Mathematical Analyses of Mandibular Arch Form in a Sudanese Adult with Normal Occlusion

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Abstract

Aims: This study aimed to analyze the mandibular dental arch forms of Sudanese adults with normal occlusion and provide practical method for orthodontists to determine different arch forms.

Materials and Methods: This descriptive, analytical, cross-sectional study determined the mandibular arch in a sample of 104 Sudanese university students. The measurements were collected from the mandibular dental cast, established three arch width and three arch length measurements, and determined five ratios. The arch form was analyzed according to Raberin’s polynomial method.

Results: The mid arch form was the most prevalent (75%), followed by the narrow arch form (11.54%), wide arch form (6.73%), and pointed arch form (6.73%). No case had flat arch form.

Conclusion: Four types of arch forms were recognized in Sudanese subjects. Norms of transverse and sagittal dimensions of mandibular arch to determine types of the mandibular arch form in Sudanese orthodontic patients were established.

Keywords: mandibular arch form, dental cast, sudanese

Introduction

Dental arch shapes have considerable implications in orthodontic diagnosis and treatment planning, affecting the space available, dental esthetics, and dentition stability [1, 2]. The dental arch is initially shaped according to the supporting bone’s configuration and following eruption by the circum-oral musculature and intraoral functional forces [3, 4].

In contemporary orthodontics, for the ease and perfection of the orthodontists, preformed archwires have gained acceptance. Furthermore, with the use of advanced materials and the use of elastic archwires, it became very important to determine the mandibular arch form’s shape [5].

The stability of orthodontic treatment outcome request no changes in the mandibular arch form [6]. The mandibular arch has different shapes in different people though each one has a normal occlusion. Many factors predispose mandibular arch form differences. One must not try to alter the original arch form to have stable results during orthodontic treatment procedures [7]. Orthodontists should select the appropriate shape of archwire for each case separately, some clinicians try to modify archwires for every case, either using arch guides [8, 9] or the computer-assisted technique [10]. The arch shape consists of two different areas; the anterior curvature and inter-canine width and posterior curvature and intermolar width. A preformed archwire also can be customized for each patient by adjusting the anterior and posterior curvatures [11].

The symmetrical dental arches were studied through different methods. Simple qualitative descriptions; tapered, ovoid, and square arch forms, were used [11, 12]. Also, human dental arch forms have been described using mathematical methods; Catenary curves [13, 14] and trifocal ellipse [15]. Some authors reviewed more complex procedures involving different curve-fitting mathematical models. Ferrario et al. [16] evaluated maxillary and mandibular arches by a fourth-order polynomial and mixed model (ellipse and parabola).

Ferrario et al. [17] proved that the Euclidean Distance Matrix Analysis (EDMA) is suitable for analyzing human dental arches, calculated the center of gravity or centroid of each tooth from cusp tip coordinates and used these points as landmarks later used in the EDMA calculations.

Raberin et al. [5] classify mandibular dental arches into five types (pointed, wide, narrow, mid, and flat) based on the k-means clustering method and the use of polynomial functions of the sixth degree.

Dental arch variations exist among different racial groups [18]. Comparison of the shape and dimension of the dental arches between African and Caucasian subjects revealed significant differences between

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the two ethnic examples in a previous study [19]. Every population should be managed according to its characteristics.

Few studies have explored the predominant mandibular arch forms among Sudanese subjects. This study evaluates mandibular dental arch forms in Sudanese adults with normal occlusion. It establishes a practical mathematical technique of identifying different arch forms that are readily available in every orthodontics clinic.

**Subjects and Methods:**

This cross-sectional descriptive and analytical study was carried out for university students in the Republic of Sudan’s capital city (Khartoum). The students were selected based on the following inclusion criteria.

- Sudanese nationality
- Aged 16–26 years
- Bilateral Angle’s Class I molar and canine relationship
- Dental arches with well-aligned teeth and space discrepancy of 0 ± 3 mm
- Normal overjet and overbite (2 mm ± 1 mm)
- All teeth were present and fully erupted from the second right molar to the second left molar
- No history of previous orthodontic treatment

**Sample size:**

The study sample was calculated using the following equation:

\[ n = \left( \frac{Z_{\alpha/2}}{e} \right)^2 \text{deff} \]

The calculated sample size was 52. Therefore, the overall sample was 104 (52 males and 52 females).

**Study design:**

The cluster sampling technique was applied to select faculties. Ten of nineteen faculties of the AL Neelain University were selected for the study. A simple random method were used to select students from each chosen faculties.

Ethical Approval was provided by the Central Institutional Review Board of AL Neelain University, Khartoum on 3 September 2016. Participation in the study was voluntary, and all student participants provided informed consent. Initial screening for the students was carried out under natural daylight. Each student was examined to determine if met all the inclusion criteria. The examination comprised an intraoral inspection of the teeth and occlusion. For impression taken, Alginate hydrocolloid impression material (ALGINMAX) was mixed according to the manufacturer’s instructions. Dental models were poured and prepared with dental stone (OrthoStone).

**Measurements:**

The mandibular arch measurements were carried out with an electronic digital caliper (0–150 mm /6” X0.01 JAPAN). The reference points determined [5] as the mid incisal edge on the labial side, canine cusp tips, mesiobuccal cusps of the first molars, and distobuccal cusp tips of the second molars.

The analysis of dental arches was divided into six dimensions [5]: three arch width and three arch length measurements (Figure 1).

![Figure 1: Arch width and Length measurements in the mandibular cast](image)

The arch breadth (L33) between the canine tips. The mean intermolar width (L66) between the mesiobuccal cusps of the first molars. The posterior intermolar width (L77) between the distobuccal cusps of the second molars. The canine depth (L31) from the mid incisal edge to the line joining the canines’ cusp tips. The mean arch length (L61) from the mid incisal edge to the line joined the first molars’ mesiobuccal cusps. The total length (L71) from the incisal edge to the line joined the second molars’ distobuccal cusps.

From these measurements, we generated five ratios [5] (L31/L33, L61/L66, L71/L77, L33/L66, L61/L71) for arch form analysis.

Statistical analysis

Data was collected, cleaned and enter to the computer using the SPSS (Statistical Package for Social Sciences, Chicago, USA) 20.0 statistical program. The threshold for statistical significance was set at \( p < 0.05 \). The following tests were used:

1. Error of method: The same researcher performed all measurements. Furthermore, all the variables were measured twice, with a 2-week interval between the two recordings on 25 casts selected at random: intra-observer variability was calculated using Dahlberg’s formula. The measurements obtained ranged between 0.90 and 1.42.

2. Descriptive analysis, including the transverse dimensions, sagittal dimensions, and calculated ratios among the sample.
3. Student’s t-test and Fisher’s Exact Test evaluated the presence of statistically significant differences between males and females. The data distribution normality test, through the quantile plots graphical method (Figure 2), revealed all the data were normally distributed.

**Results**

The mean age of students who participated in this study was 19.5 ± 2.2 yrs. Table 1 shows descriptive statistics for mandibular arch widths and lengths measurements of the total sample.

![Quantile plots](image)

**Figure 2:** quantile plots a graphical method for the normal distribution of the data.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch width</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 33</td>
<td>27.97</td>
<td>1.65</td>
<td>23.30</td>
<td>32.20</td>
</tr>
<tr>
<td>L 66</td>
<td>46.88</td>
<td>2.49</td>
<td>40.60</td>
<td>53.60</td>
</tr>
<tr>
<td>L 77</td>
<td>55.46</td>
<td>3.16</td>
<td>48.50</td>
<td>63.10</td>
</tr>
<tr>
<td>Arch Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 31</td>
<td>6.08</td>
<td>1.16</td>
<td>3.70</td>
<td>10.50</td>
</tr>
<tr>
<td>L 61</td>
<td>25.22</td>
<td>1.96</td>
<td>19.80</td>
<td>29.10</td>
</tr>
<tr>
<td>L 71</td>
<td>40.92</td>
<td>2.62</td>
<td>33.60</td>
<td>47.90</td>
</tr>
</tbody>
</table>

Table 1: Dimensions (in mm) of the mandibular dental arch (n = 104)

Table 2 shows a comparison of arch width and length measurements between males and females. Arch dimensions were significantly higher in males than in females (p ≤ 0.05), and there were statistically significant differences in all dimensions except L31 (p = 0.961) and L61 (p = 0.591).

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Male (n = 52)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Female (n = 52)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch width</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 33</td>
<td>28.43</td>
<td>1.58</td>
<td>27.51</td>
<td>1.61</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 66</td>
<td>48.09</td>
<td>2.41</td>
<td>45.67</td>
<td>1.94</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 77</td>
<td>57.08</td>
<td>2.98</td>
<td>53.84</td>
<td>2.43</td>
<td>&lt;0.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arch Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 31</td>
<td>6.08</td>
<td>1.19</td>
<td>6.07</td>
<td>1.14</td>
<td>0.961</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 61</td>
<td>25.32</td>
<td>1.95</td>
<td>25.12</td>
<td>1.98</td>
<td>0.591</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 71</td>
<td>41.67</td>
<td>2.57</td>
<td>40.18</td>
<td>2.47</td>
<td>0.003*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Dimensions (in mm) of the mandibular dental arch by gender (n= 104)

Table 3 shows the calculated five ratios of arch form dimensions of the total sample.
Determination of arch form for individual case:

The five types of arch forms were classified using Raberin’s [5] method:

**Narrow arch form:** All sagittal/Transverse ratios (L31/L33, L61/L66, L71/L77) are higher than average.

**Wide arch form:** All sagittal/Transverse ratios (L31/L33, L61/L66, L71/L77) are below average.

**Mid arch form:** None of the ratios deviates from the average

**Pointed arch form:** Only the L31/L33 ratio is higher than the average

**Flat arch form:** Only the L31/L33 ratio is below the average

The present study results revealed that 75% of Sudanese adults possess the mid dental arch form, 11.54% possess the narrow, 6.73% the wide and, 6.73% the pointed arch form. The flat arch form was not presented (Table 4). The difference in gender distribution was not significant in Fisher’s Exact Test, p = 0.607 Table 4.

**Discussion**

This study included young adults. According to growth studies in arch width changes, inter-canine and intermolar widths did not change after 13 years in females and 16 years in males [20]. Therefore, this sample had reached the adult level in arch dimensions.

The current study collected measurements from the anatomical points, incisal edges, molars, and canine cusp tips as evaluated by Raberin et al. [5]. According to Raberin, these points constitute the landmarks that define the mandibular arch’s breaking points that limit sectors on which different muscle groups act. Previous literature and studies on dental arch shape used conventional anatomical points on the incisal edges and molar cusp tips, etc., to classify dental arch forms using various mathematical forms [21]. Despite their clinical impact, conventional anatomic points do not provide clinical evidence of appropriate archwire absolute forms. On the contrary, points taken on the tooth facial axes vestibular surface give the exact shape of clinical archwire [22]. These relate directly to the brackets’ position in fixed orthodontic appliances.

The arch width and length measurements we observed in our sample were significantly higher in males. In most studies, [5, 7, 23, 24] the arch dimensions were smaller in females, so our results are consistent with these studies.

The present findings confirm that the Sudanese adult with normal occlusion has no single arch form, consistent with many studies conducted in different populations [5, 7, 23, 24]. Table 5 shows a comparison between Sudanese and other populations.

<table>
<thead>
<tr>
<th>Type of arch form</th>
<th>Sudanese</th>
<th>Caucasian</th>
<th>Nepalese</th>
<th>Indian</th>
<th>Yemeni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow</td>
<td>11.54%</td>
<td>23.7</td>
<td>18</td>
<td>17.5</td>
<td>30.9</td>
</tr>
<tr>
<td>Wide</td>
<td>6.73%</td>
<td>19.7</td>
<td>24</td>
<td>26.4</td>
<td>23.9</td>
</tr>
<tr>
<td>Mid</td>
<td>75%</td>
<td>18.7</td>
<td>13</td>
<td>22.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Pointe</td>
<td>6.73%</td>
<td>19.4</td>
<td>19</td>
<td>15.8</td>
<td>17.6</td>
</tr>
<tr>
<td>Flat</td>
<td>0%</td>
<td>18.3</td>
<td>26</td>
<td>17.5</td>
<td>18.3</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td>278</td>
<td>100</td>
<td>57</td>
<td>398</td>
</tr>
</tbody>
</table>

**Table 5:** Comparison of the types of arch form among Sudanese and other racial groups.

The mid arch form type was the most predominant one in the Sudanese sample. The narrow arch form type is predominant in Caucasian [5] and Yemeni [23] samples. Flat arch form types are predominant in Nepalese [24]. Wide arch form types are predominant in Gujarati [7]. This finding might be related to the fact that dissimilar populations show different arch form types’ different distributions.

The current study provides norms for mandibular transverse and sagittal dimensions that can be used as an easy method of classifying different forms of mandibular arches in Sudanese orthodontics patients (Figure 3).
Conclusion

Based on the present study’s results, the following conclusions can be drawn:

- In Sudanese adults, the mid arch form is predominant.
- Arch form types are not significantly associated with gender.
- A guide for the classification of mandibular arch forms in Sudanese orthodontics patients are available.

References

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