Three-dimensional assessment of facial asymmetry among pre-pubertal class III subjects: a controlled study

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SUMMARY

BACKGROUND/OBJECTIVE: Facial asymmetry is very common in adult class III patients; however, the degree of facial asymmetry in growing class III subjects has been poorly investigated. Therefore, the aim was to assess the degree of facial asymmetry of growing class III subjects and to compare it with a sample of growing subjects without malocclusion, recorded using a three-dimensional laser scanning method and classified according to the dentition phase.

SUBJECTS/METHODS: A group of 156 Caucasian subjects, 52 with class III malocclusion (28 females and 24 males) and 104 without malocclusion (control, 51 females and 53 males), with an overall mean age 6.7 ± 1.4 years (range 4.3–10.3 years), were included. The subjects were further subdivided according to the presence of either primary or early/intermediate mixed dentitions. Facial asymmetry was assessed on three-dimensional surface facial images obtained using a laser scanning device in terms of mirrored face distances and percentages of asymmetry. Multivariate analyses were used to assess the differences among class III and control groups.

RESULTS: Complete facial symmetry was not seen in any subject. No significant differences of facial asymmetry were observed between the class III and control groups, neither in the primary nor in the early/intermediate mixed dentition phases.

LIMITATIONS: No conclusions about longitudinal changes in the degree of facial asymmetry among class III subjects could be drawn from the present cross-sectional study.

CONCLUSIONS: Based on three-dimensional facial asymmetry analysis, class III subjects do not show clinically relevant facial asymmetry, at least during the pre-pubertal growth period.

Introduction

Facial asymmetry can be recognized as differences in the size or relationship of the two sides of the face. This may be the result of discrepancies either in the form of individual bones or a malposition of one or more bones in the craniofacial complex (Sutton, 1968). It has been reported that the mandibular region may have relevant degree of asymmetry (Vig and Hewitt, 1975; Shah and Joshi, 1978; Primozic et al., 2012, 2013b) due to factors related to both dental arches and skeletal dysgnathia, which may be causes of craniofacial asymmetries (Lundström, 1961; Primozic et al., 2009; Primozic et al., 2013b,c). In the United States, 25–34 per cent of facial asymmetry is associated with skeletal dysgnathia (Proffit et al., 1990; Severt and Proffit, 1997), whereas in Europe, facial asymmetry was observed among 18–23 per cent dysgnathic patients (Willems et al., 2001; Good et al., 2006).

class III malocclusion is defined as a sagittal discrepancy; therefore, its morphological characteristics were mainly investigated in the sagittal plane (Chen et al., 2007; Choi et al., 2010). On the contrary, very little data have been reported about any associated asymmetry in the frontal plane (Sutton, 1968; Haraguchi et al., 2002; Staudt and Kiliaridis, 2010). Facial asymmetry was observed in 40 per cent (Severt and Proffit, 1997) to 80 per cent (Haraguchi et al., 2002) adult class III patients as assessed by extra-oral photographs or X-ray analysis. Of interest, in the very same sample of adult class III patients, a noteworthy difference in the prevalence of skeletal (80 per cent) and soft tissue (56 per cent) asymmetry on the frontal plane has been reported (Haraguchi et al., 2002). However, the reported studies were performed on adult populations, with only one reporting a prevalence of 58 per cent facial asymmetry associated with class III malocclusion in growing, i.e. pre-pubertal, subjects (Haraguchi et al., 2008). Further, prevalence rather than the degree of asymmetry was assessed using two-dimensional methods; therefore, the degree of facial asymmetry using an objective and accurate method among pre-pubertal class III subjects remains to be determined.
It has been reported that the characteristics of class III malocclusion have the tendency to worsen along with growth and development, especially during the pubertal growth spurt (Kuc-Michalska and Baccetti, 2010; Almeida et al., 2011; Primozić et al., 2013a), resulting in severe facial deformity not only in the sagittal but also in the frontal plane and therefore increasing treatment difficulty with age (Campbell, 1983; Guyer et al., 1986; Burns et al., 2010).

Although the optimal treatment timing of class III malocclusion is still controversial, it has been accepted that orthopaedic approach for such malocclusion is effective when performed early at a pre-pubertal stage of development (Masucci et al., 2011). Considering that growth in the transverse plane ends up before those in the vertical and sagittal planes, an early diagnosis of any facial asymmetry in the frontal plane associated with class III malocclusion in growing subjects would be recommended.

Therefore, the aim of the present study was to compare the degree of facial asymmetry of growing class III subjects with a sample of growing subjects without malocclusion, recorded using a three-dimensional laser scanning method and classified according to the dentition phase.

Subjects and methods

Ethical approval for this study was gained from the Slovenian Ethical Committee of the Medical University in Ljubljana, Slovenia, and informed consent was obtained from the parents of all subjects.

A group of 156 Caucasian subjects, 52 with class III malocclusion (28 females and 24 males) and 104 without malocclusion (control, 51 females and 53 males), with an overall mean age 6.7±1.4 years (range 4.3–10.3 years), were included. The subjects were further subdivided according to the presence of either primary or early/intermediate mixed dentitions. Within each of the dentition phase, the number of subjects was 26 and 52 for the class III and control groups, respectively. The mean age for the class III group was 5.5±0.5 years and 7.9±0.6 years, whereas the mean age for the control groups were 5.4±0.4 years and 8.0±0.9 years in the primary and early/intermediate mixed dentition phases, respectively.

The class III subjects were randomly selected from a pool of patients referred to the Department of Orthodontics, University Clinical Centre. Only the subjects with a reverse overjet, at least a bilateral half-cusp class III molar (either primary or first permanent) relationship and a class III profile, were included. Further, Wits appraisal among all class III subjects had to be below a threshold value of −1 mm. Subjects with craniofacial syndromes or with unilateral posterior crossbite due to a lateral mandibular shift were excluded. The control subjects were randomly selected from a local school and only subjects without malocclusion and a normal profile associated with a good general health without any respiratory, mastication, or deglutition problems were included. All the clinical assessments were performed by an experienced operator (MO).

The appraisal of the dentition phase was carried out according to the following definitions: 1. primary dentition, when all the primary teeth were erupted, 2. early mixed dentition, when the first permanent molars and incisors were erupting, 3. intermediate mixed dentition, when the permanent incisors and first molars had fully erupted, with presence of the primary canine, and first and second molars (Franchi et al., 2008).

Assessment of facial asymmetry

Surface facial images were obtained using two Konica/Minolta Vivid 910 eye safe laser scanners (Konica Minolta, Inc., Japan) angled to capture left and right sides of the face with significant overlap in the anterior part of the face to facilitate registration and merging of the two images to produce one facial image (Kau et al., 2004). Natural head posture was adopted for this study as this has been shown to be clinically reproducible (Chiu and Clark, 1991). The technique for positioning the patient and image capture has been validated and described elsewhere and their use in growing subjects has been previously validated (Kau et al., 2004).

The three-dimensional data were imported to a reverse modelling software package, Rapidform™ 2006 (INUS Technology Inc, Seoul, Korea). Each scan (left and right images) of the face was processed in order to remove unwanted data, registered and merged to produce a complete facial image. Left and right scans were merged only if there was at least 70 per cent matching between them in the overlap area with ±0.5 mm tolerance (Toma et al., 2009; Djordjevic et al., 2011; Primozić et al., 2012; Primozić et al., 2013c).

The facial image was divided into three functional parts: 1. the upper part (forehead), defined as the part of the face above the endocanthion plane, 2. the middle part (maxillary), from the endocanthion plane to the plane through the outer commissures of the lips, and 3. the lower part (mandibular), below this plane (Figure 1). To check for left/right symmetry, the face was mirrored across the Y–Z plane and the mirrored images were superimposed using the automatic best-fit procedure of the mirrored facial image surfaces (Kau and Richmond, 2010).

Asymmetry was assessed quantitatively as the average distances (in millimetres) between the mirrored images and as the percentage of mirrored images not coinciding within 0.5 mm (percentage of asymmetry). The greater the average distance was between the mirrored images and the greater the percentage of asymmetry the greater the asymmetry of the face was. The parameters were calculated for the whole face and for each part of the face separately. The assessment was performed by an experienced operator.
Sample size calculation and method error analysis

A sample size of at least 26 subjects per group was necessary to detect an effect size coefficient (Cohen, 1992) of 0.8 for either of the asymmetry parameters (average distance or percentage of asymmetry) in any comparison between the groups, with an alpha set at 0.05 and a power of 0.80 (Perinetti et al., 2011). The effect size coefficient is the ratio of the difference between the recordings of the two groups, divided by the within-subject standard deviation. An effect size of at least 0.8 is regarded as a ‘large effect’ (Cohen, 1992).

The method error for each asymmetry parameter was calculated using the intraclass correlation coefficients (ICC) on a random sample of 10 replicate measurements. With the aim of quantifying the full method error of the recordings for both of these asymmetry parameters, the method of moments (MME) variance estimator was used (Springate, 2012). Therefore, the mean error and 95% confidence intervals (CIs) between the repeated recordings were calculated using the MME variance estimator, and were expressed as percentages (Perinetti et al., 2012). The MME variance estimator has the advantages of not being affected by any unknown bias, i.e. systematic errors, between pairs of measurements (Springate, 2012).

Statistical analysis

The Statistical Package for Social Sciences (SPSS® Inc., Chicago, Illinois, USA) was used to perform the data analysis. Each data set was tested for the normality of the data by means of the Shapiro–Wilk test and by Q-Q normality plots; equality of variance was also tested by means of the Levene test and Q-Q normality plots of the residuals. Through this analysis, a root-square transformation of the data sets was required to meet the assumption for using parametric methods. For each part of the face two-way multivariate analysis of covariance (MANCOVA) were performed to assess differences in the average distance and asymmetry. Dentition phase and group were entered as independent fixed factors, whereas age and gender were entered as covariates. A P-value less than 0.05 was accepted for rejection of the null hypothesis.

Results

The ICC for the asymmetry parameters ranged from 0.85 to 0.92 for the average distance and percentage of asymmetry, respectively. Method errors as mean (95% CI) ranged from 5.6 per cent (2.6–9.2) to 7.5 per cent (3.5–12.4) for the percentage of asymmetry and average distance, respectively.

No face was perfectly symmetric (Table 1). In the whole group (n = 156), the average distance between the mirrored images for the whole face ranged 0.22–0.85 mm and the percentage of asymmetry ranged 7.8–66.9.

At the two-way MANCOVAs for the upper, middle, and lower parts of the face, no significant interaction was seen. The only exception was the whole face, in which the groups yielded a significant interaction at the multivariate level (F = 4.01; P = 0.020). However, at the corresponding subsequent univariate analyses, no significant differences were seen. Moreover, no significant difference was seen among the different parts of the face (upper, middle, and lower)

Table 1 The facial asymmetry parameters in the class III and control groups for the whole face and each part of the face separately, according to the dentition phase.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Portion</th>
<th>Group</th>
<th>Dentition phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primary</td>
<td>Early/intermediate mixed</td>
</tr>
<tr>
<td>Average distance</td>
<td>Whole</td>
<td>class III</td>
<td>0.48±0.20</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>0.40±0.10</td>
<td>0.42±0.08</td>
</tr>
<tr>
<td>Upper</td>
<td>class III</td>
<td>0.42±0.15</td>
<td>0.40±0.09</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>0.40±0.10</td>
<td>0.41±0.11</td>
</tr>
<tr>
<td>Medium</td>
<td>class III</td>
<td>0.45±0.22</td>
<td>0.42±0.15</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>0.41±0.15</td>
<td>0.40±0.14</td>
</tr>
<tr>
<td>Lower</td>
<td>class III</td>
<td>0.39±0.19</td>
<td>0.39±0.14</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>0.39±0.14</td>
<td>0.45±0.16</td>
</tr>
<tr>
<td>Asymmetry (%)</td>
<td>Whole</td>
<td>class III</td>
<td>31.69±14.38</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>28.06±9.45</td>
<td>29.85±7.87</td>
</tr>
<tr>
<td>Upper</td>
<td>class III</td>
<td>29.16±14.79</td>
<td>28.36±10.40</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>28.19±10.81</td>
<td>29.00±11.22</td>
</tr>
<tr>
<td>Medium</td>
<td>class III</td>
<td>30.73±19.37</td>
<td>31.30±15.93</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>28.48±14.22</td>
<td>28.74±13.00</td>
</tr>
<tr>
<td>Lower</td>
<td>class III</td>
<td>26.94±17.59</td>
<td>27.41±14.32</td>
</tr>
<tr>
<td>(mm)</td>
<td>Control</td>
<td>26.89±13.56</td>
<td>33.91±16.15</td>
</tr>
</tbody>
</table>

Data are presented as mean ± standard deviation; n = 52 and 104 for the class III and control group, respectively, equally divided into the primary and early/intermediate mixed dentition phase group. No significant differences between the groups were seen in any of the comparisons.
lower) when this classification criterion was entered as a repeated factor in a further MANCOVA.

Discussion

In the present cross-sectional controlled study, facial asymmetry of class III subjects was assessed in the primary and early/intermediate mixed dentition phases and compared with a control group of subjects without malocclusion using a non-invasive three-dimensional laser scanning method. The results show no significant differences of facial asymmetry between the class III and control groups in the pre-pubertal growth period.

Previous evidence shows that facial asymmetry is common among class III patients, as 40 per cent of Caucasian (Severt and Proffit, 1997) and 66 per cent of Japanese (Haraguchi et al., 2008) class III patients exhibit some degree of soft tissue asymmetry. However, previous investigations regarding facial asymmetry associated with class III malocclusion were limited by the use of two-dimensional recordings on standard extra-oral photographs (Severt and Proffit, 1997; Haraguchi et al., 2008) or postero-anterior head films (Haraguchi et al., 2002). Moreover, only in these studies (Severt and Proffit, 1997; Haraguchi et al., 2002, 2008), facial asymmetry was not reported as absolute scores, but only as a positive when above a certain threshold, thus missing information about the degree of asymmetry in the examined sample. The present study made use of non-invasive three-dimensional recordings of the face with a full quantitative analysis and also included a control group of subjects with normal occlusion instead of class I malocclusion as previously reported (Severt and Proffit, 1997; Haraguchi et al., 2008). In this regard, to avoid biases in the recording of the lower face asymmetry due to lateral mandibular shift, class III subjects with unilateral posterior crossbite were not included in the present study. Further, the degree of facial asymmetry, rather than its prevalence, was examined in class III and control pre-pubertal subjects.

According to the present results, no face (including those of the control group) was perfectly symmetric, neither in the primary dentition nor in the early/intermediate mixed dentition phase, as minor non-pathologic facial asymmetry is relatively common (Shah and Joshi, 1978). Further, previous studies have shown that gender and age do not have any effect on facial asymmetry (Ferrario, 2001; Djordjevic et al., 2011; Primozic et al., 2012, 2013b,c), which is in accordance with the results of the present study. Generally, no significant differences were observed in the degree of facial asymmetry among class III and control subjects. On the contrary, facial asymmetry parameters of the whole face yielded a significant interaction at the multivariate level of the MANCOVA. However, this statistically significant interaction does not appear to have clinical relevance. Furthermore, no significant differences were seen in the facial parameters within each group (class III and controls) according to different dentition phases for the upper, middle, and lower parts of the face. However, as previously reported, soft tissues may mask the underlying skeletal asymmetry (Peek et al., 1991), and a higher degree of skeletal asymmetry might have been found if a radiographic examination had been performed (Haraguchi et al., 2002).

The subjects included in the present study were in the pre-pubertal growth period, when as suggested by previous reports the prevalence of facial asymmetry is lower compared with pubertal and post-pubertal growth phases (Haraguchi et al., 2008). However, Haraguchi et al. (2008) classified pre-pubertal subjects as being up to 11 years old, which may have caused a bias since this age is compatible with pubertal growth spurt (Baccetti et al., 2006). Instead, in the present study, the subjects included were all at ages and dentition phases compatible with only a pre-pubertal growth phase (Baccetti et al., 2006; Franchi et al., 2008). Indeed, facial asymmetry has the tendency to increase during growth and development, leading to greater facial disharmony in the post-pubertal growth period, regardless of malocclusion type (Haraguchi et al., 2008; Primozic et al., 2013b).

Clinical implication

As facial asymmetry in class III subjects does not have tendency to appear at a clinically relevant level in pre-pubertal subjects, while this becomes evident at later growth stages (Haraguchi et al., 2008), a proper interceptive treatment for this skeletal malocclusion may be indicated during early developmental stages, i.e. pre-pubertal. The treatment of class III malocclusion with an orthopaedic approach during childhood has been shown to be effective and with more long-term effects regarding the sagittal growth correction (Masucci et al., 2011). Although not shown in the present study, the results reported herein are consistent with prevention of the establishment of facial asymmetry if the class III growth tendency is treated by current orthopaedic modalities. In this regard, a comprehensive diagnosis of class III malocclusion should include also an analysis of the morphological features in the frontal plane.

Conclusions

Based on three-dimensional facial soft tissue recordings in pre-pubertal subjects, class III subjects do not exhibit a greater degree of facial asymmetry compared with subjects without malocclusion, irrespective of the different parts of the face. Further, the primary or early/intermediate mixed dentition phases have no influence on the degree of facial asymmetry, regardless of the presence of a class III malocclusion.
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