Review Article

Facial asymmetry revisited: Part I- diagnosis and treatment planning

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ABSTRACT

Facial asymmetry is an individualized characteristic and is commonly observed sub clinically in overall population. However, clinically significant facial asymmetry with associated morphologic, esthetic and stomatognathic problems warrant investigation of the underlying etiology and comprehensive clinical examination in conjunction with imaging studies for diagnosis, localization of asymmetry and treatment planning. The principal aim of this article is to present an invaluable insight into etiopathogenesis, myriad classifications and various systematic diagnostic approaches indispensable for formulation of treatment plan and appropriate management of facial asymmetry.

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1. Introduction

There is no perfect bilateral body symmetry existing in living organisms in real sense. Any two congruent but mirror type images existing in nature usually exhibit right-left variations. Humans frequently exhibit functional and morphological asymmetries, in form of right and left handedness as well as preference for one eye or one leg.¹

Human facial symmetry is a key determinant for assessing facial attractiveness and expressions in psychology and anthropology.² Facial asymmetry is defined as the presence of a clinically significant variation between the two halves of the face that the patient [or parents, in the instance of most congenital

asymmetries] is concerned about and that can be quantified by the clinician.³

Slight nonpathologic asymmetry is usually indiscernible and often considered normal, but owing to the subjectivity of facial esthetics, the threshold of its clinical significance cannot be easily determined; and thus the acceptability probably depends on the region of asymmetry, clinician's sense of balance and the patient's perception of imbalance.^{1,4}

Esthetic and functional problems associated with significant facial asymmetry may adversely affect the patient's orofacial, nutritional and psychosocial development. Critical evaluation and more precise treatment planning is required as anything short of an optimal result will often precipitate dissatisfaction with the result.³ This article intends to provide an insight into the key aspects to be taken into consideration while accomplishing an accurate diagnosis and formulation of rational integrated orthodontic-surgical treatment plan that considers correction of all aspects of the asymmetry.

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2. Epidemiological considerations

With respect to skeletal growth pattern, more frequent association of facial asymmetry with skeletal class III malocclusions and less frequent association with skeletal Class II malocclusions have been reported in the studies of Good et al.⁵ and, Severt and Proffit⁶ respectively. Greater deviation was observed in lower part of the face when compared to upper and midface. Laterality of chin to the left was also discernible in 90% of the cases.⁶ Haraguchi et al.⁷ reported equal prevalence of facial asymmetry among skeletal Class I, II and III patients. Due to greater occurrence of Class III malocclusions in Asians than in Caucasians, facial asymmetry is more prevalent among the normal population in Asia than in Western countries.⁸

3. Etiopathogenesis and classifications

Understanding the etiology of facial asymmetry is critical with regards to treatment planning, management and long-term stability. Facial asymmetry may have different origins, namely i) congenital, originating prenatally, ii) developmental, originating during growth with inconspicuous etiology, and iii) acquired, resulting from functional mandibular displacements, traumatic injury or any pathology. Congenital asymmetries include orofacial clefts, hemifacial microsomia, neurofibromatosis, congenital muscular torticollis, unilateral coronal craniosynostosis and

malformations, such as syndromes, hypoplasias and hyperplasias with varied etiologic presentations.

A flowchart depicting different documented classifications of facial asymmetry is as follows:

Cohen¹³ coined the term 'hemi-asymmetries' to classify asymmetries of craniofacial skeleton in four categories, namely hemi-hyperplasia (hemifacial hypertrophy), hemi-hypoplasia (hemifacial microsomia), hemi-atrophy (Romberg syndrome) and other miscellaneous entities (Bencze syndrome, hemimaxillofacial dysplasia).

Flowchart depicting morphological structural classifications is as follows:

positional plagiocephaly, among others. Acquired states of asymmetry include facial trauma, fractures, temporomandibular joint (TMJ) infection and arthritis, TMJ ankyloses, facial pathologies and tumours, Parry-Romberg syndrome and unilateral condylar hyperplasia or hypoplasia, among others.⁸

Based on the environmental and genetic influences on bilateral symmetry in humans, Van Valen⁹ classified asymmetry as being directional, antisymmetry and fluctuating type. Directional asymmetries and antisymmetry are considered developmentally normal. However, fluctuating asymmetry reflects the inability of the individual to develop identical bilaterally homologous structures. Presence of fluctuating asymmetry has been reported in craniofacies, and in deciduous and permanent dentitions.

The terms 'laterocclusion' and 'laterognathism' are used to distinguish between a class of "apparent facial asymmetries" and a class of "true asymmetries", respectively.¹⁰ Genesis of apparent facial asymmetries is attributable to mandibular deviation caused by occlusal anomalies; whereas true asymmetries include skeletal

Another classification proposed by Wolford¹⁷ involves 4 categories of asymmetry, as demonstrated in Table 1.

3.1. Clinical considerations

Facial asymmetries more commonly manifest in mandible (and chin) as it forms the skeletal support for soft tissues of the lower face and has longer periods of growth. On the contrary, smaller secondary role of maxilla in asymmetry is attributed to rigid attachment of maxilla to the stable region of synchondroses at the cranial base and minimal soft tissue support provided by it.

From a clinical perspective, determination of the extent of skeletal, dental, functional and soft tissue involvement of craniofacial structures is deemed necessary (Table 2).¹ Photographs representing varied clinical presentations of facial and dental asymmetry are depicted in Figs. 1 a–e and 2 respectively.

During the examination, three important factors requiring special attention are the location of the asymmetry, the tissues

Table 1

Wolford's classification of facial asymmetry.

Pseudoasymmetry	Normal facial asymmetry (nonpathologic)	Unilateral overdevelopment	Unilateral underdevelopment or degeneration
<ul style="list-style-type: none"> - Occlusal interferences - Neuromuscular dysfunction, - Habitual posturing - Condylar dislocation - Temporary unilateral facial swelling resulting from facial trauma 	<ul style="list-style-type: none"> - Genetics - Intrauterine molding - Natural growth variance 	<ul style="list-style-type: none"> - Unilateral condylar hyperplasia - Mandibular hyperplasia - Deviant prognathism - Unilateral masseteric muscle hypertrophy - Tumours (osteochondroma and osteoma) - Unilateral facial neuromuscular disorders (Facial nerve trauma, Bell's palsy, Ramsey-Hunt syndrome, Mobius syndrome, mastoid infections and cerebral vascular accidents affecting the facial nerve) 	<ul style="list-style-type: none"> - Congenital deformities (unilateral cleft lip and palate, Hemifacial microsomia, Treacher-Collins syndrome) - Acquired states of asymmetry (Trauma, Infection, TMJ ankylosis and iatrogenicities due to tumour resection, radiation, unstable orthognathic procedures and adverse surgical events) - Unilateral adolescent internal condylar resorption - Unilateral reactive(inflammatory) TMJ arthritis - Connective tissue or autoimmune diseases (juvenile rheumatoid arthritis, ankylosing spondylitis, mixed connective tissue disease, etc)

Table 2

Bishara's classification based on craniofacial structures involved.

Dental	Skeletal	Muscular	Functional
<ul style="list-style-type: none"> - Congenitally missing tooth or teeth - Premature loss of deciduous teeth - Deleterious oral habits such as digit sucking resulting in asymmetric open bite - Midline discrepancies - Occlusal discrepancies in first, second or third order plane 	<ul style="list-style-type: none"> Involving i) Maxilla, or/and ii) Mandible, or iii) number of skeletal structures on one side of face, as in Hemifacial microsomia and Treacher-collins syndrome 	<ul style="list-style-type: none"> - Hemifacial microsomia - Mobius syndrome - Cerebral palsy - Unilateral masseter or temporal muscle hypertrophy - Long term untreated cases of torticollis causing fibrosis of the sternocleidomastoid muscle 	<ul style="list-style-type: none"> - Centric prematurities causing a lateral mandibular displacement on full closure from initial tooth contact position to habitual occlusal position - Presence of malpositioned tooth, dental crossbite, constricted maxillary arch or anteriorly displaced articular disc usually results in functional deviations.

involved and the dimensions involved. A simplified, effective and clinically useful classification system for assessing the positions of three anatomical areas, namely the maxilla, mandibular body and symphysis, in relation to the facial midline and the presence of occlusal canting has been recommended for clinical use by Reyneke et al.¹⁸ The method involves construction of a prism representing the maxillomandibular complex which enables visualization and evaluation of three dimensional surgical alterations/movements of the midface and lower face required for correction of dentofacial asymmetry.

TMJ and facial asymmetry: Characteristics of different progressive facial asymmetry conditions involving TMJ are described in Table 3.¹⁷

4. Diagnostic evaluation

An assessment of structural and functional status of the patient by means of thorough clinical examination, occlusal splints, study models, face-bow transfer, comprehensive radiographic survey (including imaging of TMJ) and laboratory tests (electromyographic and ultrasonographic evaluation) is indispensable for accurate diagnosis of asymmetries.

1. Direct clinical examination commencing with determining the chief complaint and evaluating the medical history remains the foremost essential diagnostic aid revealing asymmetry in the sagittal, coronal and vertical dimensions.⁸

Extraoral direct clinical assessment involves visual inspection of facial morphology, palpation of facial structures and contours to distinguish between soft and bony defects; inspection of symmetry between the bilateral gonial angle and contours of mandibular body, mandibular deviation, cant of the inferior border of the chin and TMJ evaluation. At smiling, comparison of dental midline with the true facial midline and determination of the amount of gingival

show per side should be done.¹⁹ Additionally, smile symmetry is also assessed by the parallelism of commissural and pupillary lines to each other (Fig. 3). Canting of occlusal plane needs to be assessed at rest, and during smiling positions. Intraorally, malocclusion, tipping of anterior and posterior teeth, open bite, cross bite, midline deviations, functional mandibular shifts and maximum interincisal opening should be assessed.^{8,20}

Interestingly, patients with facial asymmetry usually exhibit compensatory head posturing due to which the head is tilted slightly to the right or left to minimize/mask the effect of asymmetry. Therefore prior to making an objective, quantitative examination, clinician should deliberately orient the patient's head to correct any compensatory head posture. Patient is also advised to eliminate other compensatory mechanisms such as mannerisms and hairstyle that might mask the asymmetric deformity, thus misleading the treatment plan.

4.1. Frontal view photographic examination

Properly oriented photographic views also help determine the amount of vertical and transverse asymmetry. Assessment of asymmetry is usually done with patient's head positioned so that the Frankfort horizontal plane and the interpupillary lines are parallel to the floor. Interpupillary line used for transverse head orientation acts as a horizontal reference line and adjacent structures are measured relative to this line. Facial midline assessment should be done in centric relation with the teeth in their initial contact position. A midsagittal plane passing directly between the medial palpebral fissures i.e. middle of nasion is helpful in assessing the degree of left-to-right asymmetry involving structures such as maxillary and mandibular incisors, chin and nasal structures. Philtrum and the distance of the canines to the corners of the mouth can also be used as stable soft tissue

Fig. 1. (a) Frontal view photograph illustrating facial asymmetry of deviate prognathism type. (b) Frontal photograph depicting facial asymmetry of hemimandibular hyperplasia type. (c) Frontal view photograph depicting facial asymmetry due to left TMJ ankylosis. (d) Frontal view photograph showing facial asymmetry due to right sided hemifacial microsomia. (e) Frontal view photograph depicting facial asymmetry due to left side masseteric hypertrophy.

Fig. 2. Intraoral frontal view depicting asymmetric open bite due to long persistent unilateral digit sucking habit.

landmarks for determining facial midline. The “V” formed by center of philtrum is a suitable landmark for location of maxillary dental midline.²⁰

Evaluation of dental midline should be done at mouth open, in centric relation, at initial contact and in centric occlusion positions. True uncomplicated dental and skeletal asymmetries exhibit similar midline discrepancies in centric relation and in centric occlusion. Contrary to this, functional mandibular shift at initial tooth contact is usually observed in asymmetries arising due to occlusal interferences. The shift can occur in the same direction or opposite direction of the dental or skeletal discrepancy, thus accentuating or masking the asymmetry.

An asymmetric mandible can be guided laterally until the chin midline is relatively symmetric with the true facial midline (except in TMJ conditions in which condyle does not translate). The occlusion and facial structures are subsequently evaluated for asymmetry in this position. This maneuver helps in getting an

Table 3
Different clinical presentations of facial asymmetry conditions involving TMJ.

Clinical presentation	Diagnosis
Progressive development and worsening of facial asymmetry during early teen years or later in life with or without skeletal, soft tissue and occlusal changes	TMJ pathology or tumour
Progressively worsening Class III occlusal relationship with a contralateral crossbite and mandibular and chin deviation to the opposite side	Unilateral condylar hyperplasia
Unilateral vertical lengthening of face and jaws with lateral open bite on the involved side, usually with Class I occlusion and clinically significant transverse occlusal and facial cant	Unilateral mandibular condylar osteoma or osteoblastoma
Development and progressive worsening of anterior open bite (Apertognathia) in conjunction with Class II occlusion (distocclusion)	Condylar resorption

Fig. 3. Assessment of smile symmetry by the parallelism of commissural and pupillary lines to each other.

improved perspective in the transverse dimension on the effect of surgical correction of transverse mandibular asymmetry.¹⁷

Vertical occlusal evaluation (Roll) includes assessment of the cant of occlusal plane by asking the patient to bite on a tongue blade/spatula or wooden sheet placed transversely between the maxillary and mandibular cuspid or first bicuspid area, and determining its relation to the interpupillary plane (Fig. 4a). Greater than 4° of inclination of occlusal plane has been reported to cause significant discernible asymmetry on patient's face.²¹ Significant canting of occlusal plane could be the result of pathology such as osteoma, osteochondroma and condylar hyperplasia affecting the vertical dimensions of the mandibular ramus and/or condyle, thus resulting in progressive development of ipsilateral unilateral open bite.

Transverse evaluation (Yaw) – Asymmetry in the buccolingual relationship, as in unilateral posterior crossbite needs careful assessment to ascertain the skeletal, dental or functional causes of asymmetry. Intraoral occlusal views and oclusograms are helpful in assessing the overall shape of dental arches and differences in the buccolingual inclination of the teeth.¹

Assessment of deviation of midline structures such as nasal bridge, nasal tip, philtrum and the chin point should also be carried out, in addition to bilateral structural comparisons.

The profile views (right and left) are usually more helpful in determining the anteroposterior and vertical position of maxilla, mandible and chin than asymmetry evaluation.¹⁷

Extraoral frontal (without and with smile, and cant of lower border of mandible) views are supplemented with adjunctive standardized three-quarter, submental (inferior) and superior

Fig. 4. (a) Frontal view photograph showing assessment of cant of occlusal plane in relation to interpupillary plane. (b) Frontal view photograph showing true facial midline for documenting facial asymmetry with deviation of mandible toward left side. (c) Frontal view photograph illustrating cant of lower border of mandible. (d) Submental view photograph documenting mandibular asymmetry. (e) Superior (Bird's eye) view photograph.

(Bird's) views for documentation of symmetry of different craniofacial structures (Figs. 4b–e). Submental view, taken with patient's head in hyperextended (about 45°) position and superior view, taken with patient's head in hyperflexion (about 45°) are useful in assessing symmetry and projection of the anterior cranial vault, orbital areas and cheeks. Nasal deformities and cheek deformities can be documented and studied in submental and superior views, respectively.

2. Study models – Properly trimmed study models simulating the anatomy provide a more comprehensive three-dimensional view of dental relationships, with the added advantage of enabling the occlusion to be viewed from the lingual aspect. Mounting the dental casts in centric relation by face-bow transfer onto an adjustable anatomic articulator helps in further evaluation of the diagnosis of rotary displacement of maxilla. However, for mounting study models with best simulation of the patient's specific asymmetry, SAM Occlusal Plane Indicator (OPI) provides better accuracy as compared to the conventional facebow transfer. 17 Articulator mounted casts are desirable in patients having asymmetric Class III dentofacial deformities with associated TMJ symptoms. In these patients, use of disclusion splint is recommended for a few days before making the retruded contact position (RCP) record so that muscle spasm and splinting do not distort the condylar position. 22

3 Radiographic examination

Unlike Lateral cephalogram which has limited utility, orthopantomogram is an essential and useful diagnostic aid.

Posteroanterior(PA) cephalometry (*Craniofacial Frontal Analysis*) – It is a vital tool that facilitates comparative study of the right and left structures since they are located equidistant from the film and x-ray source, thus minimizing the effects of unequal enlargement by the divergent rays and reducing the distortion. To determine the extent of functional deviation, PA projection can be obtained in both open mouth position and centric occlusion with head oriented in natural head position. 4

Localization of asymmetry from PA Cephalogram 1: Anatomic, bisection and triangulation approaches are usually employed for qualitative and quantitative evaluation of the extent of asymmetry. A horizontal reference line is drawn through the bilateral zygomatico-frontal sutures to act as a horizontal axis in the construction of the horizontal and midsagittal reference planes. A vertical line passing through crista galli and drawn perpendicular to the horizontal plane, usually approximates the anatomic midsagittal plane of the head. Distances of perpendicular lines drawn from the bilateral structures to the midsagittal plane are measured, and thereafter, compared to determine discrepancies in height and the distances between the bilateral structures and the midline. Additionally, comparison of maxillary and mandibular dental midlines to the skeletal midline is also done (Fig. 5).

In triangulation analysis, 23 triangles are constructed for evaluation of the symmetry of the maxilla, mandible and chin. The right and left triangles are then compared for asymmetry. Cants in the maxilla, mandible and chin in relation to cranial base, as well as to each other can be evaluated by measuring the long legs of the triangles. Transverse discrepancies on rotations can be assessed by comparing the right and left sides of the bases of the triangles. Midline asymmetries of the nasal spine, menton and dental midlines can be evaluated.

Frontal mesh diagram analysis aids in asymmetry assessment by means of graphic display in a coordinate system. Proportionate assessment of landmark location in the mesh diagram without computation of linear and angular measurements also tends to reduce the impact of errors related to identification of anatomic structures and landmarks on PA films. 4

By virtue of the patient positioning (with Frankfort horizontal plane parallel with the film cassette and allowing upward

Fig. 5. PA headfilm tracing showing frontal facial(mandibular) asymmetry.

projection of the facial bones), *submental-vertical radiographs* offer advantages of ease of identification of reliable midline reference structures in assessment of craniofacial asymmetry. Grayson et al 24 reported the use of multiplane cephalometry (analysis of PA and basilar cephalograms at various depths) for evaluation of asymmetry of craniofacial skeleton.

Serial tracings of cephalograms over a minimum interval of 1 year may be helpful in determining if the asymmetry is static and stable or if it is progressive.

Adjunctive techniques – Additional soft tissue markers such as barium markers can be used to enhance the diagnostic value of PA and lateral cephalogram. The PA barium cephalometric radiograph in conjunction with facial anthropometric measurements is beneficial in planning correction of the cant of occlusal plane. 3

Majority of cases require supplementation of clinical examination with other diagnostic modalities such as stereophotogrammetry, stereolithographic models and special imaging techniques for accurate localization of level of deformity in asymmetric structures.

Stereophotogrammetry – Three- dimensional stereometry, utilising two or four cameras configured to capture a pair of stereo images of the surface of patient's face, is used to generate a 3-D image of the face by triangulation performed through sophisticated stereo algorithms. MorphoStudio (3dMD's synchronized digital six-camera 3dMDface system) photogrammetric imaging system provides a precise and accurate 3-D assessment of soft tissue asymmetry (without the posing error found in conventional photogrammetry) before and after orthognathic surgery. 25

3-D Stereolithographic (3-D-SLA) models – The use of 3-D-SLA models in maxillofacial surgery has significantly improved predictability of clinical outcomes when compared to similar

treatments without its use. These 3-D models can be generated from either acrylate or epoxy resin; or they can be 3-dimensional printing (3-DP) models. 3-DP models facilitate direct visualization of anatomic structures and can be used as educational tool for patients. However, in clinical scenario, acrylate SLA models offer advantages of higher strength, higher temperature resistance, lower moisture absorption, and lower shrinkage. Moreover, they can be sterilised and their superior accuracy has been reported in the literature. Other advantages include improved reconstruction of form and function, decreased operating room time due to advanced treatment planning, and ability to perform more precise and accurate surgical procedures.²⁶

5.1. Special/Sophisticated imaging

1) Corrected tomograms – Axially corrected tomograms are helpful in delineating the shape and size of the abnormal condyle in cases of condylar hyperplasia or osteochondroma.

2) Computed tomographic(CT) scans with 2-D and 3-D views provide advantages of improved and accurate radiographic diagnosis and resolution, particularly in anomalies such as craniosynostosis, hemifacial microsomia and TMJ ankyloses. 3D CT scan reconstruction graphically illustrates the foramina representing the location of great vessels and cranial nerves in the base of the skull which are in close proximity near the operative area of TMJ ankylosis. This permits the surgeon to change technique or to make preoperative contingency plans prospectively, thus increasing the safety and predictability of the final surgical outcome.³ Additionally, 3-D CT images can provide useful information for the fabrication of stereolithographic models to facilitate evaluation and surgical planning.

In recent times, Cone-beam computed tomographic (CBCT) scanning of TMJ has gained popularity as it provides the clear images of skeletal tissues with fairly low quantity of radiation dose (Fig. 6). It also offers the advantages of acquisition of multiple cuts from a single scan and allows multiple images of the joint to be viewed in the lateral and PA dimensions during the same scan. Visualization of the articular disc can be improved by injecting radio-opaque contrast material into the joint space before obtaining the scans.

Accurate integration of CBCT and 3-D photorealistic surface imaging of the face facilitates rapid and precise creation of patient-specific 3-D computer models that can be used for diagnosis, treatment planning, treatment simulation and assessment. Moreover, appropriate application of digital 3-D diagnostic and

treatment planning imaging softwares (Digigraph, Dentofacial Planner, etc) aid in estimation of skeletal and soft tissue effects of orthognathic surgery, improving communication among clinician, patient and staff, thus allowing treatment changes (based on Surgical Treatment Objective) which can be recommended based on patient's individual preference within his or her anatomic, biologic and physiologic limits.²⁷

3) Magnetic resonance imaging(MRI) – MRI, utilising non-ionizing radiation is a valuable aid in obtaining extremely accurate images of internal hard and soft tissues of the TMJ, which assists in diagnosing osteoarthritis, condylar resorption, avascular necrosis and regressive remodelling involving the TMJ in dentofacial asymmetries.

MRI data used in conjunction with facial scan helps to create a 3-D photorealistic head model of the patient, thus assisting in visualization and simulation of the treatment effects in a virtual space.

4) Skeletal scintigraphy (Radionuclide scans) – It is a dynamic method of growth analysis depending on the differential uptake of technetium-99m methylene diphosphonate (Tc-99m) radioisotope into metabolically active bone.²⁸ Radionuclide scans are potentially useful in diagnosis and treatment planning of asymmetries of condylar hyperplasia and deviate prognathism type (Fig. 7).

Recently, better precision and reproducibility with a significantly lower error rate has been reported with use of global approach as a novel screening tool for asymmetry, instead of landmark- based approach that utilises anthropometric data points.²⁹ Global method involves registration of mirror images, independent of a midsagittal plane and calculation of a root mean square(RMS) score. The results of global method are depicted as a color-coded facial map (with a corresponding histogram) highlighting the regions of greater and lower asymmetry.

As described by Patel et al³⁰, fast, simple and landmark independent assessment of soft tissue facial asymmetry can be done using a Weibull distribution curve probabilistic model. The model is generated from the RMS error data for the symmetrical group which designates the level of asymmetry representing a normal range.

A simple and clinically useful classification (based on 3D CBCT image acquisitions) assisting in evaluation of treatment outcomes of mandibular asymmetry in Class III patients according to

Fig. 6. 3-D cone beam computed tomography volume rendering image depicting mandibular laterognathism.

Fig. 7. Tc scan revealing increased osteoblastic activity of right mandibular condyle.

different characteristics of asymmetry, has been proposed by Chen et al.³¹

According to Lee et al.³², a reference plane passing through median point of right and left endocanthion provides an effective means of establishing an appropriate midsagittal facial midline in 3D CBCT image reorientations for facial asymmetry analysis.

SUMMARY

A profound knowledge of facial asymmetry is essential to critically analyse all the features involved, and accurately quantify the magnitude of disproportion. This would help formulate more satisfying treatment plan in terms of optimizing esthetics and function while taking into consideration the perceptions and expectations of the patient.

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