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Research Paper
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Comprehensive analysis of soft tissue changes in response to orthognathic surgery: mandibular versus bimaxillary advancement

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Abstract. This study was performed to compare soft tissue changes in response to mandibular and bimaxillary advancement osteotomy. Preoperative and postoperative cone beam computed tomography scans of 24 cases were analysed: 12 underwent bimaxillary advancement and 12 underwent mandibular advancement. The skeletal surgical movements were measured and soft tissue changes were displayed on a three-dimensional colour map. The intensity and shade of the colour indicated the magnitude and direction of the changes. In the bimaxillary advancement group, maxillary advancement was 5.5 ± 2.7 mm with anterior vertical impaction of 2.7 ± 2.5 mm; mandibular advancement was 4.6 ± 3.2 mm. Most of the mediolateral soft tissue changes were limited to the anatomical boundaries of the paranasal region – the columella together with the alar bases of the nose; these showed clear forward movement, which extended to involve most of the cheeks. In the mandibular surgery group, the mean advancement was 3.5 ± 2.6 mm. The chin region, lower lip, and inferior parts of the cheek showed forward shift with minimal changes at the vermilion border, which was only displaced in an upward direction. In conclusion, dense anatomical correspondence is a clinically meaningful method of producing a visual comprehensive analysis of the changes in response to orthognathic surgery.

Key words: orthognathic; osteotomy; 3D; soft tissue; analysis.

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The assessment of facial changes following orthognathic surgery has been a topic of interest since the early 1970s[1]. Various methods have been used to evaluate the facial morphology. Landmark-based analysis of two-dimensional (2D) and three-dimensional (3D) facial images has been reported in the past[2–4]. However, this method fails to provide a comprehensive analysis of the soft tissue, as it relies on a few selected facial landmarks[5,6]. Another common method of assessment is the col-

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our-coded inter-surface distance map. This method provides an evaluation of the facial changes by measuring the closest distance between corresponding surfaces regardless of their anatomical correspondence. The method is based on recording the 3D morphology of the face using a non-invasive 3D imaging technique, making it a potentially useful means for routine clinical assessment. Variations in facial shape among different population groups[7–9] and the changes following orthognathic surgery[10,11] have been investigated using this method. However, the shortest distances between the corresponding 3D images are measured, which may not necessarily represent the actual distances between corresponding anatomical features; this represents the main shortcoming of the method[12].

The shortcomings of the colour-coded inter-surface distance map have been overcome with the development and application of anatomical dense correspondence soft tissue analysis[12]. This method has the advantages of full surface analysis powered by anatomical correspondence. It relies on the application of a generic mesh, a mathematical 3D facial mask, which is adapted to the morphology of the face in a process known as conformation. The conformed mesh is a 3D facial image composed of a predetermined set of indexed points or vertices[13]. Generic mesh conformation on facial image meshes allows tracking of the vertices between pre-treatment and postoperative image surfaces[14]. Therefore, this analysis can readily be applied to the exact 3D characteristics of each face, as each conformed image contains the same number of vertices. This will allow the comprehensive analysis of the facial morphology and overcomes the problems of restricting the evaluation to a limited set of landmarks.

The application of an anthropometric facial mask has been used to provide a full description of the facial changes due to abnormal growth and following the surgical correction of facial asymmetry[14–16]. Facial soft tissue changes following mandibular advancement using a bilateral sagittal split osteotomy (BSSO) have been investigated in past decades either by profile assessment using 2D cephalometric analysis[17–19], or more recently by 3D soft tissue analysis[16,19]. However, information in the literature on the 3D facial changes following bimaxillary osteotomy using contemporary methods of shape analysis is limited. Therefore, the aim of this study was to provide a comprehensive description of facial changes following the surgical correction of mandibular retrognathism with BSSO advancement and following the correction of maxillomandibular retrusion with bimaxillary advancement using anatomical dense correspondence analysis.

Materials and methods

The preoperative and postoperative cone beam computed tomography (CBCT) scans of 24 patients were used in this study: 12 patients underwent bimaxillary advancement (Le Fort I osteotomy and BSSO advancement) and 12 patients underwent BSSO mandibular advancement. The patients were white Caucasian, of both sexes, and aged between 17 and 46 years. Ethical approval was obtained from the local ethics committee and the Research and Development Department of Greater Glasgow and Clyde Health Board (12/WS/0133).

The preoperative and 6-month postoperative CBCT scans were superimposed on the anterior cranial base using voxel-based registration. The skeletal surgical movements were measured according to a novel method developed and reported by the present study group[20].

Three anatomical landmarks were digitized on the DICOM image slices for the maxilla (incisive foramen, right and left greater palatine foramina) and the mandible (genial tubercle, right and left mental foramina). The positional difference between pre- and postoperative landmarks in the x, y, and z directions was recorded, and the average was calculated for the three landmarks on each jaw and in each direction.

A generic facial mesh was created and conformed onto the pre- and post-surgery 3D images of the patients using in-house software. The process is started with an initial semi-automatic wrapping of the mesh, which is followed by final fully automated conformation[21]. For each patient, the conformation process produced preoperative and postoperative meshes that had the same number and index of the vertices. An average preoperative and postoperative face was created for each study group by applying full Procrustes superimposition[22]. This produced an average pre- and postoperative 3D facial soft tissue mesh that had the same corresponding vertices. Anatomical dense correspondence was applied using in-house software, and the facial soft tissue changes in each of the three directions (x, y, and z) were investigated separately for detailed analysis.

The soft tissue changes of the face as a result of surgery were considered positive if they were in the upward direction vertically, towards the right horizontally, and towards the observer anteroposteriorly; these areas were highlighted in red. The postoperative soft tissue changes of the face were considered negative if they were in the downward direction, towards the left, and away from the observer; these areas were highlighted in blue. The regions where no changes were detected were shown in green. The intensity of the colour indicated the magnitude of the change in the region examined. The colour scale was displayed on the left side of the face. The colour code, represented by the colour bar, categorized the changes into the central green colour (zero movement), an upper part with yellow, orange, red, and dark red (corresponding to 0.5 mm, 1 mm, 1.5 mm, and >2 mm movements, respectively) and a lower part with sky blue, sea blue, blue, and dark blue (corresponding to 0.5 mm, 1 mm, 1.5 mm, and >2 mm movements, respectively).

Results

Skeletal surgical movements

With regard to the bimaxillary osteotomy, the average movements of the maxilla were an advancement of 5.5 mm (standard deviation (SD) 2.7 mm), anterior vertical impaction of 2.7 mm (SD 2.5 mm), and posterior vertical impaction of 2.3 mm (SD 1.4 mm). The mandibular advancement was 4.6 mm (SD 3.2 mm), with a vertical upward displacement (mandibular autorotation) of 5.0 mm (SD 3.6 mm) and minimal lateral shift.

For the mandibular sagittal split osteotomy, the mean skeletal movements were 3.5 mm (SD 2.6 mm) advancement, with a 2.2 mm (SD 2.7 mm) downward movement.

Soft tissue changes in response to bimaxillary advancement

Soft tissue changes in the x-direction (mediolateral change)

Figure 1 shows the soft tissue surface changes in the x-direction only. The region around the nasal bridge, nasal tip, and along the central part of the upper lip was green, indicating minimal changes in these regions. The right ala of the nose displayed a blue colour, while the left ala of the nose displayed a yellowish-red colour, which is an indication of nostril widening.

Most of the changes were limited to the anatomical boundaries of the paranasal region. The commissures of the mouth and the lower lip showed minimal lateral narrowing.

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