Nasolabial symmetry following Tennison–Randall lip repair: A three-dimensional approach in 10-year-old patients with unilateral clefts of lip, alveolus and palate

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SUMMARY. Aim: To assess the degree of facial symmetry in patients suffering from unilateral cleft lip, alveolus and palate (UCLAP) by determining differences between the cleft and the non-cleft hemifaces from 3D surface data. Patients and methods: In twenty-two 10-year-old UCLAP patients, who had the lip repaired using the Tennison–Randall technique and did not undergo further revisional surgery, differences were determined between landmarks, surface areas of the upper lip vermilion and nostrils and virtual volumes of midface, nose and upper lip for cleft and non-cleft sides, separately, after having established a plane of symmetry calculated from optical 3D facial surface data. Results: Statistically significant differences could be found between cleft and non-cleft sides for the nasal landmarks Glat, Gsup and Lamed, the nostril angle and the virtual volume of the nose (pGlat = 0.011, pGsup < 0.0005, pLamed = 0.002, pnostril angle = 0.036 and pnoose volume < 0.0005, resp.). Conclusion: Analysis of 3D data shows that complete nasal symmetry is difficult to achieve with Tennison–Randall’s lip repair without revisional surgery. Further trials on larger populations of patients will allow a more comprehensive and consistent analysis of the consequence of different methods for cp repair in order to identify the techniques with the best outcome in terms of facial symmetry. © 2006 European Association for Cranio-Maxillofacial Surgery

Keywords: facial volume; optical 3D imaging; plane of symmetry; 3D cephalometry; unilateral cleft lip and palate (UCLP)

INTRODUCTION

It is generally accepted that differences between the dimensions of the left and right half of the human face are common findings even in aesthetically pleasing faces. Differences of up to 2 mm between the two hemifaces are considered to fall within a normal range (Ferrario et al., 1994). Studies on facial laterality report a larger right side hemiface in a normal population (Burke, 1971; Shah and Joshi, 1978; Burke, 1979; Farkas and Cheung, 1981; Koff et al., 1981, 1985; Peck et al., 1990). Congenital anomalies like cleft lip are causal factors that predispose to the development of facial asymmetry with a larger non-cleft side (Bishara et al., 1994).

Nasolabial appearance in rehabilitation of cleft lip malformations is of utmost importance to the patients. It has been stated that a greater degree of asymmetry hinders unobtrusive participation in social life through their most critical early years (Tan and Pigott, 1993). Therefore, revisional procedures are often carried out during childhood to decrease distress caused by visible nasolabial asymmetry (Tan and Pigott 1993; Ferrario et al., 2001). This practice may impair nasolabial growth by additional surgery perpetuating the necessity of further corrective procedures (Matthews, 1968). Unfortunately, due to case numbers, low-incidence anomalies such as clefts present major difficulties in evaluating the benefits or drawbacks of different treatments (Atack et al., 1997).

Each technique for cleft lip repair has its advantages and disadvantages. The methods available have advanced the care of the affected children to a point where new techniques and developments are likely to bring about only small changes (Atack et al., 1997). Consequently, more sophisticated methodology is required to detect improvements (Roberts et al., 1991). It is difficult to assess the facial appearance in a valid and reliable way. In particular, the quantification of asymmetry is often subjective (Bearn et al., 2002a, b). It is a 3D phenomenon with transverse, vertical, and sagittal components. The assessment of asymmetry requires a method to investigate all three components simultaneously (Ras et al., 1994a, b; 1995).
Several studies have been carried out that adopted 3D imaging for analysis of the facial surface of cleft lip patients (Table 1). Unfortunately, the determination of the plane of symmetry was often confined to a limited number of landmarks not taking advantage of all points of the facial surface (Ferrario et al., 1994; Nkenke et al., 2003a). Moreover, few studies have quantified surface areas and facial volumes in unilateral cleft lip patients as a part of the symmetry analysis (Russell et al., 2000; Ferrario et al., 2003; Nkenke et al., 2003b).

Therefore, the aim of the present cross-sectional study in 10-year-old patients was to introduce a more comprehensive technique of analysis of the facial surface, assessing the plane of symmetry by a new method from optical 3D images. The differences between visible soft-tissue volumes of healthy and affected hemifaces were determined in order to quantify the amount of asymmetry after cleft lip repair by the Tennison–Randall technique without revisional surgery.

PATIENTS AND METHODS

Twenty-two 10-year-old patients suffering from complete non-syndromic unilateral clefts of lip, alveolus and palate participated in a follow-up examination at this Department of Oral and Maxillofacial Surgery. All patients included in the study were operated on by the same consultant in oral and maxillofacial surgery with more than 10 years experience in the field of cleft surgery. The maximum width of the cleft lips documented in the files ranged from 4 to 10 mm. Primary closure of the lip was according to Tennison–Randall and an early hard palate closure with a single-layer vomer flap at a mean age of 4.1 ± 1.5 months (Pichler, 1934; Tennison, 1952; Randall, 1959). There was no primary surgery performed to the nose. Closure of the soft palate was performed using the pedicled flap repair according to Widmaier (1959) at a mean age of 13.2 ± 3.4 months.

An optical 3D sensor (CAM3D, 3D-shape GmbH, Erlangen, Germany, http://www.3D-shape.com) was used for data acquisition of the facial surface, which has been developed at the Division for Optics, University of Erlangen-Nuremberg. The sensor is based on a modification of the phase measuring triangulation method. A sequence of phase-shifted fringe patterns of structured light is projected on the region of interest. From different directions two computer-coupled device (CCD) cameras record the data. Subsequently, the images of the phase-shifted patterns are evaluated by means of a four-shift-algorithm to receive the 3D shape of the object’s surface. The 3D sensor takes advantage of an astigmatic optical device for the projection of precise sinusoidal intensity coded fringe patterns instead of a commonly used Ronchi-grating fringe projection (Haeusler and Gruber, 1992).

The optical 3D sensor was calibrated for a measurement volume of 300 × 300 × 300 mm³, adapted to the average dimensions of a human head. The required measurement time for data acquisition was 640 ms.

During data assessment the position of the patient was adjusted reproducibly using a cephalometric head holder to prevent artefacts due to movement and soft tissue distortion caused by altered inclination of the head. The optical data were assessed with the patients’ lips at rest. The acquired 3D images could be viewed immediately on the computer screen from any angle desired.

The Frankfurt horizontal plane and the plane of symmetry were used as reference for the anthropometric analysis of the facial surface data. The Frankfurt horizontal plane was defined by the line connecting landmarks tragion and orbitale of both hemifaces.

Methods of image processing were used for determining the plane of symmetry of the facial surface. Mirror images of the optical 3D surface data were generated (Fig. 1). Thereby, the point $P_i$ of the original facial surface received a corresponding point $P_i^*$ in the mirror data set. Coarse and fine registrations were performed to superimpose original and mirror images within the same co-ordinate system.

Rigid transformations of the mirror data sets were calculated that minimized the distance towards the original images. When a rigid transformation is carried out, rotational and translational movements of the object are performed that have to be superimposed with another object. The rigid transformation does not change the shape of the object that is moved. Following this procedure for each point of the original data set, the closest point in the superimposed mirror data set was determined. If the distance between these two points was larger than 2 mm, both were excluded from calculating the rigid transformation. Subsequently, the calculated rigid transformation was applied to all points $P_i$ of the mirror data set leading to a modified mirror data set consisting of points $P_i^*$. Each original data point $P_i$ now corresponded with a point $P_i^*$ in the modified mirror data set subjected to the rigid transformation. By bisecting the distances between all corresponding pairs $P_i$ and $P_i^*$, the plane of symmetry was assessed. Further detail on the procedure has been provided previously (Benz et al., 2002).

Anthropometric facial landmarks that were determined are given in Figures 2 and 3 and Table 2. $L_{\text{med}}$ is the medial intersection of the long axis of the nostril with the nostril rim. $L_{\text{lat}}$ is the lateral intersection of the long axis of nostril with nostril rim. The short axis of the nostril was defined as a line perpendicular to the long axis of the nostril showing the largest distance between two opposing points on the nostril rim. $S_{\text{sup}}$ is the superior intersection of the short axis of the nostril and the nostril rim. $S_{\text{inf}}$ is the inferior intersection of the short axis of nostril and nostril rim (Table 2). The definition of the axes of the
Table 1 – Review of the literature on indirect, 3D facial surface analysis of patients with complete unilateral cleft lip, alveolus and palate using different imaging techniques

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number of patients</th>
<th>Technique of primary lip closure</th>
<th>Age of patients (years)</th>
<th>3D imaging technique</th>
<th>Assessment of symmetry</th>
<th>Calculation of facial volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ras et al. (1994a)</td>
<td>32 (LUCLP)</td>
<td>?</td>
<td>7.4 (SD 3.1)</td>
<td>Stereophotogrammetry</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ras et al. (1994b)</td>
<td>49</td>
<td>?</td>
<td>7.4 (SD 2.8)</td>
<td>Stereophotogrammetry</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ras et al. (1995)</td>
<td>9</td>
<td>T1 T2</td>
<td>4.0 (SD 0.1) 6.0 (SD 0.0)</td>
<td>Stereophotogrammetry</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mishima et al. (1996)</td>
<td>3</td>
<td>Range 15-18</td>
<td>3D digitizer of contact type*</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Fisher et al. (1999)</td>
<td>12</td>
<td>Presurgical data assessment</td>
<td>Data assessment at 3 months of age</td>
<td>Computed tomography</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yamada et al. (1999)</td>
<td>2</td>
<td>?</td>
<td>23 (SD 11)</td>
<td>3D optical scanner</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Duffy et al. (2000)</td>
<td>10</td>
<td>?</td>
<td>Range 8–11</td>
<td>Optical surface scanner</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Russell et al. (2000)</td>
<td>11</td>
<td>Tennison–Randall</td>
<td>Mean 15.7, range 12–22.3</td>
<td>Video imaging†</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Russell et al. (2001)</td>
<td>11</td>
<td>Tennison–Randall</td>
<td>Mean 15.7, range 12–22.3</td>
<td>Video imaging‡</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yamada et al. (2002)</td>
<td>10</td>
<td>Tennison–Randall</td>
<td>Data assessment at 3 months and at 3.5 months of age</td>
<td>3D optical scanner</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ferrario et al. (2003)</td>
<td>18</td>
<td>Le Mesurier</td>
<td>23 (SD 3)</td>
<td>Electromagnetic 3D digitizer</td>
<td>Yes</td>
<td>Yes‡</td>
</tr>
<tr>
<td>Yamada et al. (2003)</td>
<td>15</td>
<td>Presurgical data assessment</td>
<td>Data assessment at 2 weeks and at 3 months of age</td>
<td>3D optical scanner</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Hood et al. (2004)</td>
<td>12</td>
<td>Presurgical data assessment</td>
<td>Range 10–16 weeks</td>
<td>Stereophotogrammetry</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

LUCLP, left unilateral cleft lip and palate; RUCLP, right unilateral cleft lip and palate; T1, first point of time of data assessment; T2, second point of time of data assessment; ?, data not specified.
*Facial plaster models were digitized.
†Nasal plaster casts were used for data acquisition.
‡Approximation via tetrahedral.
nostril and the adjacent landmarks was chosen according to Yamada et al. (2002).

The distances of the different landmarks from the plane of symmetry were calculated, when projected on the plane of symmetry perpendicular to the coronal plane. In an axial plane through the columella base (Col) differences in vertical height of corresponding landmarks of cleft and non-cleft sides were determined. Moreover, the distance between corresponding landmarks of the two hemifaces projected on the plane of symmetry was determined in an anterior–posterior direction parallel to the Frankfurt horizontal plane. Additionally, the angle between the long axis of the nostril and the plane of symmetry was calculated (Fig. 3). Nostril areas and vermilion areas were assessed for cleft and non-cleft side, separately (Figs. 4 and 5).

The visible, virtual volumes of the midface, the upper lip and the nose were determined without considering underlying voids and bony structures of oral and nasal cavity (Fig. 6). As a border for the volume determination of each half of the nose of the two hemifaces, a line along nasion, endocanthion, nasal sulcus and columella base was used. For the upper lip volume, the line proceeded along the labial fissure, cheilion, alar base and columella base. For each midfacial half the difference in volume between cleft and non-cleft sides was determined with a border along nasion, exocanthion, cheilion, and stomium. By projecting all single-data points of the border lines of the volumes onto the plane of symmetry in frontal planes perpendicular to the Frankfurt (horizontal)
plane and the plane of symmetry, the posterior boundary areas of the volumes of interest were generated.

Statistics

Mean values were given with standard deviations. For the determination of measurement errors, all parameters were reassessed after 6 months. Random error of the different parameters was calculated using the Dahlberg formula (Dahlberg, 1940; Houston, 1983). A repeated measures t-test was performed to assess systematic error. For comparison of continuous variables in paired samples, the Wilcoxon test was used. p-values equal to or smaller than 0.05 were considered significant. All calculations were made using SPSS Version 12.1 for Windows (SPSS Inc., Chicago, USA).

RESULTS

In all patients, acquisition of the optical 3D images, determination of the landmarks and calculation of
the distances, areas and volumes were successful. The repeated measures t-test yielded no significant results indicating that no relevant systematic error occurred during the assessment of the different parameters. For linear measurements, the random error was smaller than 1 mm, while it was smaller than 1.5° for angular measurements thus having no clinical importance (Sandler, 1988). The results are listed in Tables 3–6.

Table 3

(a) Facial landmarks*  

<table>
<thead>
<tr>
<th></th>
<th>Endocanthion non-cleft (mm)</th>
<th>Endocanthion cleft (mm)</th>
<th>Prn (mm)</th>
<th>Col (mm)</th>
<th>Ch non-cleft (mm)</th>
<th>Ch cleft (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>13.0</td>
<td>13.2</td>
<td>-4.1</td>
<td>-3.2</td>
<td>18.2</td>
<td>15.7</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>18.7</td>
<td>18.8</td>
<td>2.2</td>
<td>2.3</td>
<td>24.6</td>
<td>26.8</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td>15.4 (1.7)</td>
<td>15.7 (1.7)</td>
<td>-1.1</td>
<td>-0.8</td>
<td>21.1</td>
<td>21.7</td>
</tr>
</tbody>
</table>

*p 0.532 0.149 0.291

(b) Nasal landmarks3  

<table>
<thead>
<tr>
<th></th>
<th>$G_{lat}$ non-cleft (mm)</th>
<th>$G_{lat}$ cleft (mm)</th>
<th>$G_{sup}$ non-cleft (mm)</th>
<th>$G_{sup}$ cleft (mm)</th>
<th>$G_{base}$ non-cleft (mm)</th>
<th>$G_{base}$ cleft (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>14.9</td>
<td>13.4</td>
<td>10.5</td>
<td>8.4</td>
<td>9.4</td>
<td>10.6</td>
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<tr>
<td><strong>Maximum</strong></td>
<td>20.8</td>
<td>19.7</td>
<td>15.5</td>
<td>13.6</td>
<td>18.6</td>
<td>17.1</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td>18.0 (1.7)</td>
<td>16.9</td>
<td>13.7</td>
<td>11.3</td>
<td>13.0</td>
<td>13.7</td>
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</table>

*p 0.011 <0.0005 0.082

(c) Nasal landmarks3  

<table>
<thead>
<tr>
<th></th>
<th>$L_{lat}$ non-cleft (mm)</th>
<th>$L_{lat}$ cleft (mm)</th>
<th>$L_{med}$ non-cleft (mm)</th>
<th>$L_{med}$ cleft (mm)</th>
</tr>
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<td><strong>n</strong></td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>9.0</td>
<td>9.0</td>
<td>1.5</td>
<td>-1.7</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>16.3</td>
<td>15.8</td>
<td>9.3</td>
<td>7.6</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td>12.3 (2.1)</td>
<td>12.0</td>
<td>6.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

*p 0.661 0.002

Distance of facial landmarks from the plane of symmetry determined in an axial plane perpendicular to the plane of symmetry and parallel to the Frankfurt horizontal plane. Negative values reveal a deviation to the non-cleft side, positive values reveal a deviation to the cleft side. For definition of landmarks see Table 2. Non-cleft, non-cleft side; cleft, cleft side.

Distance of nasal landmarks from the plane of symmetry determined in an axial plane perpendicular to the plane of symmetry and parallel to the Frankfurt horizontal plane. Negative values reveal a deviation to the non-cleft side, positive values reveal a deviation to the cleft side. For definition of landmarks see Table 2. Non-cleft, non-cleft side; cleft, cleft side.

Table 4 – Nostril dimensions, nostril area and nostril angle formed with the plane of symmetry

<table>
<thead>
<tr>
<th></th>
<th>Nostril length non-cleft (mm)</th>
<th>Nostril length cleft (mm)</th>
<th>Nostril width non-cleft (mm)</th>
<th>Nostril width cleft (mm)</th>
<th>Nostril angle (\alpha) non-cleft (deg)</th>
<th>Nostril angle (\beta) cleft (deg)</th>
<th>Nostril area non-cleft (mm²)</th>
<th>Nostril area cleft (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>9.2</td>
<td>7.7</td>
<td>5.9</td>
<td>4.8</td>
<td>137</td>
<td>117</td>
<td>155</td>
<td>167</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>16.6</td>
<td>21.6</td>
<td>11.9</td>
<td>12.4</td>
<td>137</td>
<td>117</td>
<td>155</td>
<td>167</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td>13.7</td>
<td>15.0</td>
<td>9.0</td>
<td>9.2</td>
<td>67.6</td>
<td>84.8</td>
<td>107.9</td>
<td>107.6</td>
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</table>

*p 0.077 0.808 0.036 0.438

For definition of parameters see Table 2.  
Non-cleft, non-cleft side; cleft, cleft side.
Table 5 – Labial landmarks

<table>
<thead>
<tr>
<th></th>
<th>Lb (mm)</th>
<th>Ltlat non-cleft (mm)</th>
<th>Ltlat cleft (mm)</th>
<th>Ltvert non-cleft (mm)</th>
<th>Ltvert cleft (mm)</th>
<th>Ltap non-cleft (mm)</th>
<th>Ltap cleft (mm)</th>
</tr>
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<tbody>
<tr>
<td>n</td>
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<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Minimum</td>
<td>−4.4</td>
<td>−4.2</td>
<td>1.9</td>
<td>8.6</td>
<td>8.4</td>
<td>−3.5</td>
<td>−4.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>6.7</td>
<td>10.0</td>
<td>12.2</td>
<td>17.6</td>
<td>16.5</td>
<td>7.3</td>
<td>5.3</td>
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<tr>
<td>Mean</td>
<td>−0.1</td>
<td>6.0</td>
<td>6.1</td>
<td>11.9</td>
<td>12.2</td>
<td>0.9</td>
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<tr>
<td>(SD)</td>
<td>(2.5)</td>
<td>(3.0)</td>
<td>(2.6)</td>
<td>(2.5)</td>
<td>(2.2)</td>
<td>(2.1)</td>
<td>(2.0)</td>
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</table>

Table 6 – Area of vermilion and virtual facial volumes

<table>
<thead>
<tr>
<th></th>
<th>Area_{vermilion} non-cleft (mm²)</th>
<th>Area_{vermilion} cleft (mm²)</th>
<th>Volume_{midf.} non-cleft (cm³)</th>
<th>Volume_{midf.} cleft (cm³)</th>
<th>Volume_{nose} non-cleft (cm³)</th>
<th>Volume_{nose} cleft (mm³)</th>
<th>Volume_{lip} non-cleft (mm³)</th>
<th>Volume_{lip} cleft (mm³)</th>
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<td>22</td>
</tr>
<tr>
<td>Minimum</td>
<td>53</td>
<td>79</td>
<td>31.4</td>
<td>31.0</td>
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<td>3.8</td>
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<tr>
<td>Maximum</td>
<td>213</td>
<td>233</td>
<td>65.0</td>
<td>59.9</td>
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<td>9.6</td>
<td>11.1</td>
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<td>Mean</td>
<td>140.0</td>
<td>151.8</td>
<td>47.1</td>
<td>46.0</td>
<td>9.7</td>
<td>6.6</td>
<td>6.3</td>
<td>6.9</td>
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<tr>
<td>(SD)</td>
<td>(49.3)</td>
<td>(44.8)</td>
<td>(10.0)</td>
<td>(9.6)</td>
<td>(2.8)</td>
<td>(2.1)</td>
<td>(1.8)</td>
<td>(2.1)</td>
</tr>
</tbody>
</table>

Non-cleft, non-cleft side; cleft, cleft side.

(p = 0.291). The columella base (Col) showed a deviation to the non-cleft side of 0.8 ± 1.8 mm, when the distance from the plane of symmetry was determined. A comparable deviation of the pronasale point (Prn) to the non-cleft side could be found (1.1 ± 1.8 mm). There was no statistically significant difference from the distances from the plane of symmetry of the two landmarks (p = 0.149 Table 3a).

The most lateral point of the alar groove (G_{lat}) revealed a larger distance from the plane of symmetry for the non-cleft side (18.0 ± 1.7 mm) than for the cleft side (16.9 ± 1.6 mm). The difference was statistically significant (p = 0.011). For the most superior point of the alar groove (G_{sup}) the difference in distance from the plane of symmetry was more pronounced for the non-cleft side and statistically significant (non-cleft side 13.7 ± 1.3 mm, cleft side 11.3 ± 1.3 mm, p < 0.0005). For the most inferior point of the alar groove (G_{base}) values of 13.0 ± 2.2 mm for the non-cleft side and 13.7 ± 1.4 mm for the cleft side were found (p = 0.082, Table 3b).

The distance from the plane of symmetry of the lateral point of the plane of the nostril (L_{am}) did not differ for sound and affected facial halves (non-cleft side 12.3 ± 2.1 mm, cleft side 12.0 ± 1.7 mm, p = 0.661). The difference in distance from the plane of symmetry to the medial point of the long axis of the nostril (L_{amed}) between cleft side (2.6 ± 3.0 mm) and non-cleft side (6.3 ± 2.2 mm) was statistically significant (p = 0.002, Table 3c).

The length of the long axis of the nostril (nostril length) was 13.7 ± 2.1 mm for the non-affected side and 15.0 ± 2.8 mm for the affected side (p = 0.077). The distance between the superior and the inferior point of the short axis of the nostril (nostril width) was 9.2 ± 1.9 mm for the cleft side, and 9.0 ± 1.7 mm for the non-cleft side (p = 0.808). The angle formed by the long axis of the nostril and the plane of symmetry showed a significantly larger value for the cleft side than for the non-cleft side (non-cleft side 13.0 ± 2.2°, cleft side 13.7 ± 1.4°, p = 0.077). The nostril area was minimally larger for the healthy side (107.9 ± 30.2 mm²) than for the cleft side (107.6 ± 32.1 mm²) without a statistically significant difference (p = 0.438, Table 4).

The top of the Cupid’s bow (L_{t-lat}) showed a distance from the plane of symmetry of 6.0 ± 3.0 mm measured in a frontal plane for the non-cleft side compared with 6.1 ± 2.6 mm for the cleft side (p = 0.570). The difference in vertical height between the top of Cupid’s bow (L_{tvert}) of the cleft and non-cleft side was 0.3 mm with the top of Cupid’s bow of the cleft side being positioned more inferior (p = 0.465). The bottom of the Cupid’s bow (Lb) exhibited a deviation of 0.1 ± 2.5 mm to the cleft side in a frontal plane (Table 5).
was comparable for cleft (151.8 ± 44.8 mm³) and non-cleft side (140.0 ± 49.3 mm³, \( p = 0.115 \), Table 6).

The virtual volume of the non-cleft side midfacial half was 47.1 ± 10.0 and 46.0 ± 9.6 cm³ for the cleft side, respectively (\( p = 0.485 \)). The virtual volume of the non-cleft half of the nose was significantly larger than that of the cleft side (9.7 ± 2.8 cm³ non-cleft side, 6.6 ± 2.1 cm³ cleft side, \( p < 0.0005 \)). The volume of the upper lip did not differ statistically significantly for non-cleft side (6.3 ± 1.8 cm³) and cleft side (6.9 ± 2.1 cm³, \( p = 0.163 \), Table 6).

DISCUSSION

Satisfactory functional results can be achieved after primary lip repair in the majority of patients with unilateral clefts. From this point of view, there is only a limited need for corrections and re-operations. However, morphological results tend to be less satisfactory (Breitsprecher et al., 1999). Despite the many advances in surgery, the cleft lip nose continues to be a stigma of cleft surgery. Many patients require secondary repair because of nasolabial asymmetries (Kane et al., 2000).

It is well known that the method used to reproduce facial characteristics (2D and 3D) and the method used to quantify asymmetry (global or localized analysis) may play a major role in evaluating asymmetry (Ferrario et al., 1994). Most studies involving the quantitative assessment of facial asymmetry in living persons have been performed on 2D reproductions of hard tissue (radiographs) or soft tissue (photographs) morphology. Both methods project a complex 3D structure onto a 2D plane, thus causing loss of one of the facial dimensions, usually facial depth. It is obvious that correct evaluation of the surface of the face should involve all three (spatial) planes simultaneously (Rus et al., 1994b; O’Grady and Antonyszyn, 1999; Ferrario et al., 2001). The difficulties occurring, when landmarks are determined from 2D images, have been well illustrated previously (Cussons et al., 1993).

It is most desirable to objectively assess different facial features three-dimensionally and to analyse them statistically in order to evaluate the efficacy of the many different treatment methods with a standardized and quantitative method and to decide whether a surgical technique is adequate to improve the appearance of patients with cleft lip, alveolar and palate deformities (Coghlan et al., 1987; Laitung et al., 1993; Russell et al., 2000).

Although some studies have been carried out with different 3D imaging techniques, most of them have been confined to the determination of anthropometric landmarks. When single landmark measurements are used for symmetry analysis, endless comparisons between the two facial halves can be made. The position of a localized asymmetry can be easily appreciated, but a global evaluation of the face is not possible (Ferrario et al., 2001). Recently, a new technique of analysis of symmetry has been introduced and validated experimentally and clinically (Benz et al., 2002; Nkenke et al., 2003a). Instead of using single landmarks for determination of the plane of symmetry, it takes advantage of all the data points of a 3D facial surface image. This plane of symmetry is independent of interobserver differences in the definition of landmarks and is therefore, highly reproducible. The new method for the assessment of symmetry is now routinely available.

In addition to the symmetry analysis, a global evaluation of the face during childhood should include the assessment of differences in facial surface areas and visible soft-tissue volumes between cleft and non-cleft sides. These data allow an improved determination of the influence of surgery on facial growth (Russell et al., 2000; Ferrario et al., 2003). No relevant systematic or random errors were found for the different measurements. This fact reveals that the technique adopted for the present study is appropriate for clinical use (Sandler, 1988). To date, there are no comparable studies taking advantage of all the different afore-mentioned parameters during the evaluation of discrepancies between the two hemifaces of patients with unilateral clefts. There is a lack of comprehensive 3D data even for the standard techniques of lip repair without revisional surgery (Yamada et al., 2002).

Patients were selected for the trial, who were operated on by the same surgeon and had not received additional surgery of lip and nose or secondary alveolar bone grafting after a primary repair of the lip by the Tennison–Randall technique (Randall, 1959). Additional procedures might have camouflaged the result of the primary lip closure. Ten-year-old patients were included in the study exclusively. At this time, all patients would have gone through the first phase of intensive growth of the nose (Perko, 1987). Those subjects examined were standing just before the beginning of pubertal growth. The data assessed are relevant to support careful decision-making for or against revisional nasolabial surgery in the first decade of life (Ross, 1987; Swennen et al., 2002; Treutlein et al., 2003).

The Tennison–Randall lip repair used in the present study is one of the most widespread methods for primary reconstructions. The decisive contribution of this technique to cleft surgery is the recognition and preservation of the Cupid’s bow by lowering the peak in the margin of the cleft (Brauer and Cronin, 1983). However, one objection to the Tennison–Randall lip repair is that a scar results across the philtrum in its lower third (Romero, 1997). Moreover, other postsurgical deformities such as asymmetry of Cupid’s bow, flattened philtrum or absence of the philtrum, elongation of the white lip on the cleft side, inclination of the columella, and flattened ala nasi and nostrils have been recognized (Yamada et al., 2003). In order to improve the surgical technique, it has been suggested that the vertical height of the lip on the cleft side is reduced by 1 mm compared with the non-cleft side to avoid an overcorrection (Brauer and Cronin, 1983). This
technique has been adopted in the present study. An excess of vertical height of the philtrum was not found on the cleft side, when the position of the top of Cupid's bow (Lt) was compared to that of the non-cleft side. All in all, 3D reconstruction revealed a symmetrical reconstruction of the upper lip without statistically significant differences between the single parameters of cleft and non-cleft sides.

When the nose was analysed, statistically significant results could be found for \( G_{\text{lat}} \), \( G_{\text{sup}} \), and \( L_{\text{med}} \) for the different nasal landmarks. This underlines that the cleft lip/nose is the most difficult part to reconstruct in the affected patients (Tan and Pigott, 1993).

In the present study, deviation of the pronasale to the non-cleft side of 1.1 mm was found. This result conflicts with previous studies (Roberts-Harry et al., 1991). Using different surgical techniques for the cleft lip repair, a nasal deflection to the cleft side of up to 2.12 mm on average was found uniformly by these authors. However, their results are based on a 2D analysis of frontal photographs and, therefore, have to be interpreted with care.

Beside the use of landmarks, the determination of well-defined facial surface areas for symmetry analysis has been described previously using photographs or video imaging. (Hurwitz et al., 1999; Russell et al., 2000). With both techniques 3D structures are projected in 2D planes. Therefore, it seems that the areas assessed in the present study are more precise, because the curvature of the planes is preserved by the 3D imaging technique, while it is lost when photographs or video imaging are used. Both previous studies did not give absolute data in \( \text{mm}^2 \) for the areas but counted the number of pixels or only gave the ratio of the cleft side area to the non-cleft side area in order to characterize the dimension of the measured areas. Therefore, a comparison of these area data to the present study is impossible, where a quantification in \( \text{mm}^2 \) has been carried out.

In the current literature, techniques for the determination of facial volumes have been proposed previously (Ferrario et al., 2003). However, these authors give only rough approximations of the volume, because they do not take advantage of the complete facial surface bordering the volume of interest (Ferrario et al., 1998). The determination of volume was based on the generation of geometrical structures (tetrahedra) using only single landmarks from the facial surface as their vertices (Ferrario et al., 1998). The lateral surfaces of the tetrahedra were defined by these vertices. They did not follow the convex and concave facial surface. Therefore, a large amount of individual information on the facial surface of the single patient was lost during that kind of volume determination. In the present study, all data points of the surfaces surrounding the volumes of interest were used for volume determination. This technique has been validated experimentally and clinically (Nkenke et al., 2003b). The method seems to be more appropriate to assess minimal differences between cleft and non-cleft sides than the methods proposed previously. A statistically significant difference could be found between the virtual volumes of the nose of cleft and non-cleft sides underlining the well-known difficulties in repair of the cleft lip/nose. It seems that similar studies should be carried out after primary nasal correction performed at the time of closure of the cleft lip, to find out if this method leads to improved nasal shape in patients of comparable age (Brusse et al., 1999).

CONCLUSION

This new technique of symmetry analysis reveals that in 10-year-old patients with complete unilateral clefts of lip, alveolus and palate, who did not receive primary nose repair, or revisional surgery, a significant degree of asymmetry of the nose was present, while the upper lip exhibited a symmetrical arrangement of the different landmarks, areas and volumes. Further trials on larger populations of patients would allow a more comprehensive and consistent analysis of the consequence of different surgical methods in order to identify the techniques with the best outcome in terms of facial symmetry.

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