Relationship between dental arch width and vertical facial morphology in untreated adults

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SUMMARY The objectives of this study were to investigate if a relationship exists between dental arch width and the vertical facial pattern determined by the steepness of the mandibular plane, and to examine the differences in dental arch widths between male and female untreated adults. Lateral cephalograms and dental casts were obtained from 185 untreated Caucasians (92 males, 93 females) between 18 and 68 years of age with no crossbite, minimal crowding, and spacing. The angle of the mandibular plane (MP) to the anterior cranial base (SN) was measured on cephalograms of each patient. Dental casts were used to obtain comprehensive dental measurements including maxillary and mandibular intercanine, premolar, and intermolar widths, as well as the amount of crowding or spacing. The arch widths of males and females were analysed and the differences between them were tested for significance using a Student’s t-test. Regression analysis was used to determine the statistical significance of the relationships between MP–SN angle and dental arch width and crowding or spacing.

The results showed that male arch widths were significantly larger than those of females ($P < 0.05$). For both males and females, there was a trend that as MP–SN angle increased, arch width decreased. It was concluded that dental arch width is associated with gender and facial vertical morphology. Thus, using individualized archwires according to each patient’s pre-treatment arch form and width is suggested during orthodontic treatment.

Introduction

It is generally accepted among orthodontists that a relationship exists between vertical facial morphology and the cants of the mandibular plane. Schudy (1964, 1965) advocated the use of the anterior cranial base (SN) as the reference line to determine the steepness of the mandibular plane (MP). A subject with a high MP–SN angle (steep MP) tends to have a longer face, and one with a low MP–SN angle (flat MP) often has a shorter face (Ricketts et al., 1982; Enlow and Hans, 1996).

A long-face individual usually has narrower transverse dimensions (dolichocephalic) and a short-face individual wider transverse dimensions (brachycephalic), according to Ricketts et al. (1982), Enlow and Hans (1996), and Wagner and Chung (2005). A question therefore arises as to the relationship between vertical facial morphology and dental arch width. Also, is there any difference in arch widths between male and female subjects? Several studies have addressed these questions, but their results were inconclusive. For example, Howes (1957) found that steep MP individuals generally had larger teeth and narrower and shorter arches than flat mandibular plane individuals when measured from the buccal cusp tips of the maxillary first premolars. Isaacson et al. (1971) reported that subjects with longer faces presented with a decrease in maxillary intermolar width. However, they did not distinguish between males and females. Nasby et al. (1972) noted that the mean maxillary and mandibular arch circumference and mandibular intermolar width were greater in subjects with low MP–SN angles when compared with those with high MP–SN angles. In their study, the subjects were adolescents without discussion of gender and ethnicity. Using postero-anterior (PA) cephalograms, Christie (1977) found that adult brachyfacial males, when compared with ‘standard’ males, had greater maxillary and mandibular widths. No difference, however, was found in the arch widths of brachyfacial versus standard females.

In terms of the difference in arch width between males and females, Wei (1970) evaluated PA cephalograms of Chinese adults and noted gender differences in maxillary and mandibular intercanine widths. Eroz et al. (2000) reported that in children, males had significantly larger intermolar widths when compared with females.

Clinically, preformed archwires are routinely used by many orthodontists regardless of the facial type and gender of the patients. The purpose of the present study was to investigate if dental arch widths are correlated with vertical facial types (MP–SN angle) and if there are any differences in arch widths between untreated male and female adults.

Subjects and methods

Sample

One hundred and eighty-five untreated Caucasian adults (92 males, 93 females) aged from 18 to 68 years, whose initial
orthodontic records were taken at the University of Pennsylvania Orthodontic Clinic (n = 35) and six local private practice offices (n = 11, 21, 22, 26, 34, 36, respectively) were included in this study. Inclusion criteria included a full dentition except third molars, pre-treatment lateral cephalogram, and maxillary and mandibular dental casts available. Exclusion criteria included previous orthodontic treatment, edentulous spaces, history of trauma, significant cuspal wear, extensive restorations or prosthetics, anterior and posterior crossbites, and severe crowding (>9 mm) or spacing (>9 mm).

The sample was randomly selected, and then, for descriptive purposes, the subjects were classified into three different groups according MP–SN angle: low <27 degrees, average 27–37 degrees, and high >37 degrees. These values represent 1 standard deviation (SD) from the average MP–SN angle reported by Riedel (1952).

**Measurements**

For each subject, MP–SN angle was measured. The mandibular plane was drawn from menton (Me) to the inferior border of the angular area of the mandible (Schudy, 1965; Figure 1).

Dental cast measurements were performed using a digital calliper accurate to 0.01 mm. The following maxillary and mandibular dimensions were measured (Figure 2):

1. intercanine width (buccal cusp tip and widest labial aspect),
2. first and second interpremolar widths (buccal cusp tip and widest labial aspect),
3. first intermolar widths (mesiobuccal cusp, central fossa, widest buccal, and narrowest lingual aspect),
4. tooth size—arch length discrepancy.

**Tooth size—arch length discrepancy**

Tooth size—arch length discrepancy was calculated by first determining the arch length available (Figure 3). The arch length required was then subtracted from this value. Arch length required was equal to the sum of the mesiodistal widths of each individual tooth from second premolar to second premolar, measured from the contact points (Proffit, 2000).

The description of the male and female sample in terms of age, MP–SN angle, ANB angle (point A—nasion—point B, Figure 1), and amount of crowding or spacing are shown in Table 1.

**Statistical analysis**

Descriptive statistics, including the mean and SD, were calculated for all measurements. A Student’s two-tailed
t-test was used to determine if the differences in measurements between the male and female groups were significant. Moreover, regression analyses were carried out to determine the degree to which MP–SN variation was predicted by dental arch width and dental crowding in males and females separately.

In order to evaluate intra-examiner error, lateral cephalograms and models of 13 males and 10 females were remeasured after 4 weeks, and their mean differences were used to determine paired t-test significance and Pearson’s correlation coefficients. Significance for all statistical tests was predetermined at $P < 0.05$.

**Results**

Intra-examiner measurement error showed a high correlation with Pearson’s correlation coefficient values ($r$) of 0.90–0.99 for all angular and linear measurements. When using the paired t-test to compare the means between the duplicate measurements, only one measurement (maxillary second premolar width) exhibited a statistically significant difference ($P < 0.05$). For this, the mean difference was 0.47 mm and Pearson’s correlation coefficient 0.988, indicating a very high degree of consistency between the two trials.

Table 2 shows the dental arch width measurements of male and female subjects. It was clearly demonstrated that males had significantly larger dental arch widths than females ($P < 0.05$).

The arch width measurements of low, average, and high MP–SN angle groups of males and females, respectively, are shown in Tables 3 and 4. The low-angle group had larger arch widths than the high-angle group for most measurements. Table 5 shows the regression analysis of MP–SN angle versus maxillary and mandibular arch widths of males and females. Regression analyses of males showed statistically significant correlations between MP–SN angle and the following arch width measurements: maxillary canine cusp tip, maxillary canine most buccal aspect, maxillary first premolar cusp tip, maxillary second premolar cusp tip, maxillary first molar central fossa, maxillary first molar most buccal aspect, mandibular canine cusp tip, mandibular first premolar cusp tip, and mandibular first premolar most buccal aspect (Table 5). It should be noted that their $R^2$ square values were small. In terms of females, a significant correlation was found between MP–SN angle and arch width measurements of maxillary first premolar width (buccal cusp tip) and second premolar width (buccal cusp tip and most buccal) (Table 5). Similarly, their $R^2$ square values were small. All other dental measurements, for males and females, including maxillary and mandibular crowding, were not statistically significant.

### Table 1  Description of the sample.

<table>
<thead>
<tr>
<th></th>
<th>Male ($n = 92$)</th>
<th>Female ($n = 93$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>34.8</td>
<td>11.5</td>
</tr>
<tr>
<td><strong>MP–SN (degrees)</strong></td>
<td>29.6</td>
<td>7.6</td>
</tr>
<tr>
<td><strong>ANB (degrees)</strong></td>
<td>3.1</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Crowding (−) or spacing (+)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla (mm)</td>
<td>−0.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Mandible (mm)</td>
<td>−2.1</td>
<td>2.7</td>
</tr>
</tbody>
</table>

### Table 2  Maxillary and mandibular arch width measurements (millimetres).

<table>
<thead>
<tr>
<th></th>
<th>Male ($n = 92$)</th>
<th>Female ($n = 93$)</th>
<th>Significance ($P$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maxilla</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Intercanine width (cusp tip)</td>
<td>33.47</td>
<td>2.52</td>
<td>32.15</td>
</tr>
<tr>
<td>Intercanine width (most buccal)</td>
<td>38.49</td>
<td>2.62</td>
<td>37.08</td>
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<tr>
<td>First premolar width (buccal cusp tip)</td>
<td>39.87</td>
<td>3.27</td>
<td>38.68</td>
</tr>
<tr>
<td>First premolar width (most buccal)</td>
<td>44.36</td>
<td>2.93</td>
<td>42.79</td>
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<tr>
<td>Second premolar width (buccal cusp tip)</td>
<td>45.39</td>
<td>3.38</td>
<td>43.46</td>
</tr>
<tr>
<td>Second premolar width (most buccal)</td>
<td>49.34</td>
<td>3.20</td>
<td>47.17</td>
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<tr>
<td>Intermolar width (mesiobuccal cusp tip)</td>
<td>50.12</td>
<td>3.97</td>
<td>49.03</td>
</tr>
<tr>
<td>Intermolar width (central fossa)</td>
<td>45.91</td>
<td>3.27</td>
<td>44.16</td>
</tr>
<tr>
<td>Intermolar width (most buccal)</td>
<td>56.08</td>
<td>3.49</td>
<td>54.11</td>
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<tr>
<td>Intermolar width (most lingual)</td>
<td>33.23</td>
<td>3.13</td>
<td>31.71</td>
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<tr>
<td><strong>Mandible</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
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<td>24.87</td>
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<td>24.11</td>
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<td>2.73</td>
<td>31.95</td>
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<td>42.52</td>
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<td>Intermolar width (central fossa)</td>
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<td>3.04</td>
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<tr>
<td>Intermolar width (most buccal)</td>
<td>53.53</td>
<td>3.15</td>
<td>52.16</td>
</tr>
<tr>
<td>Intermolar width (most lingual)</td>
<td>31.87</td>
<td>2.76</td>
<td>30.22</td>
</tr>
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</table>
Discussion

The results of this study were analysed with regression line fit plots. The sample was drawn randomly from a group of untreated subjects, allowing the use of this analysis. Because the independent variable (MP–SN) and all of the predictor measurements were continuous variables, it was more appropriate to analyse the data with regression analysis rather than ANOVA. However, as the untreated subjects were not recruited from a population sample but from a university clinic and six local private practice offices, some inherent bias might be possible.
The MP–SN angle was used as the measurement of vertical facial morphology in the present study. However, due to natural cranial variation, there may be variation in the anterior cranial base (SN), which may tip up or down. The ratio of posterior face height (PFH, S–Go) to anterior face height (AFH, Na–Me) is another measurement for vertical facial morphology not based on the mandibular plane (Björk, 1969). Further research is required to determine if there is a correlation between PFH/AFH ratio and dental arch width.

Only skeletal Class I (as determined by ANB angle) subjects were examined because more dental compensation is expected in skeletal Class II or III subjects, which might obscure the relationship between vertical facial morphology and transverse dental arch widths.

The present study investigated untreated adult males and females separately. It has previously been demonstrated that males and females exhibit different skeletal facial dimensions (Wei, 1970; Ingerslev and Solow, 1975; Chung and Wong, 2002; Chung and Mongiovi, 2003), as well as differences in maxillary and mandibular arch widths (Moyers et al., 1976; Christie, 1977). Unfortunately, many of the earlier studies that examined arch width and mandibular plane angle combined the genders (Howes, 1957; Isaacson et al., 1971; Nasby et al., 1972; Schulhof et al., 1978). In addition, the present sample was limited to non-growing, adult individuals, unlike many of the previous investigations that included only growing children (Isaacson et al., 1971; Nasby et al., 1972; Eroz et al., 2000).

Ideally, this type of study should be conducted using patients with ideal dentitions without any crowding or spacing. However, due to difficulties in finding ideal untreated subjects and subsequent limitations in sample size, those with crowding and spacing up to 9 mm were included. The relationship between crowding (spacing) and arch width was also examined. Interestingly, the data suggested that the cant of mandibular plane was not related to maxillary or mandibular crowding for males and females. This is in direct opposition to the findings of Nasby et al. (1972) and Christie (1977).

For the maxillary arch, there was a statistically significant inverse relationship between the mandibular plane angle and dental arch width between the maxillary canines, first premolars, second premolars, first molars in males, and between the second premolar widths (cusp tip and most buccal measurements) in females. However, statistical analysis showed that the $R^2$ value was small, which suggests that the correlation was not very strong.

For the mandibular arch, it was found that males had a statistically significant correlation between the mandibular plane angle and mandibular intercanine and first premolar widths. Similar to the maxillary arch, the $R^2$ square value was small, suggesting the correlation was not strong. No significant correlation was found for females.

In contrast to Nasby et al. (1972), who demonstrated narrower mandibular intermolar widths in high-angle children, the present data did not support such a relationship between mandibular intermolar width and mandibular plane angle.
angle. Wagner and Chung (2005) found that while the growth of the maxilla plateaus at about 14 years of age, the skeletal width of the mandible continues to grow, at least in low- and average-angle groups. It is conceivable that as the mandible continues to increase in width, the mandibular molar compensates by inclining lingually and thereby maintaining the intermolar width. In fact, a number of authors have suggested that individuals with increased vertical dimensions have posterior teeth that tend to be more buccally inclined, whereas those with decreased vertical dimensions have posterior teeth that tend toward more lingual inclination (Isaacson et al., 1971; Schudy, 1971; Schendel et al., 1976; Guilherme et al., 2004).

Musculature has been considered as a possible link in this close relationship between the transverse dimension and vertical facial morphology. In fact, a number of studies have illustrated the influence of masticatory muscles on craniofacial growth. The general consensus is that individuals with strong or thick mandibular elevator muscles tend to exhibit wider transverse head dimensions (Ringqvist, 1973; Ingerslev and Helkimo, 1978; Weijs and Hillen, 1984; Hannam and Wood, 1989; Kiliaridis and Kalebo, 1991; Van Spronsen et al., 1991; Bakke et al., 1992; Kiliaridis, 1995). Strong masticatory musculature is often associated with a brachyfacial pattern (short face). This muscular hyperfunction causes an increased mechanical loading of the jaws. This, in turn, may cause an induction of sutural growth and bone apposition which then results in increased transverse growth of the jaws and bone bases for the dental arches. Several studies investigating masseter thickness have also illustrated an effect on the inclination of posterior teeth such that subjects with short faces generally exhibit increased masseter muscle mass, which may result in posterior teeth that are more lingually inclined (Weijs and Hillen, 1984; Kiliaridis and Kalebo, 1991; Van Spronsen et al., 1991; Bakke et al., 1992; Tsunori et al., 1998).

Dental arch width is certainly a multifactorial phenomenon (Schulhof et al., 1978). Although the data from the present study showed an inverse trend between MP–SN angle and dental arch widths, the correlation was not very strong. It seems the MP–SN angle might be only one of the contributing factors. Moreover, in agreement with Eroz et al. (2000), the results demonstrated that the male arch widths were significantly greater than female arch widths. This highlights the importance of using individualized archwires according to pre-treatment arch form and width for each patient during orthodontic treatment.

Conclusions

The following conclusions can be made from this study:

1. The dental arch widths in males were significantly greater than those in females.

2. In both males and females, as MP–SN angle increased, arch width tended to decrease.

3. Since dental arch width is associated with gender and facial vertical morphology, using individualized archwires according to each patient’s pre-treatment arch form and widths is suggested during orthodontic treatment.

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