The association of tongue posture with the dentoalveolar maxillary and mandibular morphology in Class III malocclusion: a controlled study

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SUMMARY The aim of the present study was to evaluate the association of tongue posture with the dentoalveolar maxillary and mandibular morphology in a group of Class III subjects in comparison to a group of Class I subjects. Twenty Class III subjects (9 males, 11 females, 19.2 ± 4.6 years) and 20 Class I subjects (6 males, 14 females, 17.4 ± 1.7 years) were included in the present study. Maxillary and mandibular morphology was defined by the intermolar and intercanine distances, at both the cusps and gingival levels, and by measuring surface area and volume of the palatal vault and mouth floor assessed on three-dimensional digital models. Tongue-to-palate distances were measured on lateral cephalograms. The groups were compared using the Mann–Whitney U-test and correlations between each morphological parameter and the tongue-to-palate distances were calculated using the Spearman correlation coefficient. The mandibular intermolar width at the gingival level was significantly greater in the Class III group (P < 0.01), while the maxillary intercanine widths were significantly smaller in the Class III group (P < 0.05). The mouth floor area and volume and the respective ratios between the mouth floor and palate were significantly greater in the Class III group (P = 0.01). The tongue-to-palate distances were generally greater, i.e. lower tongue posture, for the Class III subjects. Significant correlations were seen between tongue-to-palate distances in the posterior region with the area ratio (rho = 0.44, P < 0.05). Tongue posture is significantly lower in Class III subjects and is associated with the dentoalveolar characteristics of the maxilla and mandible.

Introduction

Growth of the maxilla and mandible is influenced either by genetic and/or environmental factors (Proffit, 1978; McNamara, 1980; Mew, 1986; Melsen et al., 1987). It is currently accepted that genes and gene products regulate craniofacial morphogenesis. However, these gene products do not determine growth and specific form, but they rather provide factors that may affect the receptivity and responsiveness of cells to intrinsic and extrinsic stimuli (Carlson, 2005). Therefore, it appears that a range of physiologic, pathologic, and mechanical factors can influence growth (Mew, 1986). Although it has been shown that a close form and function relationship exists, the degree of interplay is still a matter of discussion (Melsen et al., 1987). In order to assess any environmental effects on the development of Class III skeletal malocclusion the knowledge of its association with given environmental factors, i.e. tongue posture would be useful.

While several previous studies have reported (Bandy and Hunter, 1969; Postlethwaite, 1986; Tamari et al., 1991) or not (Yoo et al., 1996) an influence of tongue size on the perimeter of the mandibular dental arch (Bandy and Hunter, 1969; Tamari et al., 1991), to date it is still a matter of conjecture that tongue features would be responsible for mandibular prognathism. The aim of the present study was thus to evaluate the association of tongue posture, measured as the tongue-to-palate distance, with the dentoalveolar maxillary and mandibular morphology in a group of Class III subjects in comparison to a group of Class I subjects.

Materials and methods

Ethical approval for this study was gained from the Slovenian Ethical Committee at the Medical University in Ljubljana, Slovenia, and written informed consent was obtained from each patient.

Material and study design

Study casts and lateral cephalograms of 40 randomly selected subjects, from a pool of patients referred to our clinic, were collected for this study. Twenty (9 males, 11 females, aged 19.2 ± 4.6 years) had a severe skeletal Class III relationship (ANB angle: −4.6 ± 2.4°; Wits
appraisal: $-11.3 \pm 3.5$ mm), Class III molar relationship and reverse overjet (Class III). The control group consisted of twenty Class I subjects (6 males, 14 females, aged 17.4 ± 1.7 years) with skeletal Class I relationship (ANB angle: 2.2 ± 2.3°; Wits appraisal: $-0.3 \pm 2.4$ mm), Class I molar relationship and a mild malocclusion according to the Eismann–Farcnik occlusal index (Ovsenik and Primozic, 2007). Only subjects with a full permanent dentition, with no missing or extracted teeth were included. Further, none of the patients exhibited any tooth crown malformations. The Class I subjects included as controls in this study had a mild malocclusion (mild crowding in the dental arches, less than 5 mm), mainly seeking treatment for aesthetic reasons, with no speech or myofunctional impairment and no history of previous orthodontic/orthopaedic treatment. Only subjects in whom the peak of mandibular growth ended according to the cervical vertebral maturation method (Baccetti et al., 2002) were included.

Three-dimensional evaluation of jaw morphology

The dental and alveolar characteristics of the maxilla and mandible were evaluated on three-dimensional (3D) digital models of the subjects’ pre-treatment study casts. Study casts were scanned at a distance of 60 cm with a Konica/Minolta Vivid 910 laser scanner using a lens with a focal distance of 25 mm. With this lens, the scanner has a reported accuracy of 0.22 mm (Keating et al., 2008). The 3D data were imported to a reverse modelling software package, Rapidform™ 2006 (INUS Technology Inc, Seoul, Korea).

Intermolar and intercanine transverse widths at the cusp and gingival levels were measured on the 3D digital models of the maxillary (Figure 1A) and mandibular (Figure 1B) dental arches. Further, surface area and volume of the palatal vault and of the mouth floor were calculated.

In order to measure the palatal surface area and volume, a gingival plane and a distal plane were used as boundaries for the palate. The gingival plane was created by connecting the midpoints of the dentogingival junction of all erupted upper permanent teeth. The distal plane was created through two points at the distal of the first upper permanent molar perpendicular to the gingival plane. The palatal surface area and volume (Figure 1C) were then calculated. To calculate the surface area and volume of the mouth floor (Figure 1D), the gingival plane through the midpoints of the dentogingival junction of all lower permanent teeth was constructed and was used as the upper boundary of the mouth floor. The bottom of the mouth floor space was defined with a plane through four points at the lower canine and first molar level where the insertion of the mylohyoideus muscle was visible on study casts. The space was delimited distally with a distal plane constructed through two points at the distal of the first lower permanent molars, perpendicular to the gingival plane. The validity and reliability of volume calculation have been previously reported (Hoyte, 2007; Primozic et al., 2009; Primozic et al., 2014).

Figure 1 Assessment of the dentoalveolar maxillary and mandibular morphology on 3D digital models. The intermolar and intercanine widths assessed at the cusp (black solid lines) and gingival (black dashed lines) level on 3D maxillary (A) and mandibular (B) digital models. Calculation of the palatal (C) and mouth floor (D) surface area and volume (grey). The palate (C) was delimited using a gingival plane (light grey) and a distal plane (dark grey). The mouth floor space (D) was delimited using a gingival plane (light grey), a distal plane (dark grey) and a plane through the insertion of the mylohyoideus muscle not shown in Figure.

Assessment of tongue posture

Pre-treatment lateral cephalograms of all subjects obtained using the same X-ray machine and the same positioning method were collected. The subjects’ head was stabilised in a cephalostat and oriented with the Frankfurt’s horizontal parallel to the floor. Before taking the x-ray, the subjects were asked to swallow hard and then relax with their teeth in centric occlusion.

Tongue posture was assessed on the subjects’ lateral cephalograms using the method described by Graber (Graber et al., 1997). A template with an inscribed millimetre scale was used to assess the tongue position relative to the palate.

The template was superimposed on the lateral cephalogram with its horizontal line through the incisal edge of the lower central incisor, the cervical distal third of the last erupted molar, and the most inferior point of the uvula (or its projection on the reference line between the lower incisor and the distal point of the molar). The contours of the dorsum of the tongue and the bony palate were marked and distances from point zero were measured at four different angles. Six distances for each subject were recorded (Figure 2).

Method error for each parameter was calculated using the intraclass correlation coefficients on a random sample of 10 replicate measurements, yielding values of at least 0.89.
Statistical analysis

The SPSS software, version 13.0 (SPSS® Inc., Chicago, Illinois, USA) and Comprehensive Meta-Analysis, version 2 (BiostatTM, Englewood, New Jersey, USA) were used to perform the statistical analyses. After testing the normality of the data with the Shapiro–Wilk test and Q-Q normality plots, and the equality of variance among the datasets using a Levene test, nonparametric methods were used for data analysis, with the exception for the ages of the groups. Nevertheless, the mean and standard deviations (SDs) are reported for descriptive purposes.

Equality of groups by age and sex was tested by a Student t-test and a chi-squared test. A Mann–Whitney U-test was used to assess the significance of the differences in every parameter between the groups. To further analyse the associations between the tongue posture and the morphological characteristics of the subjects, the intermolar and intercanine widths (either at the cusp or gingival level) were converted as ratios between the mandibular and maxillary dental arches, i.e. mandibular intercanine width divided by the maxillary intercanine width. Similarly, the ratios for either the surface area or volume between the mouth floor and palate were also computed. This ratio scores were then correlated with the six different tongue-to-palate distances using a Spearman rho correlation coefficient.

Finally, to assess the results in terms of statistically and/or clinically significant differences, the effects size (ES) coefficients (Cohen, 1992) for each of the six different tongue-to-palate distances have been calculated. The ES coefficient has been defined as the ratio of the difference between the mean tongue-to-palate distances of two different groups divided by the corresponding SD, as previously reported (Cohen, 1992; Perinetti and Contardo, 2009). In this regard, a threshold of 1.0 was also used to assess which of the tongue-to-palate distances would have a greater potential diagnostic value in individual subjects (Perinetti et al., 2011). The results were considered to be significant at P values below 0.05.

Results

The two groups were balanced by age (P > 0.5) and sex (P > 0.3).

Intermolar and intercanine widths are shown in Table 1. Similar values between the groups were seen for the intermolar widths at the cusp level, for both the maxillary and mandibular dental arches, and at the gingival level for
the maxillary dental arch. The mandibular intermolar width at the gingival level was significantly greater for the Class III group \((P < 0.01)\). The mandibular intercanine widths were similar between the groups, irrespective of the cusp or gingival level of recording. On the contrary, the maxillary intercanine widths, both at the cusp and gingival levels, were significantly smaller in the Class III group \((P < 0.05)\).

Palatal and mouth floor areas and volumes with the corresponding ratios are shown in Table 2. No significant differences between the groups were seen for the palatal area and volume. On the contrary, the mouth floor area and volume were significantly greater in the Class III group \((P < 0.01)\). Similarly, the ratios between the mouth floor and palate were significantly greater in the Class III group for both the area and volume \((P = 0.01, \text{at least})\).

Tongue-to-palate distances are shown in Figure 3. The six different distances were generally greater, i.e. lower tongue posture, for the Class III group. In particular, the differences between the groups were significant for the distances 1 to 4 \((P < 0.05, \text{at least})\). The ES coefficients ranged from 0.19 (distance 6) to 1.36 (distance 2). The distances 3 and 4 yielded ES coefficient very close to 1.0.

The Spearman rho correlation coefficients for the different tongue-to-palate distances with each of the intermolar/intercanine widths and area and volume ratios are shown in Table 3. Significant correlations were seen between tongue-to-palate distances 3 and 4 with the area ratio \((\rho = 0.45 \text{ and } 0.44, \text{ respectively, } P < 0.05 \text{ at least})\), while no other significant correlations were seen.

### Discussion

The present study has shown that Class III subjects have a significantly lower tongue posture as compared to Class I subjects. The lower tongue posture has also been associated with greater values of the parameters (surface area and volume) describing the mandibular alveolar morphology, while the transverse widths of the dental arches appear not to be influenced.

As it has been shown that the growth peak in Class III subjects starts later and growth of the mandible lasts for a longer period (Reyes et al., 2006; Baccetti et al., 2007), only subjects in whom the peak of mandibular growth ended (CS 6), according to the CVM, were included.

Several dentoalveolar morphological characteristics of the maxilla and mandible were examined in the present study. The transverse dimensions of the maxillary and mandibular dental arches were determined by measuring the intermolar and intercanine widths both at the cusp and gingival levels. A different behaviour was seen of the

| Table 1 | Intermolar and intercanine widths (in mm) at the cusp and gingival levels in the different groups \((n = 20, \text{ per group})\). |
|---|---|---|---|
| Width | Level | Dental arch | Group | Diff. |
| Intermolar | Cusp | Maxillary | Class III | 51.8 ± 5.4 | 51.6 ± 4.2 | NS |
| | Mandibular | Class I | 46.5 ± 5.0 | 43.8 ± 3.0 | NS |
| | Gingival | Maxillary | 33.3 ± 4.2 | 32.5 ± 2.7 | NS |
| | Mandibular | 36.4 ± 4.9 | 32.5 ± 2.6 | \(P < 0.01\) |
| Intercanine | Cusp | Maxillary | 32.5 ± 3.6 | 34.7 ± 3.4 | \(P < 0.05\) |
| | Mandibular | 26.7 ± 2.1 | 25.8 ± 2.3 | NS |
| | Gingival | Maxillary | 23.8 ± 2.9 | 26.2 ± 3.8 | \(P < 0.05\) |
| | Mandibular | 21.1 ± 1.9 | 20.7 ± 3.9 | NS |

Diff., significance of the difference between the groups; NS, difference not statically significant. Data presented as mean ± standard deviation.

| Table 2 | The palatal and mouth floor space areas and volumes and corresponding ratios in the different groups \((n = 20, \text{ per group})\). |
|---|---|---|---|
| Parameter | Site | Group | Diff. |
| Area (mm²) | Palate | Class III | 1309 ± 190 | 1290 ± 133 | NS |
| | Mouth floor | 1607 ± 278 | 1372 ± 164 | \(P < 0.01\) |
| Volume (mm³) | Palate | 6752 ± 1386 | 6422 ± 1126 | NS |
| | Mouth floor | 9286 ± 2899 | 6941 ± 1328 | \(P < 0.01\) |

Diff., significance of the difference between the groups; NS, difference not statically significant. Data presented as mean ± standard deviation. Area/ volume ratios are defined as the areas/volumes of the mouth floor space divided by that of the palatal vault.
intermolar and intercanine widths (Table 1). While the former was greater for the Class III group in the mandibular dental arch (measurements at the gingival level), the latter was greater for the Class I group in the maxillary dental arch (measurements at the cusp and gingival levels).

Further, no significant differences were seen for the palatal surface area and volume between the two groups, while Class III patients showed a significantly greater mouth floor surface area and volume as compared to the Class I subjects.

The observed differences that were seen only for the mandibular dentoalveolar morphology are likely due to the concept that Class III subjects with a prognathic mandible rather than a retrognathic maxilla were included (Spalj et al., 2008) in the present study (data not shown). On the other hand, the lack of difference in the maxillary dentoalveolar morphology could be also due to a mild constriction of the maxillary arch present in both groups of subjects. However, the difference in the maxillary intercanine widths and the lack of differences in the mandibular intercanine widths could be a consequence of dental compensation in both dental arches. Such effects are less evident when considering the intermolar widths. Therefore, dental compensation for skeletal disharmonies in Class III subjects would be mainly in the anterior regions (Spalj et al., 2008; Busato et al., 2009).

A main finding of the present study was the noteworthy lower tongue posture seen in the Class III subjects as compared to the Class I subjects (Figure 3). According to the method described by Graber (Graber et al., 1997) and used herein, most of the differences in terms of tongue-to-palate distance were seen at the posterior regions (measurement points 1–4), while no significant differences were seen at the anterior regions (measurement points 5 and 6). The ES coefficients retrieved for the six different tongue-to-palate distances were above 1.0 for measurement point 2 (1.36) or very close to 1.0 for measurement points 3 and 4 (0.99 and 0.91, respectively). According to these results, the most reliable assessment of the tongue-to-palate distance in individual subjects should rely on these three measurement points, mainly on measurement point 2.

No cause–effect of tongue posture on the mandibular morphology could be assessed by the present cross-sectional study. However, previous studies (Lambrechts et al., 2010) found no differences in tongue pressure between the four Angle Classes and suggested that the effect of the duration of the force has a more important role on the development of malocclusion. Further, tongue movements during deglutition and the manner of bolus transfer are different in patients with skeletal Class III and Class I malocclusions, which may have an influence on mandibular morphology (Görgülü et al., 2011).

Therefore, as a clinical implication, the monitoring of tongue posture and movements, particularly in Class III patients, would be recommended and a comprehensive treatment for Class III skeletal malocclusion should include the correction of improper tongue posture in order to enhance treatment efficiency. These aspects may be of particular relevance when dealing with post-treatment stability.

Although no correlation was found between tongue posture and the intermolar and intercanine widths, likely due to dental compensation, a significant correlation was seen between the

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**Table 3** The Spearman rho correlation coefficients for the tongue-to-palate distances at the different measurement points with the intermolar/intercanine widths and area and volume ratios in the whole sample (n = 40).

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Intermolar width ratio</th>
<th>Intercanine width ratio</th>
<th>Area ratio</th>
<th>Volume ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cusp</td>
<td>Gingival</td>
<td>Cusp</td>
<td>Gingival</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.11</td>
<td>0.31</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>0.11</td>
<td>0.20</td>
<td>0.09</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>0.15</td>
<td>0.32</td>
<td>0.09</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>−0.05</td>
<td>0.16</td>
<td>0.13</td>
<td>0.06</td>
</tr>
<tr>
<td>5</td>
<td>−0.30</td>
<td>−0.04</td>
<td>0.04</td>
<td>−0.15</td>
</tr>
<tr>
<td>6</td>
<td>−0.34</td>
<td>0.04</td>
<td>−0.21</td>
<td>−0.28</td>
</tr>
</tbody>
</table>

Levels of significance: *P < 0.05; **P < 0.01.
surface area of the mouth floor and tongue posture (measurement points 3 and 4). The correlation was more significant in the posterior regions, which is supported by previous evidence (Bandy and Hunter, 1969; Tamari et al., 1991).

Previous studies report contrasting associations between tongue size (Bandy and Hunter, 1969; Vig and Cohen, 1974; Tamari et al., 1991; Yoo et al., 1996) or posture (Subtelny, 1970; Guay et al., 1978) and the characteristics of the maxilla and mandible. However, only transverse linear measurements, mainly between teeth, were measured in these studies. On the contrary, in the present study, both dental and alveolar characteristics of the maxilla and mandible were evaluated in association with tongue posture. Although no correlation was seen between tongue posture and the intermolar/intercanine widths, probably due to dental compensation, a correlation was seen between tongue posture and the alveolar maxillary and mandibular morphology. This may also explain the contrasting results of previous studies (Subtelny, 1970; Guay et al., 1978), in which only interdental distances were measured. Further, the present study pointed out the clinically most relevant parameters of tongue posture in correlation with Class III malocclusion.

Conclusions

The present study has shown that:

1. Tongue posture is significantly lower in Class III subjects as compared to Class I subjects and the difference is mainly present in the posterior regions.
2. In all subjects, tongue posture is associated with the ratios of the dental and alveolar characteristics of the maxilla and mandible.
3. Surface area and given tongue-to-palate distances are the most clinically meaningful parameters when dealing with individual subjects.

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