 ±
2	28.9 ±	48.4 ±	29.9 ±
3	28.8 ±	49.3 ±	31.4 ±
4	27.1 ±	46.6 ±	29.9 ±
5	28.8 ±	47.1 ±	30.1 ±
Maxilla			
1	35.9 ±	53.4 ±	34.5 ±
2	37.2 ±	53.6 ±	34.5 ±
3	35.1 ±	52.9 ±	34.8 ±
4	34.2 ±	53.1 ±	35.1 ±
5	36.3 ±	52.0 ±	33.7 ±

Figures

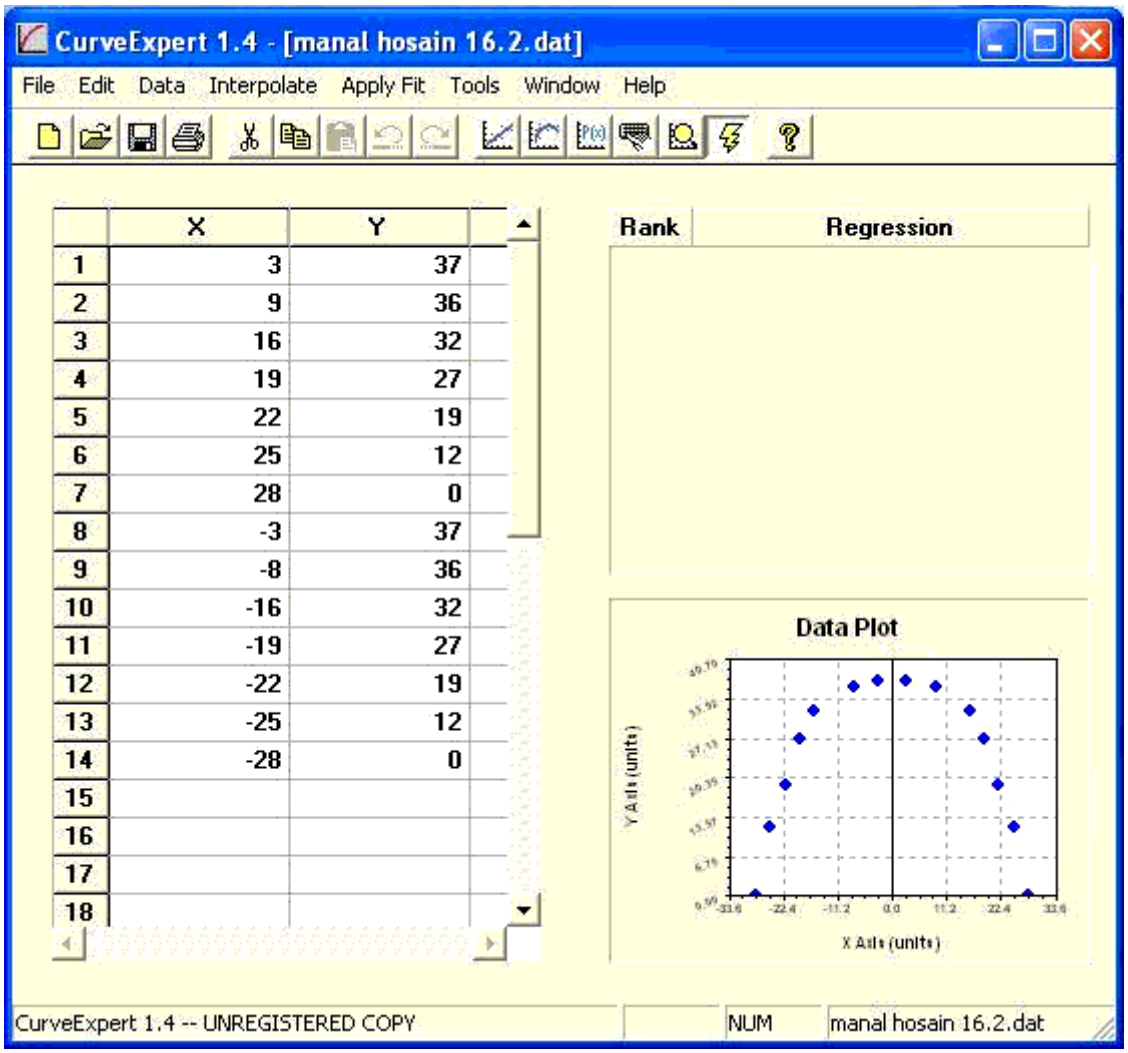

Figure 1

The function screen window of the x and y coordinates and a plot of one arch as displayed in the Curve expert software.

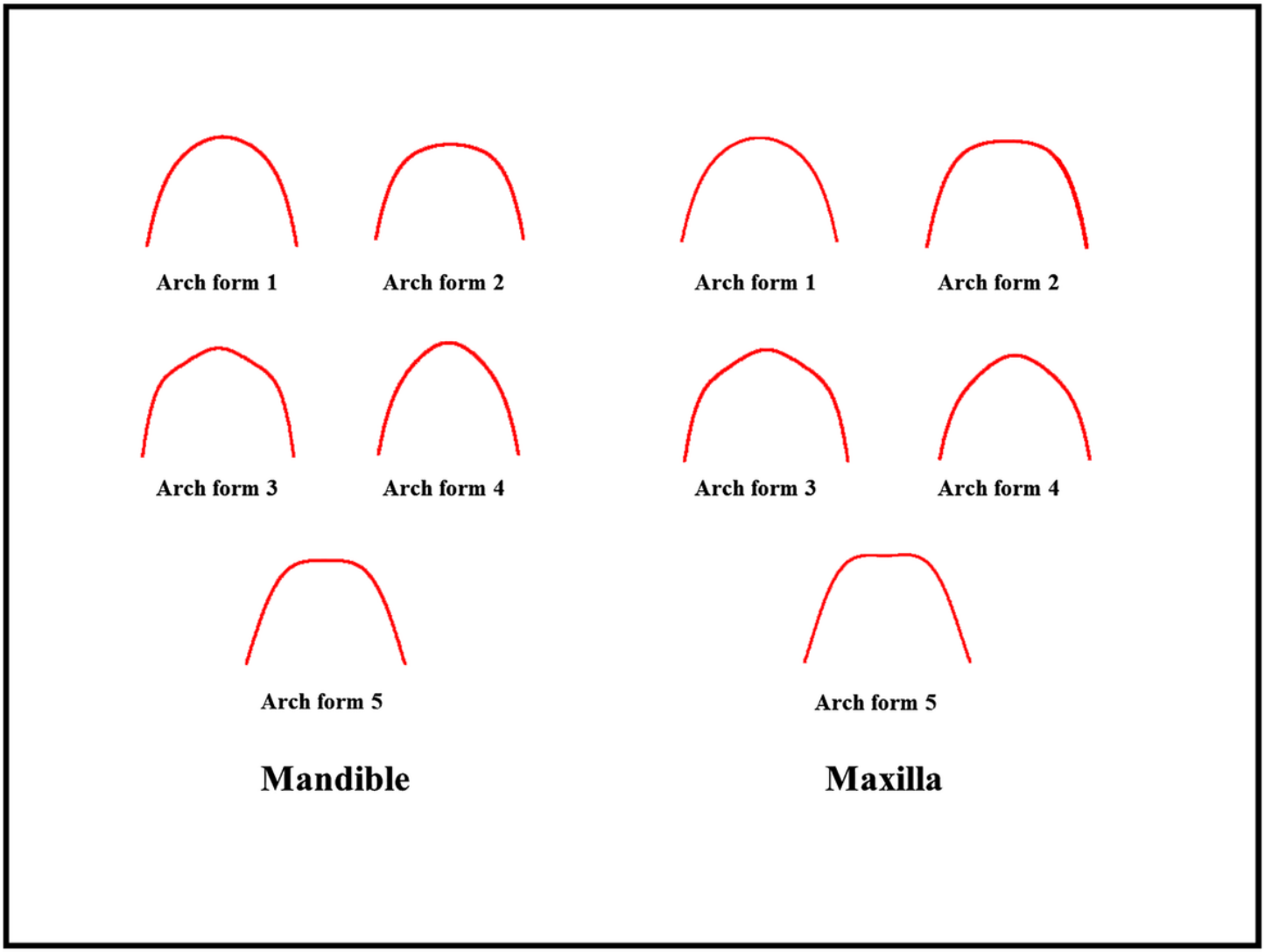

Figure 2

Graphic representations of the 5 dental arch forms for normal occlusion, in mandible and maxilla.

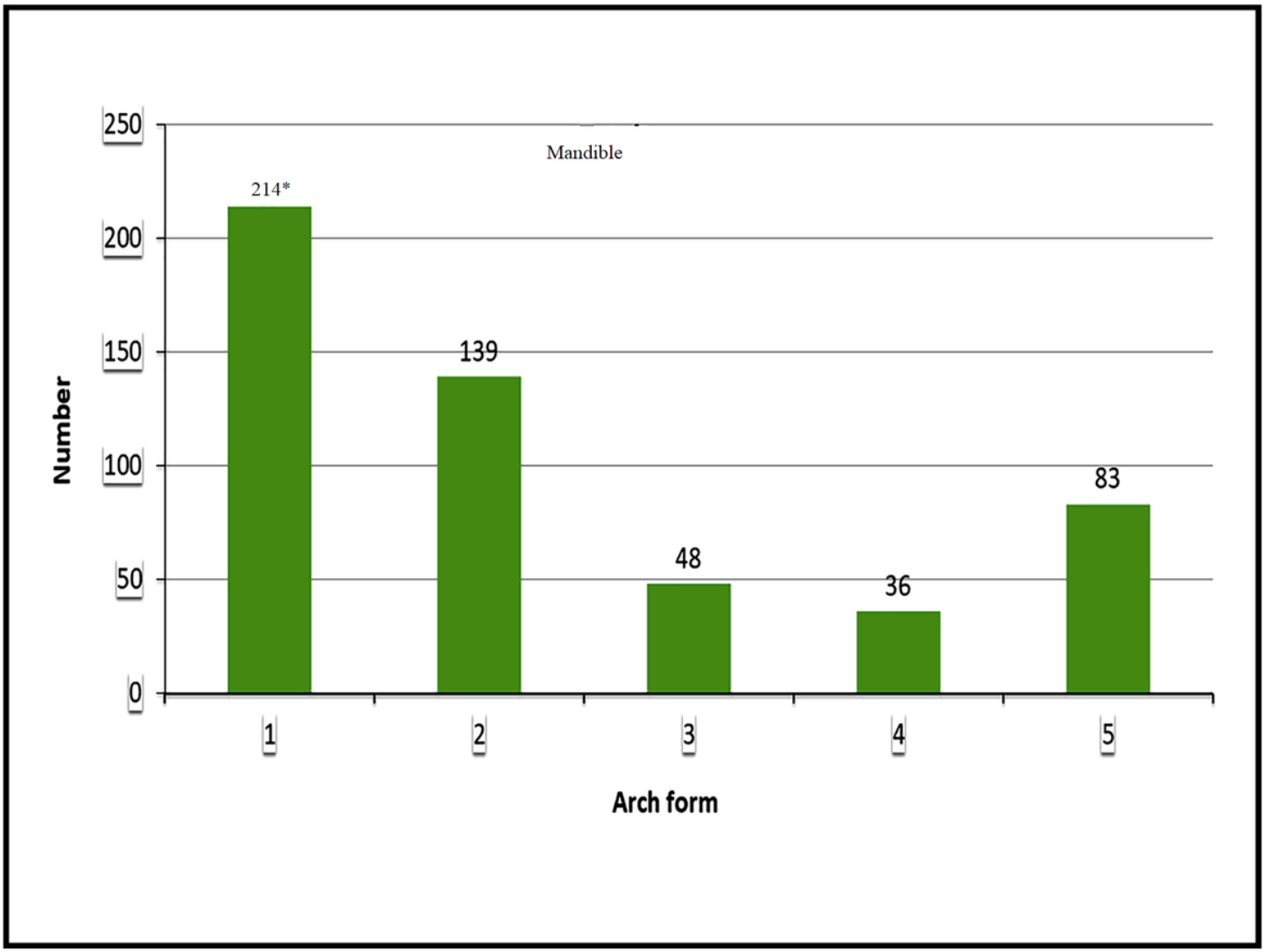

Figure 3

Distribution of subjects in each arch form in the maxilla

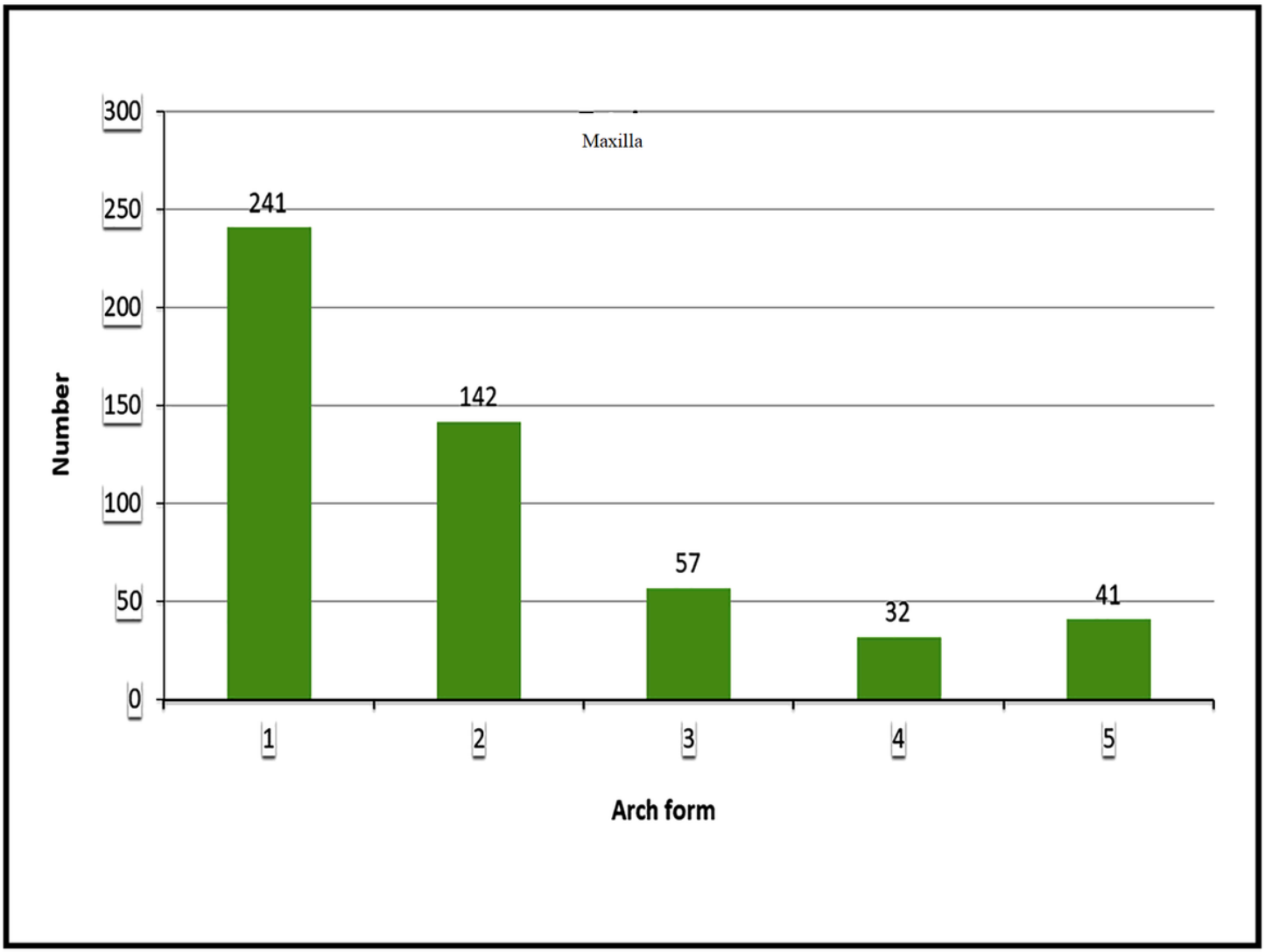

Figure 4

Distribution of subjects in each arch form in the mandible

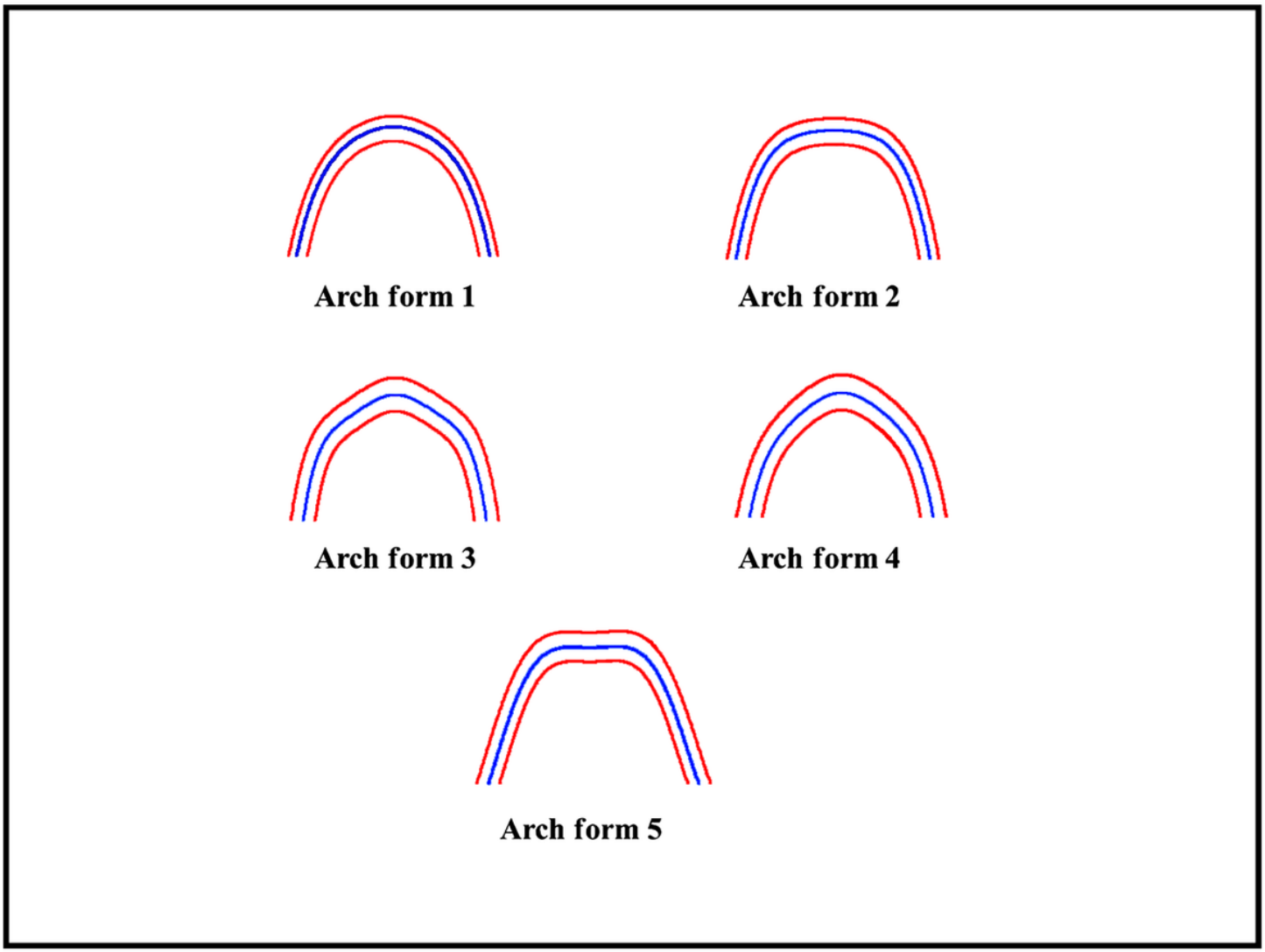

Figure 5

Graphic representations of the 5 arch forms showing 3 sizes; small, medium and large within each arch form.

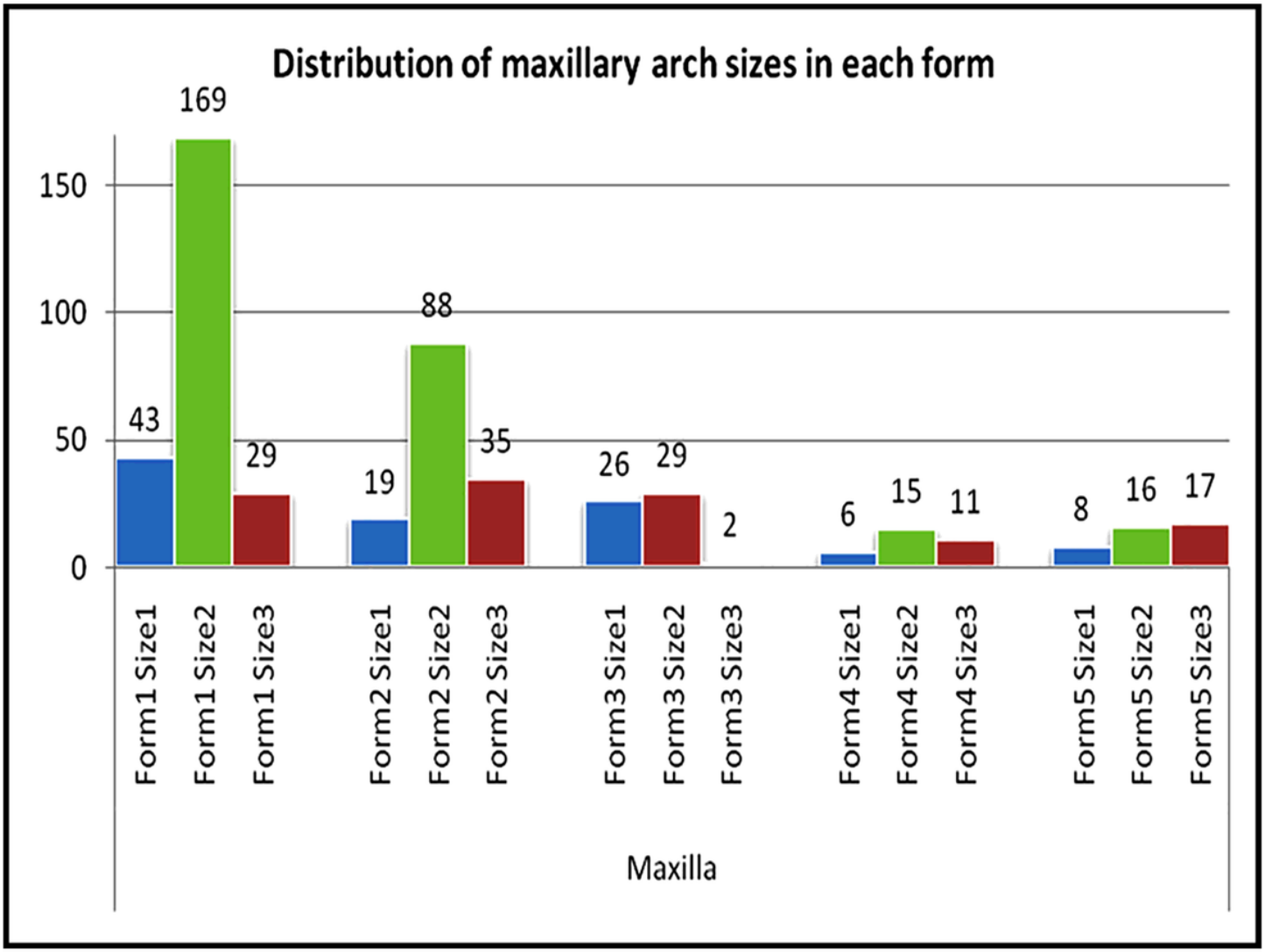

Figure 6

Distribution of maxillary arch sizes in each form

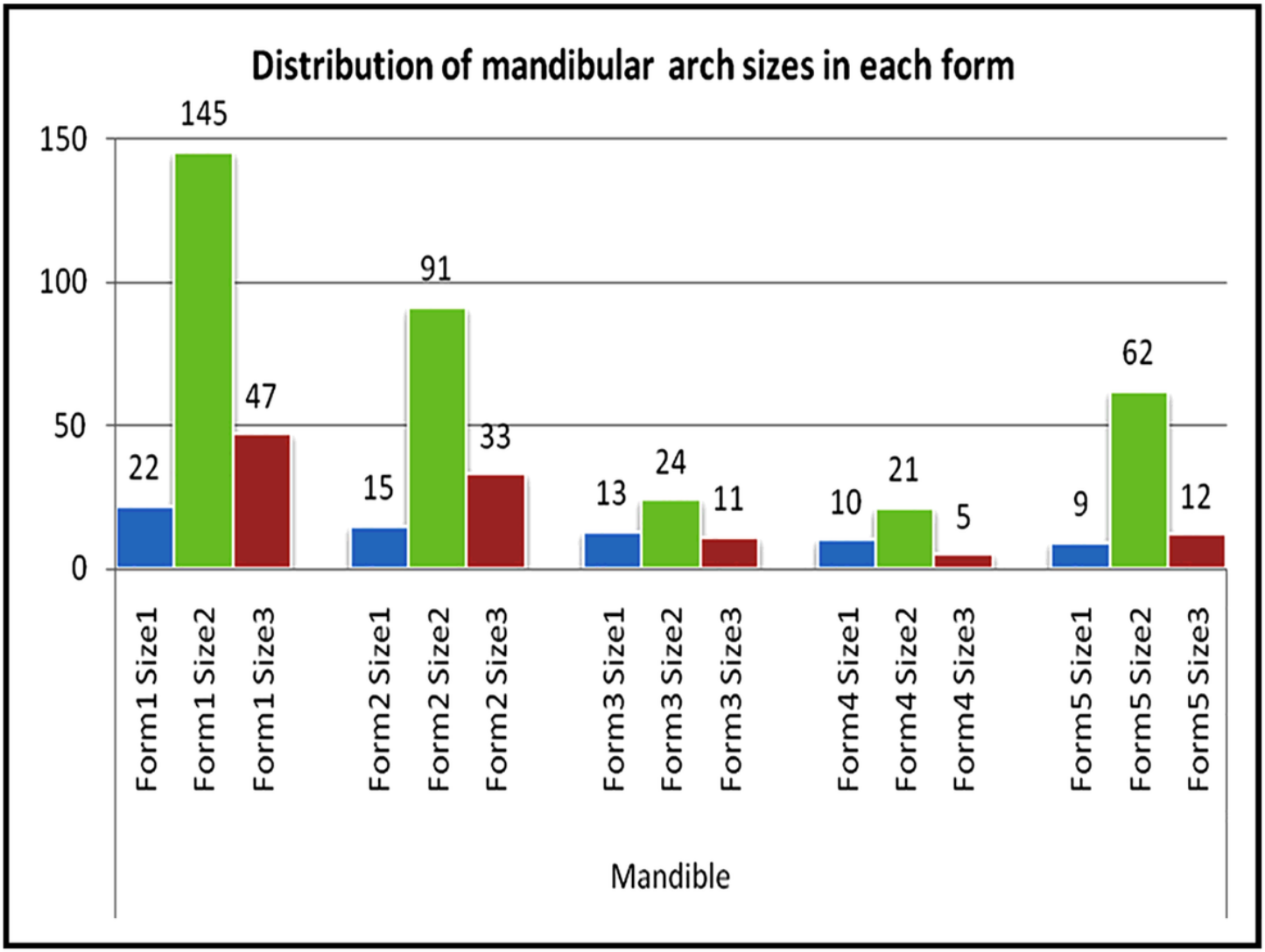

Figure 7

Distribution of mandibular arch sizes in each form