

Research Paper  
Imaging

# Evaluation of mandibular contour in patients with significant facial asymmetry

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**Abstract.** Most previous studies on facial asymmetry have not specifically differentiated mandible deviation from structural asymmetry of the mandible. The purpose of this study was to assess the symmetry of the mandible by examining its contour in a cohort of patients with significant facial asymmetry. Eleven cases of facial asymmetry with chin deviation  $\geq 10$  mm were enrolled. A voxel-paired median plane (optimal symmetry plane, OSP) and two landmark-based median planes were generated. The OSP was created by computing the best pairing of the bony voxels on the two sides. One side of the mandibular contour was mirrored onto the other side using the test plane. The contour differences were measured by distance and by area ratio. They were examined both in frontal and frontal downward inclined view. The contour symmetry of the mandible was that revealed by the plane that presented the best symmetry. The results showed that the OSP worked best in bisecting the contour into two symmetrical halves. Contour analysis showed relatively small discrepancies between the two sides. In conclusion, the mandibles retained an acceptable contour symmetry despite the presence of significant mandibular deviations. It is suggested that proper mandibular alignment be the primary objective in the correction of facial asymmetry.

**Keywords:** facial asymmetry; mandibular contour; symmetry plane; misalignment.

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Facial symmetry is one of the most significant factors in determining facial attractiveness.<sup>1,2</sup> Surgical correction is usually advocated for conspicuous skeletal asymmetry. However, residual asymmetry is a common consequence.<sup>3</sup> The mandible plays a crucial role in facial symmetry due to its key position, and therefore its symmetry has been a major clinical issue in computer-aided maxillofacial

reconstruction.<sup>4–8</sup> Traditionally, a facial midline is generated by connecting median landmarks or bisecting bilateral landmarks on the midface or cranial base. For the purpose of assessment, asymmetry of the mandible is referred to this midline.

A similar concept has been adopted in assessing mandible symmetry in three dimensions (3D). A facial median plane based on landmarks on the midface or

cranial base is used as reference.<sup>6,9–12</sup> However, the mandible has its own growth and modelling mechanisms.<sup>13</sup> Facial asymmetry can be caused by a discrepancy in size or shape of the two halves or structural asymmetry of the mandible, or by a misalignment across the midface and the mandible. The result of mandibular asymmetry assessed with the classical approach is a mixture of the two categories

of asymmetry. AlHadidi et al. studied facial median planes and concluded that with this approach there are limitations in assessing the symmetry of the rotated mandible in 3D.<sup>14</sup> To assess the structural symmetry of the mandible, it is advocated that the left and right halves be referred to the mandibular median reference plane for comparison. However, until recently, there has been no median mandibular plane described in the literature.

Symmetry of the mandible itself has been studied in subjects with an averaged or asymmetrical face.<sup>9,15–17</sup> Lee et al. studied the mandibular dimensions in facial asymmetry patients and found significant differences in bilateral condylar and ramal height, mediolateral ramal inclination, and anteroposterior condylar inclination.<sup>15</sup> Maeda et al. reported that asymmetry was most frequently observed in the mandibular body region.<sup>11</sup> However, none of these studies appear to refer to the mandibular median plane used for the study. There has also been no study examining the mandibular contour for symmetry, despite this being considered the chief determinant of the appearance of facial symmetry.<sup>17</sup>

The purpose of this study was to examine the contour symmetry of the mandible in a cohort of patients with significant facial asymmetry. Bilateral symmetry depends on the median plane chosen. In the present study, three different median planes are proposed: two median planes constructed with mandibular landmarks and a landmark-free voxel-paired median plane (optimal symmetry plane, OSP). These planes were applied for the contour analysis. According to the voxel-pairing algorithm, the OSP provides the best symmetry of the entire structure across the plane.<sup>18</sup> However, it is not clear how this would perform in the contour analysis. The contour symmetry of the mandible was that revealed by the plane that presented the best symmetry in the analysis.

## Materials and methods

### Patient recruitment and data collection

Eleven consecutive patients with significant facial asymmetry were enrolled in this study. They were recruited from the department of oral and maxillofacial surgery of a university hospital between January 2008 and July 2012. The inclusion criteria were (1) a request for correction of facial asymmetry, (2) a chin deviation distance  $\geq 10$  mm, and (3) available computed tomography (CT) data. Patients whose facial

asymmetry was due to trauma, previous surgery, or a neoplasm were excluded.

Frontal cephalometric analysis was performed in the usual fashion. Chin deviation was measured from the menton to the facial midline connecting crista galli and anterior nasal spine. Occlusal plane canting was determined by the angle formed by the Frankfort horizontal (FH) plane and the occlusal plane connecting the buccal cusp tips of the upper first molars on both sides. The patient's facial skeleton was scanned with the canthus–tragus line perpendicular to the floor using a spiral CT machine and 0.7-mm slice thickness (settings of 120 kV and 70–80 mA, with an increment of 0.7 mm) (Siemens SOMATOM Definition Flash, Erlangen, Germany). The data were stored in Digital Imaging and Communications in Medicine (DICOM) standard format and were then transferred to the laboratory computer for further processing. A symmetrical virtual model was created to serve as a positive control.

### The optimal symmetry plane

The symmetry of an object was defined as the status of having the greatest pairing of the structural elements achievable on the two sides. A computer algorithm was developed to examine the CT images by counting the number of paired voxels side-by-side. The entire hard tissue of the mandible was included for computing purposes. The higher the rate of voxel-pairing, the more symmetrical the image becomes. Using an optimization algorithm, the OSP is the flat plane presenting the highest rate of voxel-pairing. The automated method has been described in previous publications.<sup>18,19</sup> The mandibular OSP served as one of the test median planes in this study.

### The landmark-based median planes

A landmark-based median plane for the mandible has not so far been reported in the literature. Two sets of landmarks were developed in the present study to build the mandibular median planes. The anterior-weighted landmark plane (ALP) was built with two anterior landmarks and one posterior landmark. The anterior landmarks were the midpoint of the genial tubercles and the mid-alveolar crest, i.e., the midpoint between the two lower central incisors on the alveolar crest. The posterior landmark was the mid-gonion, i.e., the midpoint of the right and left gonions. The mid-alveolar crest has been used to represent the upper border of the median

mandible.<sup>11</sup> The posterior-weighted landmark plane (PLP) consisted of two posterior landmarks and one anterior landmark. The posterior landmarks were the mid-gonion and the mid-condyle, i.e., the midpoint of the medial poles of the right and left condyles. The anterior landmark was the midpoint of the genial tubercles (Fig. 1). Four researchers, including one senior orthodontist, two graduate students, and one research fellow, were recruited to locate the landmarks. They were instructed to use the computer to identify the landmarks in 3D. A case that was not included in the study was used for practice before the actual localizations were performed.

### Mandible contour analysis

First, a Cartesian coordinate system was defined. A midface OSP was constructed as described.<sup>19</sup> Bilateral orbitales and porions were identified and projected onto the midface OSP. The mid-orbitale was the midpoint between the projected orbitales, and the mid-porion was the midpoint between the projected porions. The mid-porion was defined as the origin. The *y*-axis was oriented from the mid-orbitale to the mid-porion. The *x*-axis was orthogonal to the midface OSP and pointed to the left half of the face. The *z*-axis was orthogonal to both the *y*- and *x*-axes and pointed upward. The *YZ* plane was the median reference plane of the face, and the *XY* plane resembled the FH plane. The *XZ* plane was the frontal plane coplanar with the projected porions. For contour analysis, the mandibles were de-rotated on *y*- and *z*-axes, so that their median planes coincided with their midface OSPs. According to the prescribed coordinate system, the frontal and the frontal downward inclined planes were constructed to build the mandible contours in two dimensions (2D). The frontal projection was obtained on the *XZ* plane. The frontal downward inclined projection was obtained on the plane formed by rotating the *XY* plane 45° along the *x*-axis (Fig. 2).

The tested median planes divided the mandible into left and right halves. The computer-generated mandibular model is a surface-based geometry consisting of cloud points and associated meshes in 3D. The left and right halves of the mandibular models were projected onto the frontal or the frontal downward inclined plane. Contours were formed on the frontal or the frontal downward inclined plane by connecting mandible border vertices with equal chord length distribution. The upper boundaries of the left and right contours were set by the levelling lines, which were orthogonal to the median

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