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Nabila Anwar
Aga Khan University

Mubassar Fida
Aga Khan University

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Variability of Arch Forms in Various Vertical Facial Patterns

Nabila Anwar and Mubassar Fida

ABSTRACT

Objective: To compare arch forms in various vertical facial patterns and to make arch form guides based on posterior intermolar widths.

Study Design: Cross-sectional comparative study.

Place and Duration of Study: The Aga Khan University Hospital, Karachi, from June 2007 to May 2008.

Methodology: Subjects with age range of 13-30 years were selected having full complement of teeth (upto second permanent molars) with absence of severe crowding (less than 7 mm). Exclusion criteria were presence of dental anomalies, previous dentoalveolar surgery, trauma or orthodontic treatment and craniofacial syndromes. One hundred subjects including 40 normodivergent, 30 hypodivergent and 30 hyperdivergent cases were selected. Occlusograms were made and various arch dimensions were measured. Arch forms were calculated according to ratios of three sagittal to three transverse dimensions.

Results: The mean age of the sample was 21 years and 5 months. Differences in arch dimension were found only in maxillary total arch length ($p=0.03$) and mandibular posterior intermolar width ($p=0.04$). Wide lower arches were predominant in all face types. Wide upper arches were predominant in only hypo- and hyperdivergent subjects.

Conclusion: Wide lower arches were predominant in all face types whereas wide upper arches were predominant in both hypo- and hyperdivergent subjects. A non-linear relationship was found between arch length and arch width; so arch form guides could not be made for specific face types.

Key words: Arch dimensions. Arch forms. Vertical face types.

INTRODUCTION

It is important to understand the relationship between craniofacial structures and arch dimensions.¹ Many studies have attempted to clarify the morphological features of craniofacial structures,²⁻⁴ dental arch widths⁴⁻¹⁶ and dental arch forms.^{5-8,11,14,17-19} Certain malocclusions are associated with specific facial types.⁴ Ricketts²⁰ reported that a correlation can exist between facial type and dental arch. The size and shape of the arches have a considerable implication in orthodontic diagnosis and treatment planning, affecting the space available, dental aesthetics and stability of dentition.^{7,20} The dimensions of a dental arch which include arch length, widths, and depth, also can have considerable implications in orthodontic diagnosis and treatment planning.⁵ Arch dimensions are usually modified according to treatment plan. Arch dimensions are also modified by the various arch wires used during treatment affecting the stability of the results achieved. These dimensional changes ultimately affect arch forms.

Dental arch form is basically a reflection of underlying bony morphology.¹⁷ Dentition usually compensates for

any underlying bony discrepancy. The mandibular dental arcade (arch) is considered as the major reference element of diagnosis and therapy in dentofacial orthopaedics. Although stability of arch form is undoubtedly one of the most desirable goals of orthodontics yet unfortunately it is the least understood goal.¹⁷ Arch form tends to return to its original form so the patient's existing arch form appears to be the best guide to future arch form and stability.¹⁸

Many geometric forms and mathematical functions have been proposed as models of the human dental arch.²¹⁻²⁵ However, it has become clear that the models defined by only one parameter cannot describe the dental arch form accurately.²⁶ The most suitable approach for comparing arch forms between groups of subjects is to quantitatively compare size and shape simultaneously.¹⁹

According to the results of Kageyama *et al.*¹ brachyfacial and hypodivergent faces tend to have relatively broad dental arches with increased arch depths as compared to other facial types. Previous knowledge suggests a correlation between craniofacial structures and arch forms. However, the strength of associations is not clearly reported in the literature. Also individual variations still are not uncommon and therefore, understanding the pattern in the patient pool being received at our clinic becomes essential.

The data present still seem insufficient to correlate face types with arch forms and therefore, this study was undertaken to quantify the nature of the arch form in various vertical facial patterns.

Department of Surgery, The Aga Khan University Hospital, Karachi.

Correspondence: Dr. Nabila Anwar, Asst. Prof. Orthodontics, Women Medical College, Murree Road, Abbottabad-22080.

E-mail: nabilabangash@gmail.com

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METHODOLOGY

This cross-sectional comparative study was done at the dental clinics of the Aga Khan University Hospital, Karachi, Pakistan from June 2007 to May 2008. One hundred subjects were selected with non probability purposive sampling having 40 normodivergent and 30 hypodivergent and 30 hyperdivergent cases.

Inclusion criteria were full complement of teeth (upto second permanent molars) and age ranging from 13 to 30 years. Exclusion criteria included severe crowding (less than 7 mm),⁴ presence of dental anomalies of form, structure, number and development; previous dentoalveolar surgery or maxillofacial trauma, cranio-facial syndromes, previous orthodontic treatment and asymmetry of greater than 2 mm.

Data were obtained from pre-treatment study casts and cephalographs of orthodontic patients at the Dental Section, the Aga Khan University Hospital, Karachi. Subject selection from patients at our clinic was based on facial patterns, determined by the amount of vertical growth by mandibular plane angle and Jarabak's facial height ratio on the cephalographs taken using standard techniques.

Reproducible reference points were marked on the study casts (both upper and lower) with a 2 H pencil which included mid mesioincisal edges of central incisors (labial side), canine tips, mesiobuccal cusp tips of the first permanent molars and distobuccal cusp tips of the second permanent molars. Occlusograms were made by photocopying study casts with two millimetric rulers placed at right angle to control parallax and magnification¹⁵ as shown in Figure 1. Dimensions of the dental arches were determined according to three transverse and three sagittal measurements. These points constituted the landmarks of the dental arch form and defined the breaking points of the arch and limit sectors on which different muscle groups have an action in formulating the final arch form.

To asses measurement error, randomly selected 10 cephalographs and 10 casts were retraced and recopied respectively, 2 weeks after the initial procedure and remeasured. Paired sample t-test was applied between the two groups of readings. The result was found to be insignificant (p value > 0.05) and a high correlation (r ≥ 0.9) was found between the two set of records.

SPSS for Windows (version 15.0, SPSS Inc. Chicago) was used for statistical data analysis. Descriptive statistics including mean and standard deviation for the various arch dimensions in various vertical facial types were computed. Statistical significance level was set at ≤ 0.05. For evaluation of arch form, ratios of three sagittal (L₃₃, L₆₆, L₇₇) to transverse measurements (L₃₁, L₆₁, L₇₁) were determined. As a result one anterior (L₃₁/L₃₃), one middle (L₆₁/L₆₆) and one posterior arch

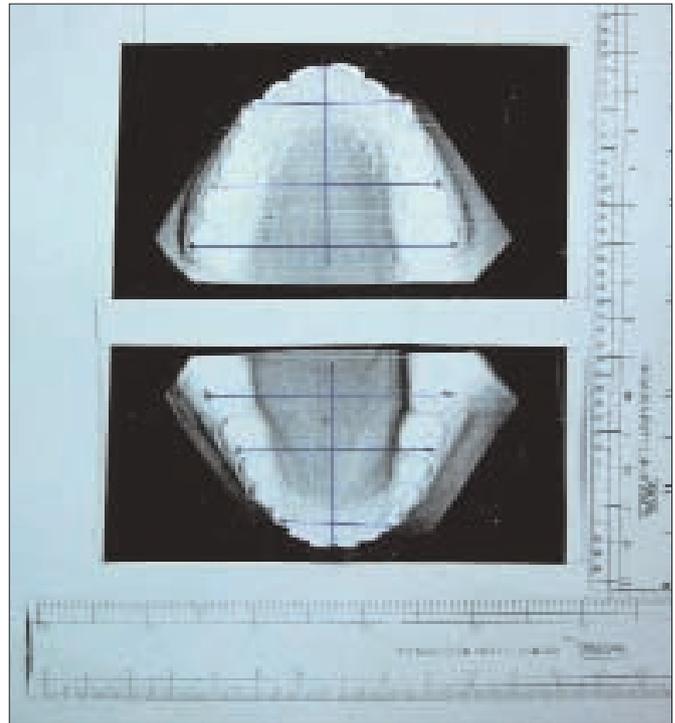


Figure 1: Occlusogram with measurements for arch form characterization.

Arch form was characterized by the values of the following ratios: L₃₁/L₃₃, L₆₁/L₆₆, L₇₁/L₇₇. Average values will be calculated and arch form will be classified as one of the following:¹

Form 1 narrow, the differences in three sagittal/transverse ratios are positive.

Form 2 wide, the differences in three sagittal/transverse ratios are negative.

Form 3: mid, further classified as:

Form 3a: Narrow wide, when difference L₃₁/L₃₃ is positive while differences L₆₁/L₆₆, L₇₁/L₇₇ are negative.

Form 3b: Wide narrow, when difference L₃₁/L₃₃ is negative while differences L₆₁/L₆₆, L₇₁/L₇₇ are positive.

Form 4: unclassified, which does not fit any of the above classes.

dimension ratios (L₇₁/L₇₇) were formulated to characterize the arch form. Arch dimension ratios were compared in the three face types by ANOVA. Arch forms were formulated by the classification given in Figure 2. Pearson's correlation was used to determine the strength of association of posterior intermolar width and total arch length. Chi square test was used to determine the association of face types and arch forms.

RESULTS

The mean age of the entire sample was 21 years and 5 months with the standard deviation of 7 years and 8 months. The sample consisted of 67 females and 33 males and therefore, the collected sample was predominantly of female subjects. Table I shows the maxillary and mandibular arch dimensions ratios amongst the three facial types and their comparison in the three face types by ANOVA.

In the mandibular arch, 34 cases had negative differences of all three ratios from the mean value which therefore, classified those cases as *Form 2* or *Wide arches*. The differences in 22 cases were positive from the mean value and therefore, those arches were classified as *Form 1* or *narrow arches*. Out of the rest of 44 cases, 50% (n=22) had positive differences in the anterior ratio

Table I: Comparison of maxillary and mandibular arch dimensions ratios amongst the three facial types.

Ratios	Total N=100 Mean ± SD	Hypodivergent N=30 Mean ± SD	Normodivergent N=40 Mean ± SD	Hyperdivergent N=30 Mean ± SD	p-value
Maxillary Anterior Ratio L ₃₁ / L ₃₃	0.33 ± 0.32	0.39 ± 0 .59	0.31 ± 0.06	0.30 ± 0.05	0.47
Maxillary Middle Ratio L ₆₁ / L ₆₆	0.60 ± 0.13	0.61 ± 0.22	0.61 ± 0.06	0.57 ± 0.06	0.36
Maxillary Posterior Ratio L ₇₁ / L ₇₇	0.79 ± 0.10	0.79 ± 0 .10	0.7987 ± 0.13	0.78 ± 0.06	0.93
Mandibular Anterior Ratio L ₃₁ / L ₃₃	0.29 ± 0.53	0.41 ± 0 .97	0.58 ± 0.21	0.76 ± 0.09	0.31
Mandibular Middle Ratio L ₆₁ / L ₆₆	0.58 ± 0.13	0.25 ± 0 .06	0.57 ± 0.05	0.77 ± 0.05	0.95
Mandibular Posterior Ratio L ₇₁ / L ₇₇	0.77 ± 0.07	0.22 ± 0.06	0.57 ± 0.10	0.77 ± 0.07	0.86

Test of significance: ANOVA; Level of significance: $p \leq 0.05$.

L₃₁/L₃₃ and 50% had negative difference from the mean in this ratio. This shows that 50% cases were narrowed anteriorly whereas 50% cases were wide anteriorly. Also, 59.1% (n=26) arches were converging posteriorly as shown by a positive difference in the ratio L₇₁/L₇₇.

Further classification of arch form was done on the basis of results of cross tabulation. It was found that 11 cases were characterized as *Form 3a* or *narrow wide* arches being narrowed anteriorly and wide posteriorly. Fifteen cases were characterized as *Form 3b* or *wide narrow* arches. Eighteen cases did not follow any of the above arch forms and therefore, remained *unclassified* and these were grouped into *Form 4*.

The overall summary of the mandibular arch forms in the various facial patterns shown in Figure 2 reveals that wide arches were predominant arch form in all the face types.

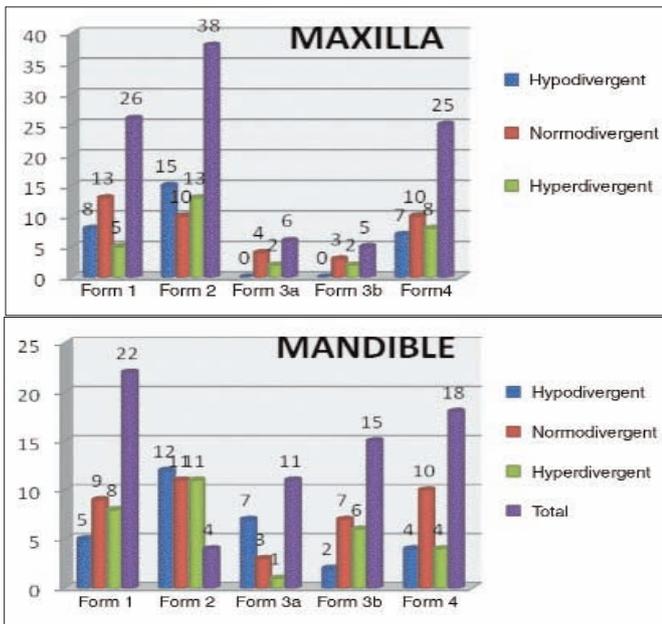


Figure 2: Summary of overall maxillary and mandibular arch forms.

Distribution of other arch forms in the mandible in various facial patterns were as follows: *Form 1* or *narrow arches* and *Form 3b* or *wide narrow* were the commonest in hyperdivergent group (26.6% and 20% respectively), *Form 2* or *wide arches* and *Form 3a* i.e. *narrow wide* were the most common in hypodivergent group (40% and 23.3% respectively). The highest amount of *Form 4* or *unclassified* arch forms were found in the normodivergent sample (25%).

Similarly in the maxillary arch 26 cases had all positive differences of the ratios from the mean value which therefore, classified them as *Form 1* or *narrow* arches, the difference in 38 cases were negative and therefore those arches were classified as *Form 2* or *wide* arches. Out of the rest of 36 cases, 12 cases (33.3%) had positive differences in the ratio L₃₁/L₃₃ and 24 cases (66.6%) had negative difference from the mean in this ratio. This shows that 33.3% cases were narrow anteriorly whereas 66.6% cases were wide anteriorly. Six cases were characterized as *Form 3a* or *narrow wide* and 5 cases were characterized as *Form 3b* or *wide arches*. Twenty five cases did not follow any of the above patterns and therefore, remained unclassified and were placed in *Form 4*. The predominant maxillary arch forms was such that wide arches were predominant arch form in hypodivergent subjects (50%) and hyperdivergent subjects (43.3%) whereas narrow arch form was more common in normodivergent subjects (32.5%).

Form 1 or *narrow* and *3b* *wide narrow* arches were the commonest in normodivergent group (32.5% and 7.5%), *Form 2* or *wide* arches were the most common in hypodivergent group (50%) and *Form 3a* i.e. *narrow wide* arches were commonest in hyperdivergent group of sample (32.5%).

Figure 3 shows the characterization results of arch forms in various face types in both the arches. In hypodivergent sample the predominant arch form was wide for both the maxilla (50%) and mandible (40%). In normodivergents, the predominant arch form in maxilla was narrow (32.5%) and in the mandible it was wide (27.5%). Predominant arch form in hyperdivergents was wide for the maxilla (43.3%) and the mandible (36.6%).

Strength of association for the posterior intermolar width was weak with the total arch length as found in the correlation analysis. For maxillary intermolar and maxillary total arch length, it was $r = -0.003$ and $p = 0.97$ and for mandibular intermolar and mandibular total arch length, it was $r = -0.04$ and $p = 0.69$. Scatter plots (Figure 4) confirmed this non-linear relationship for both the upper and lower arch posterior intermolar widths with the total arch length. Therefore, arch form guides could not be made for the different vertical face types.

Chi square test was used to see association between particular face types and arch form types. The Fischer's exact value for the maxillary arch forms was 0.237 and for the mandibular arch forms was 0.218.

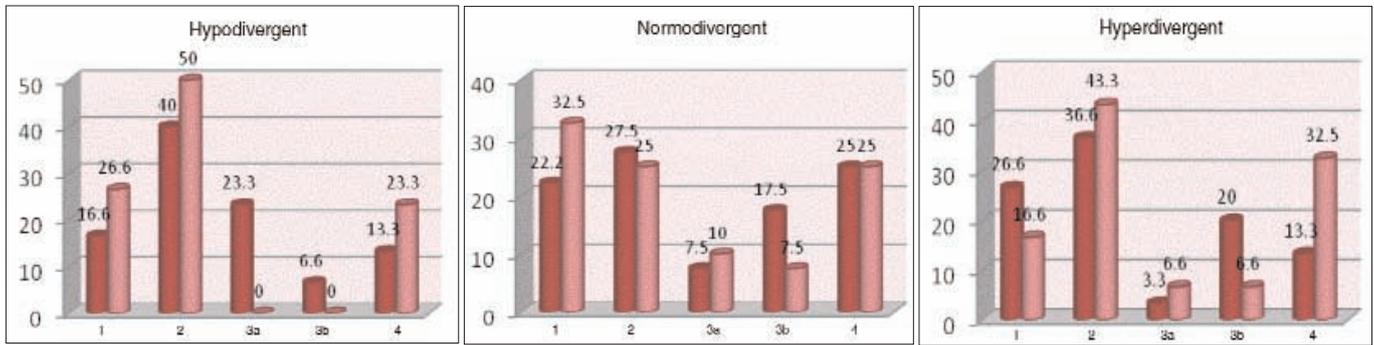


Figure 3: Summary overall arch forms in percentages in various face types: arch form guides for the various vertical facial patterns taking posterior intermolar width as a primary determinant of the arch form.

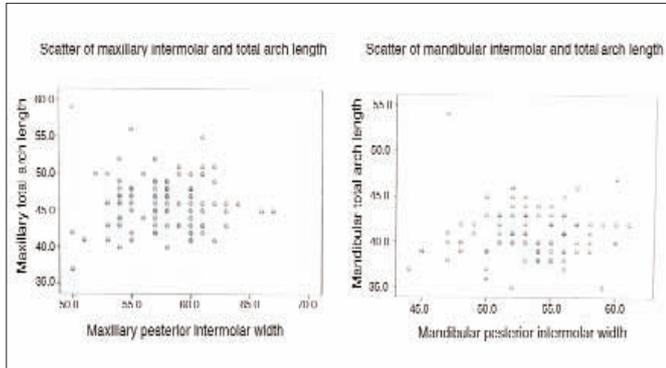


Figure 4: Scatter plot of maxillary intermolar and total arch length and mandibular intermolar and total arch length.

DISCUSSION

Arch form characterization is desirable since a fundamental goal in orthodontics is the maintenance or successful and stable treatment modification of that arch form. The most commonly used terms of square, ovoid, tapered or wide or narrow forms of the dental arch have not yet been mathematically defined and therefore, three ratios were chosen across the whole of dental arch so as to better define the dimensions as well as form. Some authors, like De LaCruz¹⁸ postulate the maintenance of arch form because of increased tendency to relapse towards pre-treatment form.

The pattern of arch form in the overall sample and the individual face types were seen to find any possible associations of the arch forms with the craniofacial pattern. The anterior or L₃₁/L₃₃ ratio characterizes the anterior curve of the arch. This part of the arch depends on the length and width of the incisivocanine arch. When only the anterior ratio was considered in the whole sample similar results for both the arches were seen in both the maxillary and mandibular arches. Fifty-six percent cases had negative difference from the mean in the anterior ratio whereas rest had positive difference from the mean. The results show that the whole sample did not show a characteristic anterior narrowing of the arch. Forty-four percent sample had anterior narrowing of the arch. Particularly this dimension is aimed to be maintained or be unexpanded while sequencing stainless steel arch wires during orthodontic treatment.

In the mandibular sample it was found that wide arches were more common (34%) as compared to the narrow arches (22%). Similar pattern was also evident for the maxillary arch: 38% wide arches as compared to 26% narrow arches. So the overall predominant arch form in this sample was *Form 2* or *wide* arch for both the maxilla as well as the mandible.

The evaluation of predominant of a particular arch form in the individual face groups was also aimed in this study. In the mandible, wide arches were found to be predominant in all three face types, frequency however, varied: hypo- (40%), normo- (27.5%) and hyper- (36.6%). In the upper arch however, the predominant arch form in normodivergent was narrow arch or *Form 1* (32.5%) whereas *wide* arches were dominant in both hypo- (50%) and hyperdivergent (43.3%). This finding confirms the concept given by Ricketts²⁰ who believed that brachyfacial hypodivergent faces have relatively broad dental arches. The results also are in agreement with the results of Kageyama *et al.*¹ The relatively lower frequency in the mandibular arch in hypodivergent subjects as compared to the maxillary arch however, is quite debatable. Kageyama *et al.*¹ in their study found that mandibular arch form did not correlate with facial types. The low prevalence according to them was due to anteroposterior displacement and/or rotation of mandible in vertical malocclusions. The probable cause of low frequency in our subjects apart from other environmental factors might be more muscular forces on the lower arch which includes the perioral muscles and the intraoral functional forces. Although wide arch form predominated in all face types in both arches (except in maxillary normodivergent), the prevalence was variable being the highest in maxillary hypodivergent sample (50%).

The relationship between form and function still remains unclear. The greatest variability in arch form was seen in normodivergent sample. The predominant type in the mandible was wide (27.5%) followed by narrow arches (22.5%). Predominance in maxilla was narrow (32.5%) followed by wide (25%). Twenty-five percent cases in both the arches were *Form 4* or *unclassified*. This shows a highly variable pattern of arch form in the normodivergent

sample. The highest frequency of *Form 4* or *unclassified* was found in normodivergent sample for both the upper (25%) and lower (25%) arches. The highest frequency of various arch forms in different vertical face types were as follows; in the mandibular arch, *Form 1* was found with highest frequency in hyperdivergent (26.6%), *Form 2* in hypodivergent (40%), *Form 3a* in hypodivergent (23.3%), *Form 3b* in hyperdivergent (20%) and *Form 4* in normodivergent (25%). In the maxillary arch, *Form 1* was found with highest frequency in normodivergent (32.5%), *Form 2* in hypodivergent (50%), *Form 3a* in hyperdivergent (32.5%), *Form 3b* in normodivergent (2.5%) and *Form 4* in normodivergent (25%).

There were statistically insignificant associations between arch forms and face types in this sample. Very few studies, to date, have been conducted on the concept of relationship of craniofacial dimension with the arch form.^{1,20} The results of this study also shows variations in the predominant arch form and therefore, a strong association of arch form with vertical face types was not found. This implies to the multiple epigenetic and environmental factors that come into play in the formulation of the ultimate arch form of an individual and therefore, a particular arch form for the particular face type could not be found from this study result. A 'particular' arch form for a particular face type can be considered unprevalent in nature.

One of the objectives of this study was to make arch form guides for specific face types taking posterior intermolar width as a reference. Because a weak linear relationship between posterior intermolar width and other sagittal arch dimensions was noted in this study, therefore, predictability of these variables by posterior intermolar width was not achievable with high accuracy and hence arch form guides could not be made for a particular face type according to their specific posterior intermolar width. Because of the great variability in individual arch forms a single arch form cannot be used in all orthodontic cases.²⁷

Limitations of the study include small sample size which was predominantly female sample. It is recommended to identify the factors to allow for individual modification of treatment and Pakistani population norms for the arch dimensions.

CONCLUSION

Forty-four percent of the arch forms in this sample were narrowed anteriorly. Wide arch form was predominant in lower arch whereas narrow arch form was predominant in upper arch. Hypodivergent and hyperdivergent facial patterns had predominantly wide arches while normodivergent facial pattern had variable arch forms. There was a non-significant association between arch forms, arch dimensions and face types. Arch form guides

could not be formed because of a weak linear relationship between posterior intermolar width and total arch length.

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