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Plane-to-plane analysis of mandibular misalignment in patients with facial asymmetry

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Introduction: Little is known regarding how the mandible rotates in facial asymmetry. The purpose of this study was to study mandibular misalignment with a new plane-to-plane analysis method in patients with facial asymmetry. **Methods:** Optimal symmetry planes (OSPs) were generated by computing the greatest count of paired voxels on opposing sides of the computerized tomography image of the structure. The mandibular OSP was measured against the midfacial OSP for its alignment. The deviation angle formed by the 2 OSPs was broken down into a y-axis component (frontal deviation angle) and a z-axis component (horizontal deviation angle). Fifty-nine patients who sought correction for facial asymmetry were included for study. **Results:** The new analysis method was feasible. Fifty patients (83%) had significant mandibular misalignment (deviation, ≥4° or 4 mm). The locations of the rotational axes exhibited significant variations that could explain the varied features of the asymmetry. The frontal deviation angle (mean, 3.80° ± 3.89°) was significantly larger than the horizontal deviation angle (mean, 2.77° ± 1.71°). There was no significant correlation between the horizontal deviation angle and the anterior deviation distance or the posterior deviation distance. **Conclusions:** Proper mandibular realignment was suggested to be the primary aim in surgical correction of most jawbone asymmetries. Because of the greatly varied rotational axes and the obscure z-axis rotation, realignment could be difficult with the traditional approach. The OSP-based analysis is advocated to guide planning. (Am J Orthod Dentofacial Orthop 2018;153:70-80)

Symmetry is essential for facial beauty and attractiveness.[1,2] Studies have shown that up to 67% of the orthognathic patient population has some form of facial asymmetry.[3,4] The treatment goal is a symmetrical dentofacial configuration with a functional occlusion. A comprehensive evaluation of the asymmetry is mandatory. Traditionally, the assessment is done by referencing median or bilateral landmarks to the facial midline or the median plane, which is constructed by connecting median landmarks or bisecting bilateral landmarks on the midfacial bone and cranial base. The analysis results are presented as chin deviation distance, facial width discrepancies, occlusal plane canting angle, or the dihedral angle formed between the midline and the anterior nasal spine-menton line.[5-13] A similar approach has been adopted in 3-dimensional (3D) cephalometry. This approach considers the facial skull as 1 structural unit and examines primarily asymmetry of landmarks. Correction of asymmetry aims to neutralize the occlusal plane cant and chin deviation.

Another approach to facial asymmetry assessment involves dividing the asymmetry into structural asymmetry and alignment asymmetry.[14] The former represents the internal asymmetry of the individual facial bone subunits. The latter denotes the asymmetry caused by a mismatch in position or orientation across 2 structural

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components in the facial bone unit; in most cases, this is the deflection of the mandible from the midfacial bone or mandibular misalignment. This approach acknowledges the theory that the mandible has its own growth and modeling mechanisms. Unequal mandibular growth has been shown to be a major cause of facial asymmetry.[15,16] In that context, the mandible is separated from the rest of the facial bone in symmetry evaluation. A matching optimal symmetry plane planning method has been proposed to correct facial bone asymmetry surgically.[17] This was done by initially realigning the mandible to the midface using its optimal symmetry plane (OSP) as a guide, followed by bone contouring for residual asymmetry, if necessary. Mandibular misalignment is considered to be the major cause of facial bone asymmetry; however, the assumption lacks proof in the literature. Studies of mandibular misalignment are scarce. Most are technical notes or reports on a few patients. It has been described as roll or yaw of the mandible.[18] A few studies have described how the roll or yaw was measured.[19] There is doubt about whether they showed rotations of jawbones or merely dental arches. The anterior nasal spine or nasion has been designated as the rotational center for frontal cephalometric analysis of facial asymmetry.[13] However, there are no relevant studies of the rotational center or the rotational axis in the literature. Little is known regarding how the mandible rotates and how rotations affect facial asymmetry. The purpose of this article was to define mandibular misalignment with a plane-to-plane symmetry analysis method in patients who required facial asymmetry correction. The specific aims were to (1) study the rate of significant mandibular misalignment in these patients, (2) locate the rotational axes of the misalignments, and (3) quantify the magnitude of the rotations in 2 and 3 dimensions. An attempt was made to characterize the asymmetry with the location of the rotational axis.

MATERIAL AND METHODS

A retrospective review was conducted of a cohort of patients with facial asymmetry for whom the analysis method had been applied. The inclusion criteria were (1) facial asymmetry as a major reason for seeking treatment in the Department of Oral and Maxillofacial Surgery or the Department of Orthodontics at National Cheng Kung University in Tainan, Taiwan, and (2) complete analysis records for the patient were available. Patients with neoplasms or previous orthognathic surgery were excluded. A total of 78 patients with facial asymmetry had visited the department with or without other facial disharmonies and received facial bone computed tomography (CT) examinations from May 2010 to February 2015. Nineteen patients were excluded because of incomplete data (n = 18) and previous orthognathic surgery (n = 1), resulting in a final cohort of 59 patients. The institutional review board of the hospital approved the study, and all participants provided written informed consent. We reviewed the Declaration of Helsinki and followed the guidelines in this investigation.

All patients underwent CT examinations for symmetry analysis and 3D orthognathic planning. Each patient's facial skeleton was scanned (with the canthus-tragus line perpendicular to the floor), using a spiral CT machine at 0.7-mm thick slices (settings, 120 kV and 70-80 mA; increment, 0.7 mm; STOMATOM Sensation 16; Siemans, Erlangen, Germany). The CT images were stored digitally in a standard digital imaging and communications in medicine format. All data obtained were transferred to a personal computer in the laboratory for additional processing using the self-developed imaging-processing software. For the routine facial skeleton study, the structures behind the external auditory meatus were excluded and erased.

Symmetry was defined as the pairing of the bilateral structural elements across an imaginary plane. The higher the rate of pairing, the more symmetrical the structure. The OSP is the sagittal plane that results in the greatest count of paired voxels on opposing sides of the CT image. A mathematical optimization algorithm was developed to compute the highest rate of voxel pairing. The plane that yields the highest rate is the OSP, obviating the need of landmark identification. The calculation is done automatically by the computer (Fig 1). The method has been described in previous articles.[17,20,21] Because a flat plane is generated, local asymmetry may occur with a major growth disturbance (Fig 2).

A virtual bony tumor study was conducted in which spherical bone tumors of an incremental size of 5 mm in diameter were added to the canine or molar region of a mandible model in the computer until the OSP diverted. The new mandibular OSPs were computed, and the dihedral angles between the new OSPs and the original OSP were measured. The result showed that the OSP remained steady, unless the tumor was large enough to overwhelm the original structure. Then, the OSP diverted abruptly to traverse the virtual mass (Fig 3). The original OSP could be recovered by erasing the tumor grossly and recalculating the rate of paired voxels of the mandible.

In the plane-to-plane symmetry analysis system, the skull was orientated with the midface OSP as the midsagittal plane. The horizontal plane was the plane perpendicular to the midsagittal plane and coplanar with midporion and midorbitale (midporion, midpoint of the right and left porions in the midsagittal plane; midorbitale, midpoint of the right and left orbitales in