Frontal Cephalometrics: Practical Applications, Part 2

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Aims: *To (1) demonstrate the needs and benefits of three-dimensional diagnostic and treatment applications; (2) illustrate practical clinical applications of anteroposterior images and frontal analysis; and (3) enhance utilization of the Ricketts and Grummons frontal analyses.* ***Methods:*** *Frontal analysis methods and applications are specified and integrated into facial, smile, jaw, and occlusal therapies. Asymmetry conditions must be differentially diagnosed and effectively treated. Frontal and related image analysis and tracing steps are detailed.* ***Results:*** *Asymmetry of facial parts is the rule, rather than the exception. Dental and facial midlines, occlusal plane, chin location, and smile esthetics are primarily emphasized. Beautiful facial proportions and smile harmony can be developed despite initial facial dysmorphosis and disproportions.* ***Conclusions:*** *Patients view themselves from the frontal perspective, so this carries priority when assessing problems. It is important to know the etiology of asymmetry to assist others with genetic counseling. Facial harmony and smile beauty are optimal when facial and maxillary dental midlines are aligned. The maxillary dentition width should be sufficiently wide to be in harmony with the individual patient facial morphology. The occlusal plane should be level and the chin centered as much as possible. Best facial development and proportionality exist when the skeletal and dental components are optimized transversely and are symmetric.* World J Orthod 2004;5:99–119.

Great smiles have harmony, symmetry, and a broadness consistent with the individual's facial form, morphology, and balance. Smiles communicate, are expressive, and especially beautiful when full. People do not perceive narrow arch smiles to be appealing. A proportional smile fills the lip embrasures and eliminates black triangles. We see this as beauty in nature, and such symmetry is preferred by the public. Orthodontic capabilities have increased with improved 3-dimensional knowledge of dentofacial growth and refined facial orthopedic procedures. The technology of tooth movement, fixed functional appliance efficiencies, space-gaining methods, and nonextraction approaches further enhance facial esthetics and symmetry of the outcome. Optimal transverse dimension should be developed for esthetic and functional advantages. Facial, skeletal, and dental midlines should be centered, with pleasing facial and dental proportionality.[1,2]

FACIAL ASYMMETRY

Definitive treatment philosophy

Maxillofacial and plastic surgeons, orthodontists, periodontists, and/or restorative colleagues can make significant and positive improvements for patients with asymmetric smiles. Beneficial results occur structurally, dentally, emotionally, and esthetically for those patients having dentofacial dysplasia with associated malocclusion. Progressive clinicians today must capably handle these asymmetric and dysfunctional patients in an interdisciplinary team approach. The frontal analysis applications described in this two-part article[3] provide meaningful, practical,

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and progressive information regarding asymmetric and often complex treatment situations. Ordinary cases may be routine, while unusual asymmetry problems challenge the understanding and expertise of the therapeutic team. Tools available to differentially handle such disproportional and dysfunctional patients have advanced significantly. Better patient management and predictable treatment responses can occur with therapy based upon fundamentals of basic science, with clinical sensibility in comprehensive and definitive clinical approaches. Answers and approaches for these asymmetric patients emphasize facial orthopedic, orthodontic, restorative, orthognathic surgical, and/or intracapsular temporomandibular joint (TMJ) management. All this stresses sensible and progressive treatment, provided in a caring manner.[4] Knowledge is knowing facts; wisdom is knowing what to do with them.

Attractiveness and Health

Beauty or attractiveness really is in the eye of the beholder; a genetic component exists. Men whose photographs show facial asymmetry are reported more likely to have psychological problems, difficulties with concentration, and lower intelligence than those men judged to be facially symmetric.[5] Males whose faces are viewed as high in symmetry are rated as more attractive, dominant, sexy, and healthy. Women whose photographs exhibit facial asymmetry show poorer health, emotional instability, and are less active lifestyles, and were less happy and less intelligent than those whose photographs are facially symmetric. We choose our friends, mates, employees, and role models based in part on their facial symmetry. Having a symmetric face does not automatically imply superior traits, but human facial asymmetry has long been a critical factor for evaluation of attractiveness. There is cross-cultural agreement; faces judged as attractive in one society are judged to be equally attractive in other societies.[6,7] People with attractive faces receive more positive reactions than those with unattractive faces[8] and are given positive attributes purely on the basis of facial beauty.[9]

Facial actions

Jaw asymmetry may be obvious cosmetically, and often there is a functional impairment, resulting in difficulty with facial actions, expressions, chewing, biting, and swallowing. The face can appear asymmetric during facial expression, with one side appearing more expressive. The source of this asymmetry is in facial motion and structural facial asymmetry.[10] Structural asymmetry (neutral expression) accounts for asymmetry at peak expression for joy, anger, and disgust. Expressions are produced more intensely on the left side of the face, consistent with the hypothesis that the right cerebral hemisphere is dominant for the expression of facial emotion.

EXAMINATION AND EVALUATION FOR ASYMMETRIES

Examine patients from directly in front while they are seated, and level the interpupillary plane horizontal with the floor to look for facial asymmetries.[11] Look for any cant of the occlusal plane, which can be measured from the inner canthus of the eye to the tip of the canine. It is clinically relevant to observe midline discrepancies and important to recognize facial asymmetries. Malar hypoplasia is confirmed by examining the patient from above. Examine and note any asymmetry of the middle or lower third of the face, while examining the patient in front. This may be facilitated by placing marks on the patient's face and by analyzing a clinical photograph (Fig 1). Clinicians must do a thorough diagnosis at the onset and observe important clues during treatment regarding facial asymmetries that may be subtle or latent.

Photographic images

The following images should be taken and examined:

- Full face frontal and angular three-quarter views at rest, smiling, and animated
- Right profile; both profiles if asymmetry is observed
- Anterior teeth in occlusion and slightly apart
- Right and left buccal segments

In addition, black and white, computer-reversed embossed images of the patient's frontal and profile views can be useful for treatment planning. Family photographs are also helpful in establishing the origin of the deformity and predicting the postoperative norm. For images to be of greatest value, hair should be retracted or removed from the face. To construct a photographic montage, profile photographs are cut and computer flipped; the pieces are then rearranged to give an impression of what is likely to be achieved by facial orthopedics or surgery.[12] This method is empirical and simplistic, but it can be helpful (Fig 2). The montage has limitations, the most obvious being soft tissue representation (Fig 3). Since the montage does

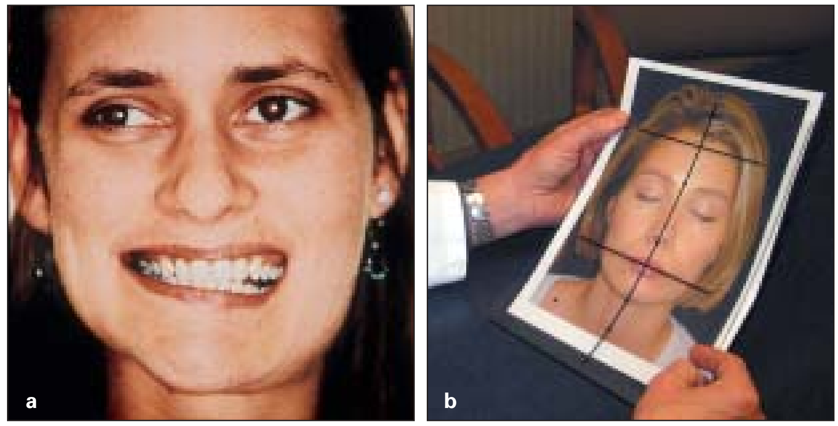


Fig 1 **(a)** Significant hemimandibular hyperplastic asymmetry. **(b)** Facial assessment is facilitated with acetate overlay upon patient photo.

Fig 2 Interocclusal bite registration with vertical and horizontal references to reveal dental and maxillomandibular asymmetries. Dental floss is held vertically as a further visual guide.

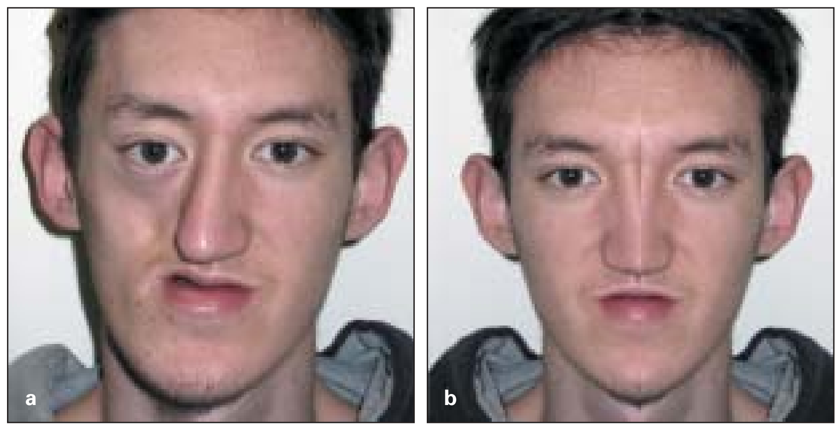


Fig 3 Facial image cropped at facial midline, then copied and flipped; this results in a useful symmetric facial projection image.

not accurately superimpose on the lateral skull image or radiograph, computerized simulations can do this.

Cast analysis

Analysis in the mandibular dental arch regarding teeth in the frontal dimension concerns mandibular molar and premolar width, dental midlines, and dental to skeletal midline. The maxillary molars relative to the mandibular molars are measured from the widest points on the buccal contours. Thus, the condition and position of the mandibular arch becomes the basis, since it is the most limiting factor and influences maxillary arch emplacement. Even a routine cast analysis reveals asymmetry, especially in a unilateral malocclusion (Fig 4). When one side of the mandibular arch is tipped lingually more than the opposite side[1] (Figs 5 to 7), the clinician should be particularly observant.

For uncomplicated cases, a hinge articulator may be used. For complex cases, especially those with facial asymmetry and craniofacial problems, a facebow recording and/or anatomic articulator are essential. Important markings on the casts, made while directly comparing on the patient are:

- Facial midline in relation to the dental midline. This can be marked on the patient's gingivae and teeth with a felt-tipped pen before taking the impressions. The ink mark will be transferred to the cast.
- Buccal segment markings to indicate the centric relationship on the casts, or that of maximal intercuspation, ie, habitual occlusion. Maximal intercuspation is the final relationship to which the surgical jaw movements are usually planned. However, the preoperative difference between centric relation and habitual occlusion may be large, and can give rise to misleading predictions of movement.

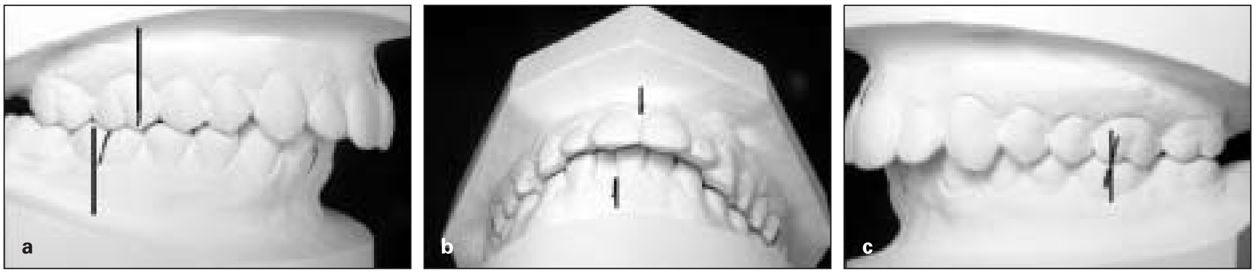


Fig 4 **(a)** Class II, subdivision right malocclusion. **(b)** Mandibular midline to right side due to mandibular asymmetric skeletal deficiency. **(c)** Left-side relationship is Class I dental.

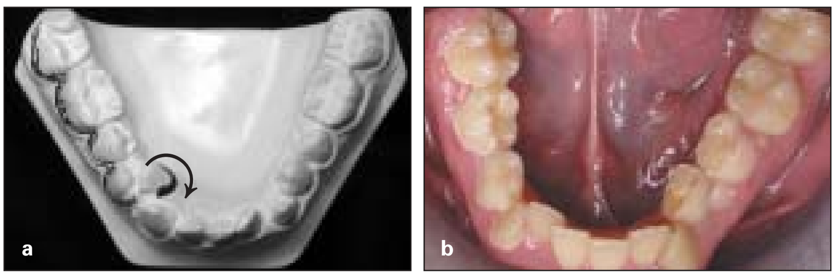


Fig 5 **(a)** Mandibular premolars and molars are in lingually compressed positions with excessive unilateral crowding. **(b)** With narrow maxillae, the mandibular posterior teeth incline inward.

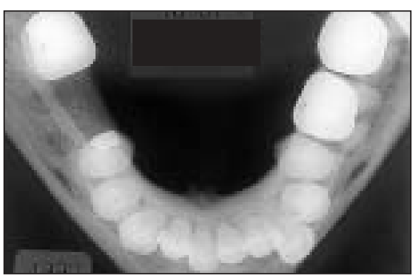


Fig 6 *(left)* The mandibular occlusal radiographic image is particularly useful to locate asymmetric variations, such as dental and skeletal midlines, chin location, arch irregularity, transverse compensations, and lingual angulations.

Fig 7 *(right)* Dental arch asymmetry and asymmetric arch-length excess required 6 incisors in final result to create best occlusion and stable symmetric outcome.

Radiographs and digital imaging

Understanding the importance of 3-dimensional anatomy, Ricketts introduced the frontal cephalometric radiographic analysis to aid in diagnosis.[13–17] A craniostatic posteroanterior (PA) view of the skull helps to reveal facial bone asymmetry. However, remember that the head may be tilted in the headholder if the external auditory meati are asymmetric, giving a distorted radiographic image (Fig 8). Clinicians routinely use 2-dimensional images, including panoral radiographs (Fig 9), facial and intraoral photographs, and cephalometric tracings. These 2-dimensional views have limitations; such geometric, rotational, and head positioning errors mean that the anatomy is not accurately represented. Some elements can be obscured, and calibrating the views is a problem (Fig 10). True 3-dimensional information includes plaster casts of the teeth, which so often are not accurately merged or calibrated with the other diagnostic information.

Use of an interactive 3-dimensional digital model of a patient's anatomy (Fig 11) would greatly improve the ability to determine different treatment options, monitor changes over time, predict and consistently display fine treatment results, and measure treatment outcomes more accurately.[18] The Acuscape method (Acuscape International, Glendora, CA, USA) combines standard cephalometric radiographs and routine photographs to create a 3-dimensional matrix and a 3-dimensional digital patient.[19] Three-dimensional radiographic imaging of dental structures is becoming a reality due to the advent of cone beam computer tomography (CT) and 3DX multi-image microcomputer tomography (NewTom, Aperio, Sarasota, FL, USA). Whether viewing bone, periodontal ligament space, enamel, dentin, or pulp, the 3DX images are better than can be generated by the medical CT machine (Figs 12 to 14). The calculated skin dose for the 3DX scan is about 1/400 the medical CT scan—a huge reduction. Many companies are working on cone beam units able to image the whole head,

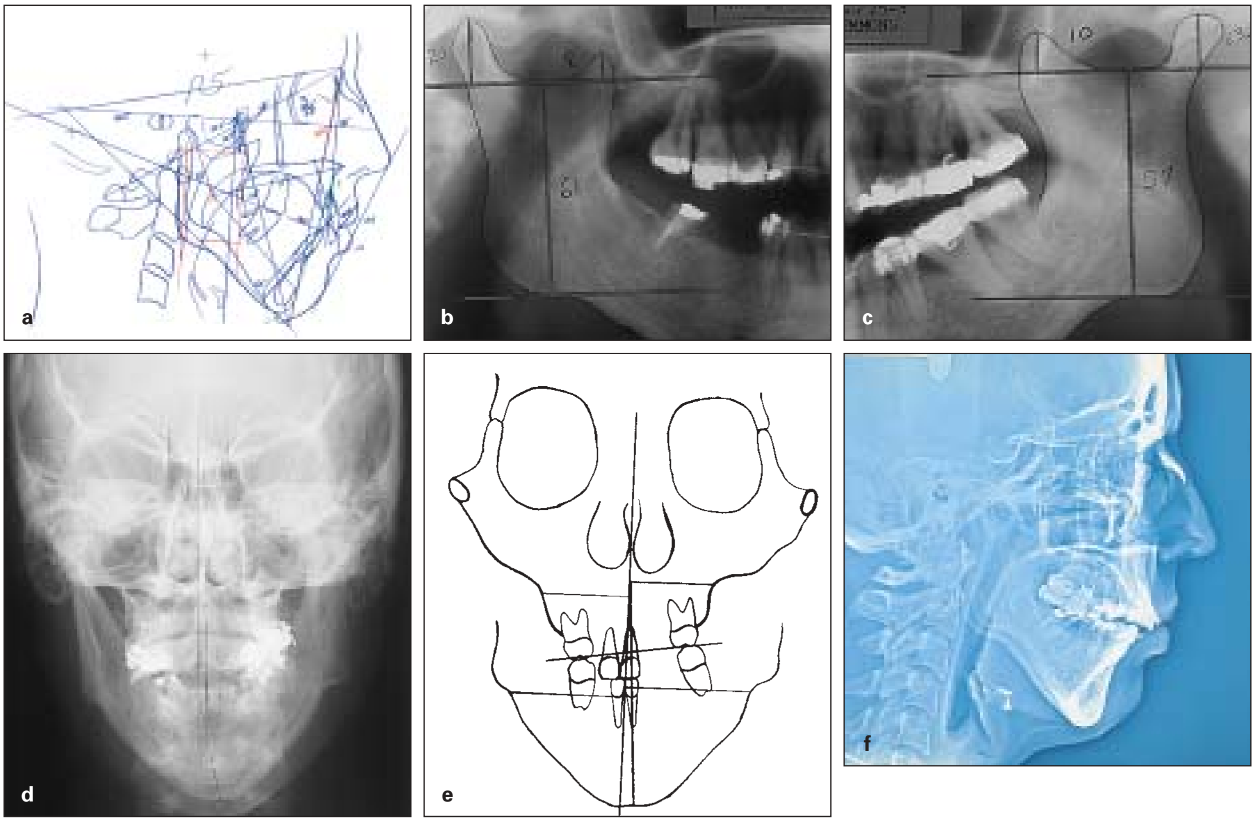


Fig 8 **(a)** Asymmetric mandibular borders, which can be due to true skeletal asymmetry, or the head may be tipped sideways to fit into the cephalostat due to asymmetric auditory meatus/porion locations. **(b)** Typical morphology of ramal and condylar process. **(c)** Morphologic adaptive changes on the asymmetric short side. **(d)** Frontal image reveals maxillomandibular asymmetry. **(e)** Frontal asymmetry tracing. **(f)** Mandibular borders are different; compare the two sides.

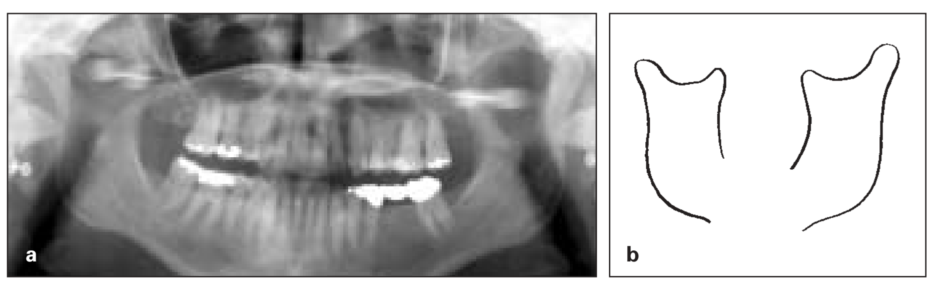


Fig 9 By tracing the ramal and condylar processes from panoral image of mandible **(a)**, the two sides can be compared for reliable asymmetry assessment **(b)**.

Fig 10 *(left)* Frontal xeroradiograph clearly depicts anatomy.

Fig 11 *(right)* Acuscape 3-dimensional frontal image (Acuscape Services, Glendora, CA, USA).

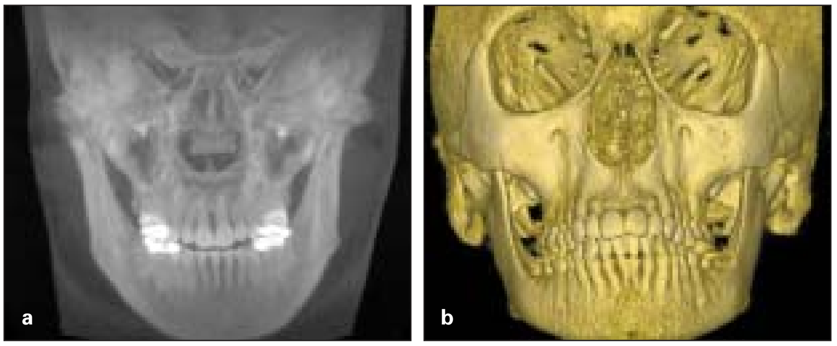


Fig 12 **(a)** Frontal 3-dimensional image generated with NewTom 9000 (Aperio Services, Sarasota, FL, USA). **(b)** NewTom frontal image, coronal section.

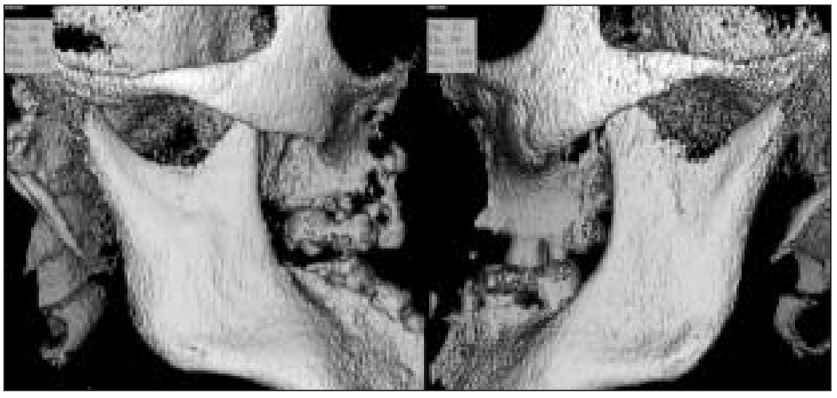


Fig 13 Ramal process and zygomatic arch asymmetries are evident when right/left sides are compared.

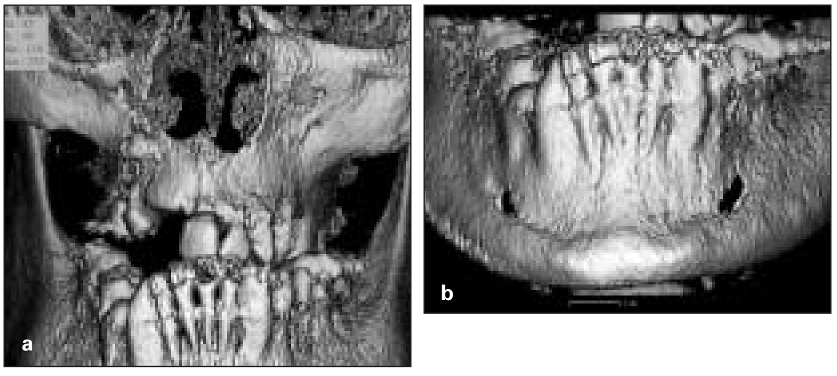


Fig 14 **(a)** Hemimaxillary and hemimandibular skeletal and dental asymmetries captured by NewTom 9000 3-dimensional imaging technologies. **(b)** Asymmetric mandibular morphologic variations.

which will ultimately replace today's cephalometric and panoral images with one 3-dimensional scan.

Three-dimensional, corrected TMJ tomography reveals TMJ degenerative joint disease (DJD) which commonly occurs subsequent to facial macro- or microtrauma, facial jaw asymmetry, complex Class II or Class III skeletal/dental malrelationships, major dental rehabilitation, dental crossbite, deep-bite conditions, open bite (anterior) conditions, multiple missing posterior teeth, and/or parafunction that is excessive or long-term.[4]

MAXILLOMANDIBULAR ASYMMETRY FEATURES

Many facial asymmetries are mild or so slowly progressive that they are not clinically significant. Other facial asymmetries necessitate reevaluation and become recognizable during adolescent growth. There are dental, skeletal, and functional asymmetries; most are a combination. The simplest asymmetry to treat is the dental asymmetry, if recognized and treated in the mixed dentition stage. These asymmetries can be due to premature loss of teeth, as when one primary canine is exfoliated significantly earlier than its contralateral. Ankylosed teeth can also lead to a dental asymmetry. A dental asymmetry recognized early is routine to correct and manage; waiting until the permanent dentition stage creates a problem more complicated and costly to overcome. A dental asymmetry demonstrates a symmetric skeleton and growth pattern. A functional asymmetry involves a symmetric jaw and dentition, while the patient functions in an asymmetric way. Untreated functional shifts usually result in a skeletal asymmetry.[20] A skeletal asymmetry is characterized by a symmetric dentition without functional shift. It can be present at birth, with growth subsequently being symmetric (nonprogressive asymmetry), or may be a progressive skeletal asymmetry that worsens with continued asymmetric growth. Most individuals with asymmetric facial growth have compensations in the dentition. A problem list should be generated to differentially diagnose and treat facial asymmetries.

Asymmetry assessment and treatment strategies

When a developing asymmetry is recognized, the clinician should promptly take the appropriate progress records, reevaluate the case, and establish a specific, differential treatment strategy with alternatives. Remove the orthodontic appliances at the right stage, if the patient is younger, and wait for growth to be completed. Treat with definitive jaw surgery later. Watch for latent growth, especially if a mandibular hyperplasia is suspected. Surgeons readily diagnose asymmetries when they evaluate patients after growth is completed, but such a diagnosis is more difficult in younger patients because the asymmetry may not be as developed nor as recognizable. After patients complete their adolescent growth, problems become evident. Facial asymmetry subsequent to a ramal or mandibular body hemihypertrophy, condylar process elongation, or aplasia may also occur.

Functional observations:

- Occlusal and transverse plane asymmetry; panoral and cephalometric views
- Lower border superimpositions; on cephalogram and panoral images
- Distance between first molars and the vertical ramus; panoral view
- TMJ dysfunction; manual jaw posturing or positioning splint
- Dental casts; midlines coincident or not

Structural asymmetry:

- Signs of developing asymmetries
- Asymmetric canine buccal overjet
- Asymmetric mandibular canine positions within arch
- Unilateral posterior open bite
- Crossbites that develop
- Second molar unerupted on asymmetric side
- Tipping of the occlusal plane
- Midlines no longer coincident
- Body length and ramal height not symmetric, nor is the distance from the second molar to the anterior border of the ramus
- Vertical asymmetries observed on lateral cephalometric images, with lack of superimposition of the occlusal plane and lower borders of the mandible
- Frontal cephalometric images reveal changing dental and skeletal midlines, changing chin location, occlusal plane and gonial angle changes

Asymmetry development:

- Rule out oral pathosis, such as infratemporal fossa or condylar tumor
- Check for displaced or degenerative disc with change in jaw position or morphology
- Consider trauma as etiology of asymmetry
- Identify likely patients for eventual orthognathic surgery
- Maintain maxillary midline coincident with the face, and the mandibular midline reasonably coincident with underlying mandibular skeletal support
- Coordinate arches to compensate for the asymmetry, or set up the arches for eventual jaw surgery
- Consider dental compensations, but not beyond the biologic limits; or decompensate the dentition for later surgery
- Limit maxillary occlusal plane tipping by using occlusal splints and/or a transpalatal arch or quad-helix appliance for anchorage support

By 8 years of age, 80% of adult head size has developed. Thus, the facial orthopedist and orthodontist have only 20% of remaining growth to influence and utilize to augment the result othopedically and occlusally. At 13 years of age, 90% of head size has developed and thus only 10% remains. The difference of this 20% at 8 years and 10% at 13 represents twice the capability for the orthodontist to utilize. The clinician clearly wants to be treating these facial orthopedic problems by 7, 8, or 9 years of age.[12,21–22]

FRONTAL ANALYSIS—SIMPLIFIED

Treatment planning often requires at least two patient evaluations with clinical interviews, photographic and video imaging, dynamic and animated assessments, cephalometry, and dental casts. At least two parameters should be used to confirm any part of the asymmetry analysis. For instance, compare the external facial proportions with the measurements of the hard tissue cephalometry, or the radiographic incisors angulation measurements,

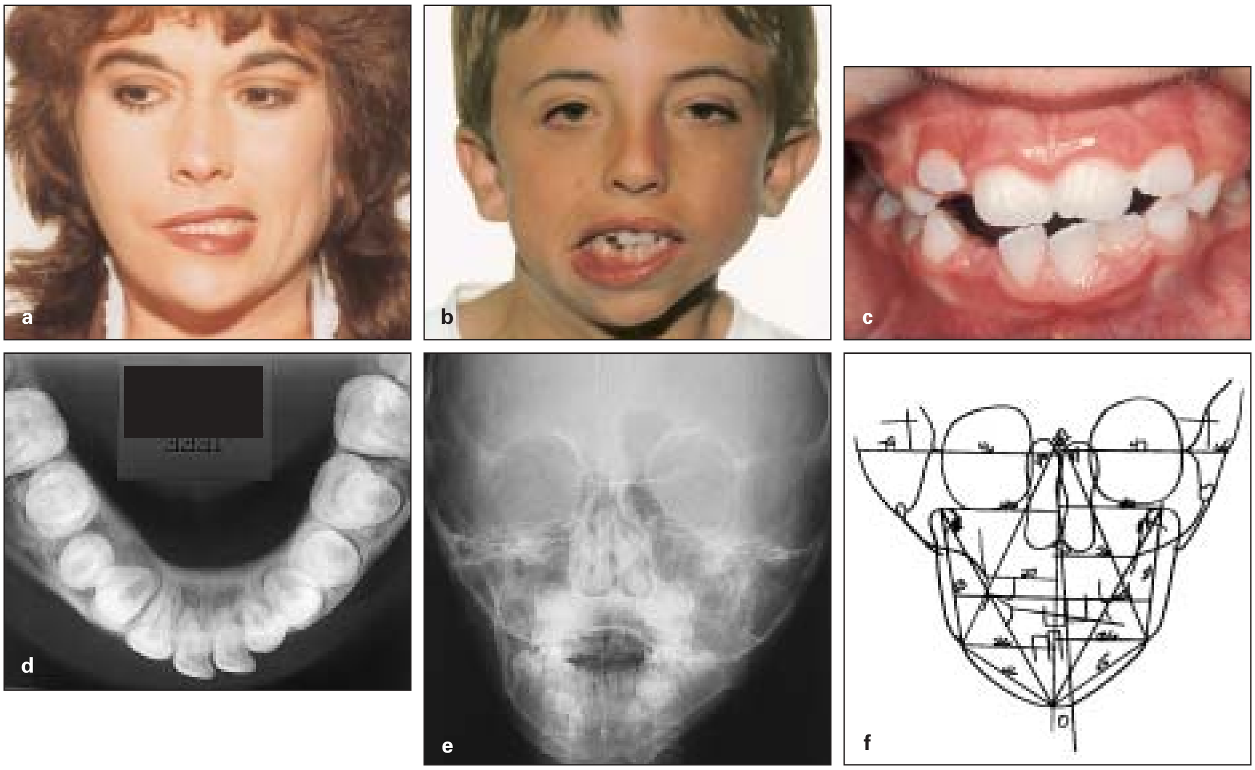


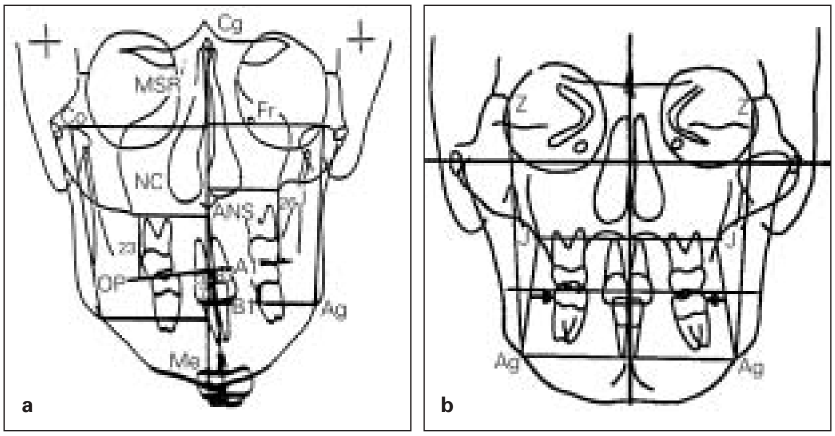
Fig 15 **(a)** Facial neuromotor deficit creates soft tissue asymmetry. **(b)** Mandibular developmental asymmetry. **(c)** Dentofacial compensations with asymmetry. **(d)** Transverse constriction irregularities. **(e)** Mandibular asymmetry with maxillary compensations. **(f)** Tracing of same image.

compared with the study casts and the patient. Both linear and angular measurements are useful and directive, but must be used rationally. Some patients have values at the extremes of the normal range (Fig 15). In such cases, de-emphasize the measurements in favor of other methods of prediction, such as a template or sensible clinical judgments.[3,23]

Frontal (PA) radiographs or digital images are recommended when the clinician is analyzing and providing functional jaw orthopedics, orthognathic surgery, asymmetry mechanics, TMJ disease management, and/or treating jaw growth disorders. As part 1 of this article explained, two versions of the Ricketts and Grummons frontal analyses are used worldwide.[3,24] The simplified version is the most practical and useful analysis (Fig 16). It permits the clinician to readily observe the midsagittal reference (MSR) line to compare right and left sides for disproportional relationships and specific location and extent of facial asymmetry.[25] The complex frontal analysis version is volumetric and intended for computerized processing and analysis.[26,27] The MSR is the skeletal midline reference line that compares the right and left sides of a patient's face to detect skeletal and dental asymmetry. It is constructed from the anatomic christa galli (Cg), vertically through the anterior nasal spine (ANS), and extended inferiorly beneath the chin (Me). From specific skeletal and dental landmarks (Figs 17 and 18), perpendicular lines can be drawn laterally (transversely) to assess relationships between skeletal and dental references. Observing down the MSR line, the intersection of the right and left references can be easily compared where they intersect the MSR to see and measure asymmetries.[2,3,24] For example, if the line from the right side antegonion (Ag) is 3 mm above the intersection of the left Ag line, then the clinician knows that these points are asymmetric by 3 mm vertically.

There are several specific facial growth concepts that the clinician should keep in mind when using the frontal analyses:

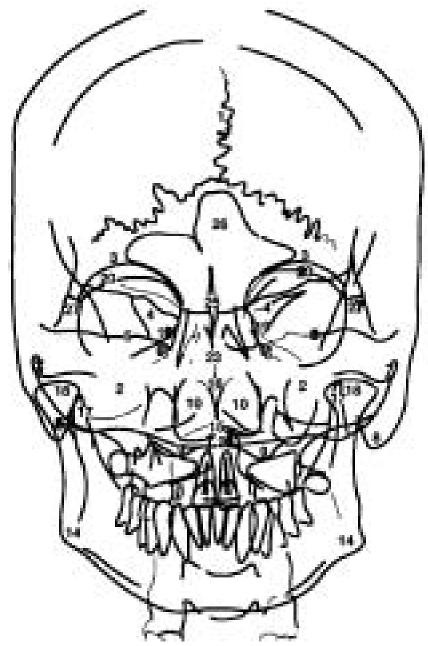
1. *Frontal growth.* Using the behavior of the normal in width as reference and indicator.
2. *Nasal width.* The inside border of the nasal cavity (Nc) increases only 0.5 mm per year until maturity.
3. *Maxillary width.* The increase between J points is 1 mm per year. When the measurement increases by 6 mm in 24 months, the clinician can hope that essentially 4 mm of that is orthopedic.
4. *Mandibular width.* Width increases 1.35 mm a year at Ag points until maturity.



- Maxillary width
- Occlusal plane
- Facial midline—upper dental to facial
- Dental midlines—upper to lower
- Chin location

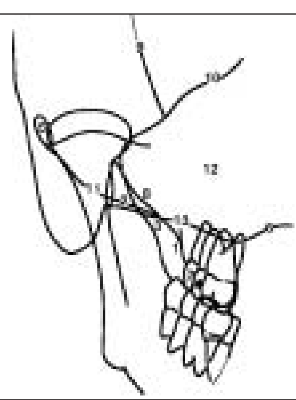
c

Fig 16 **(a)** Grummons frontal analysis. **(b)** Ricketts frontal analysis. **(c)** Frontal asymmetry indicators.



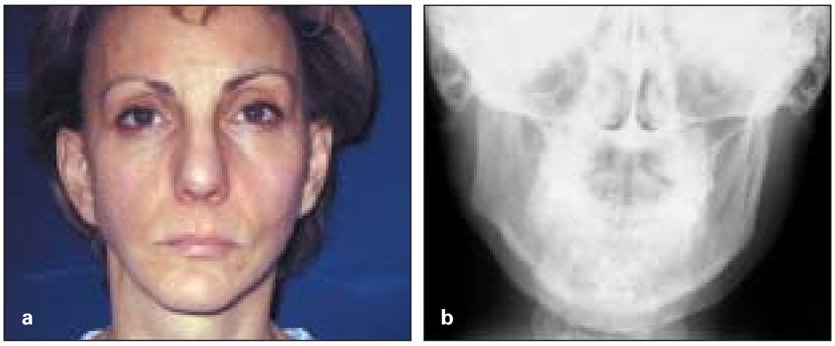
1. Sagittal suture or longitudinal suture
2. Maxillary sinus
3. Orbital surface (frontal bone)
4. Superior orbital fissure
5. Superior border of petrosal part
6. Foramen rotundum
7. Zygomatic arch
8. Mastoid process
9. Occipital condyle
10. Nasal cavity
11. Basion
12. Mental foramen
13. Mental spine
14. Angle of mandible
15. Anterior nasal spine
16. Nasal septum
17. Coronoid process
18. Condylar head or condyle
19. Orbital plate or lamina papyracea (ethmoid bone)
20. Supraorbital margin
21. Articular tubercle
22. Styloid process
23. Perpendicular plate (ethmoid bone)
24. Coronal suture
25. Crista galli
26. Frontal sinus
27. Frontozygomatic suture
28. Odontoid process

Fig 17 Anatomic renderings by Kunihiko Miyashita, DDS, in Contemporary Cephalometric Radiography (Tokyo: Quintessence, 1986). Reprinted with permission.



1. J point
2. Malar (Ma)
3. Maxillare (Mx)
4. Maxillary first molar
5. Zygomatic arch
6. Inferior border of the skull base
7. Second molar
8. Lateral wall of the maxillary sinus
9. Oblique line
10. Outer surface of the upper part of the maxillary sinus
11. Inferior border of the zygomatic bone
12. Maxillary sinus
13. Outer surface of the maxillary tuberosity

Fig 18 Anatomic relationships at lateral facial region. Line drawing and legend by Kunihiko Miyashita, DDS, in Contemporary Cephalometric Radiography (Tokyo: Quintessence, 1986). Reprinted with permission.



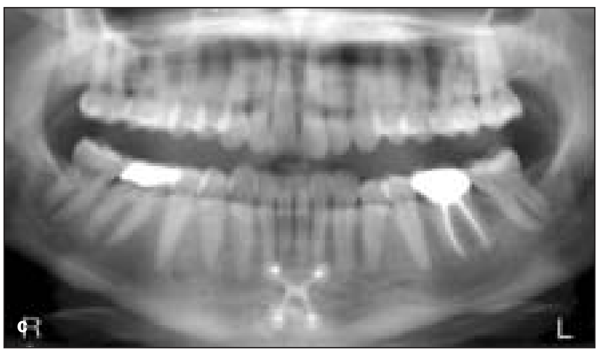


Fig 19 **(a)** Mandibular body asymmetry disguised by genioplasty procedure. **(b)** Chin centered despite ramal and body regional asymmetry. **(c)** Chin relocated to symmetric position to disguise underlying mandibular asymmetry.

5. *Mandibular molar width.* Mandibular first permanent molars change little in width once erupted. Any measurable increases or decreases in intermolar width is probably an induced change. Maxillary molars tend to be stable but are altered by tongue conditions and breathing changes. Usually width changes are associated with treatment effects.
6. *Mandibular first premolar width.* Once the first premolars reach the plane of occlusion, little width change can be expected.
7. *Frontal growth and angular parameters.* This follows a triangular form from the Ag points and meets at the nasion region. The vertex of a triangle for maxillary growth at J has an apex level with the top of the orbits.

In the lateral perspective, the mandibular incisor position receives priority; in the frontal, the maxillary incisor dominates treatment decisions. Maxillomandibular analysis starts with the nasal width, then proceeds to the maxillae, particularly the maxillary incisors to facial midline, then to the maxillary molars, and finally to the mandibular arch.[1,15,17,28,29]

ASSESSMENT OF THE CHIN

The chin is worthy of special consideration. The need for chin surgery may be difficult to predict because many procedures influence its position. The vertical chin height and its prominence can be independently modified surgically by reduction, lateral movements, and/or augmentation. If in doubt, chin profile changes should be examined preoperatively with a lateral cephalometric and frontal prediction tracing. If still in doubt, educate the patient that postoperative correction may be indicated. Again, it is important to compare the dental midlines to each other and with the midlines of the face, nose, philtrum, and the chin. Various mandibular discrepancies can be resolved with a rotation genioplasty after the dental relationships have been corrected (Fig 19).

Derotation of an asymmetric chin is esthetically important. If the asymmetry also includes a tilt in the transverse occlusal plane, this can be simultaneously leveled with osteotomies of both jaws (bimaxillary procedure) or asymmetric mandibular advancement with greater occlusal gap on one side compared to the other, so the lower jaw borders can become symmetric on both sides.

ESTHETIC CONCERNS OF MAXILLARY ASYMMETRY

The maxillary midline is one of the most sensitive esthetic concerns of patients. Treatment decisions for asymmetries often revolve around the position of the maxillary incisors relative to the facial midline. Clinicians must determine what level of asymmetry that orthodontic treatment alone can correct, and assess when and if surgery is needed to correct the deformity. Soft tissues can compensate or camouflage the underlying skeletal asymmetry and make the decision more challenging. According to Kokich,[30] a maxillary midline deviation of 4 mm from the facial midline is needed for the general dentist or layperson to recognize the defect, while Grummons found that patients could perceive maxillary dental to facial midline variations once they reached only 2 mm.[2,12] The patient can ultimately decide whether to pursue surgery to correct the midline deviation. Canting or tilting of the maxillary anterior teeth can occur when attempting to move the maxillary midline. Therefore, bodily movement and teeth uprightness are important in midline correction.

TRANSVERSE AND OCCLUSAL PLANE

Clinical examination and study casts will indicate whether orthodontic treatment or segmental surgical correction is required to coordinate the dental arches. Avoid tipping of molars to buccal excess when orthodontically expanding the maxillary arch, since molars will relapse back to physiologic axial inclination. Nongrowing patients should undergo expandsion with surgical assistance. Whenever there is a surgical alteration in the maxillary occlusal plane, a mandibular osteotomy is typically required to match it, or at least other movements with differential posterior teeth eruption to the new postoperative occlusal plane. Identify the positive attributes of a patient's smile and protect those pleasing characteristics. The responsibility of the orthodontist includes understanding growth and development in dentoskeletal terms, and also soft tissue growth, maturation, and aging because of individualized dynamics.

The transverse cant of the maxillary occlusal plane can be due to differential dental eruption (Fig 20). Display of the anterior teeth can be modified orthodontically, surgically, or with cosmetic periodontics. Skeletal asymmetry of the mandible will result in a compensatory cant to the maxilla, often requiring orthognathic correction. The oblique view of the smile reveals characteristics of the smile not obtainable on the frontal view and certainly not obtainable through any cephalometric analysis. The palatal plane may be canted anteriorly or posteriorly. In the most desirable orientation, the occlusal plane is consonant with the curvature of the lower lip on smile. Modification of the occlusal plane in preadolescents can be accomplished with growth modification appliances such as vertical control functional appliances, the differential Herbst appliance, and high-pull headgear. In late adolescent and adult patients, surgical modification of the maxillary occlusal plane is often indicated. Clockwise occlusal plane rotation by maxillary or double-jaw surgery may harmonize the positions of the maxillary incisal edges with the lips.[23]

TURBOS

Turbos or bonded resin adhesives to the occlusal surfaces help to establish a new and improved mandibular reference position. While these turbos are in place on primary molars, the permanent first molars can erupt several millimeters more. Thus, a more optimal vertical dimension with leveled and symmetric functional occlusal plane can be established. With this, the TMJs become postured optimally (decompressed), airway and head posture are helped, and the incisors can clear during function. Unilateral bonding can be at a different height than the contralateral side, so that asymmetric posterior eruption can be encouraged and guided. This improves occlusal plane symmetry.

ASYMMETRIC PROTRACTION FACEMASK THERAPY

The Grummons protraction facemask (Great Lakes Orthodontics, Tonawanda, NY, USA) is effective in influencing midfacial hypoplasia and maxillary Class III deficiency without compression on the chin and unfavorable TMJ overloading. It facilitates anterior movement of the maxillary skeletal complex and/or maxillary and mandibular teeth (functional jaw orthopedics). One side can be protracted more than the opposite side; hence asymmetric forward and inferior movements. The earlier the treatment, the more the face adapts to the concept and responds to the therapy. The later the treatment, the more the treatment plan must adapt to the face.[21] Movements can be greater on one side than the other, which alters the maxillary midline and occlusal plane toward the treatment objectives, with better facial and dental symmetry.

MAXILLARY TRANSVERSE APPLIANCE THERAPY

A common clinical situation is a child with an apparent unilateral crossbite, but when the mandible is positioned in centric relation, the crossbite is actually bilateral. Long-term, those individuals with a unilateral posterior crossbite with a CR-CO shift have been shown to have a higher incidence of temporomandibular disorders.[4,31] Assessment of dental arch

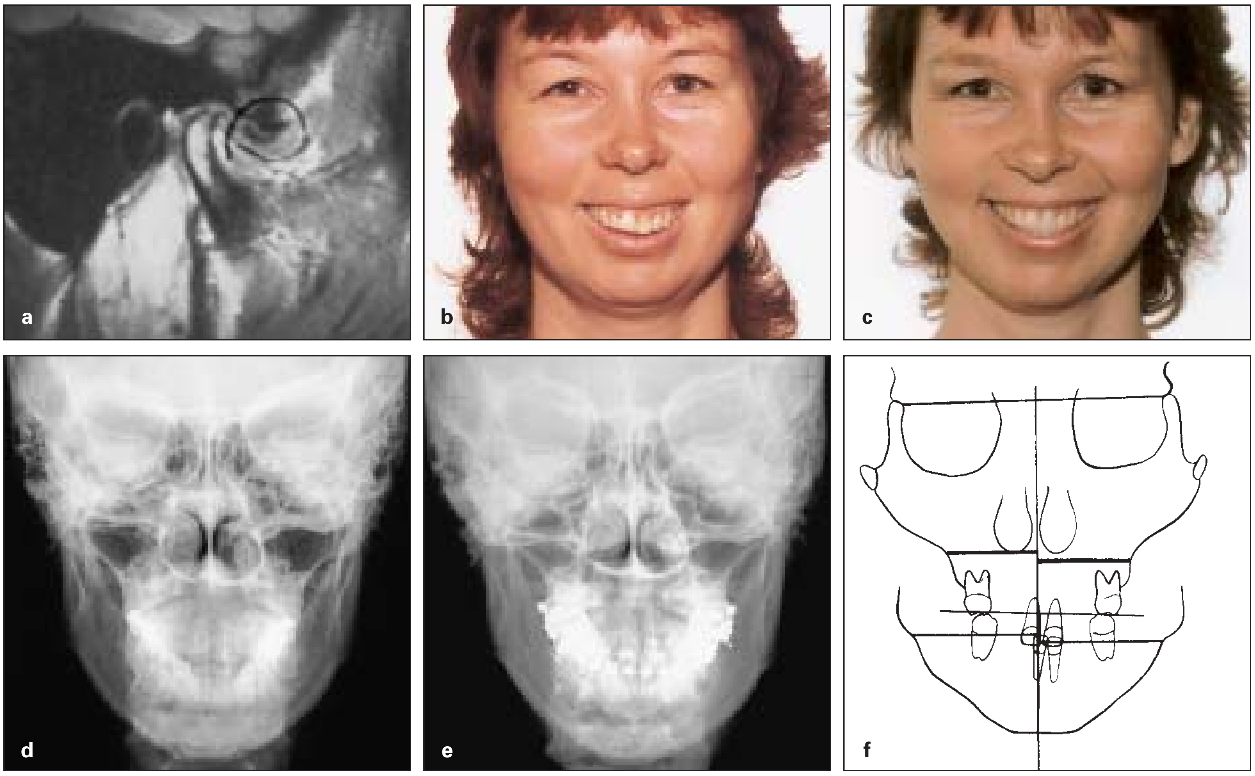


Fig 20 Maxillary vertical asymmetry. **(a)** Unilateral nonreducing TMJ meniscus and advanced osteoarthrosis caused mandibular asymmetry on the short side. **(b)** Occlusal plane tipped as a compensation to mandibular asymmetry. **(c)** Occlusal plane and smile made level with symmetric facial components after maxillary surgical, orthodontic, and periodontal therapies. Frontal imaging at **(d)** pretreatment and **(e)** posttreatment, and **(f)** frontal summary analysis. The patient had a Class II malocclusion. **(g)** Asymmetric smile plane. **(h)** Short-side Class II problems. **(i)** Optimized occlusal correction. **(j)** Differential posterior tooth eruptions to level the occlusal plane.

asymmetry in the mixed dentition may be useful in exploring dysmorphogenesis.[32] Transverse intra-arch asymmetries exceed AP asymmetries in magnitude and prevalence. In addition, individuals with obstructive airway conditions have abnormally high asymmetry values. Dental arch asymmetry in children with large overjets is evident 30% of the time, with transverse asymmetries of 2 mm or more at the maxillary first permanent molars.

A maxillary transverse hypoplasia results in narrow posterior segment, with a constricted and lingually compensated lower curve of Wilson and a constricted arch form. When one side of the maxillary component is more narrow than the other, asymmetric lower compensation exists, reflecting opposing arch irregularities. The side of greater constriction is the side of greater asymmetry, with the maxillary arch serving as the template for the mandibular arch.[12,21] Often asymmetric crowding in the mandibular arch mirrors the asymmetric skeletal problem in the maxillary arch. As the maxillary arch differentially expands, the mandibular arch can unlock and become transversely uprighted and symmetrically aligned.[33,34] As mandibular dental compensations are reversed, the mandibular posterior compressed arch is buccally uprighted to normalize the curve of Wilson. Care is necessary to avoid expansion beyond the transverse guidelines, as described by Ricketts[1] and Grummons[2] for each facial pattern (wider in brachyfacial patients, less wide in mesofacial, and tapered for dolichofacial patients).[3] The envelope of stability determines the transverse parameter of correction. Mandibular alveolar widening and favorable alveolar orthopedic remodeling occur when an expansion appliance is used in the mandibular arch while primary molars/canines are present. Asymmetric mandibular arch widening can be achieved by placing the expansion screw at the corner of the arch, rather than at the midline.[4]

MANDIBULAR ARCH AS THE TARGET ARCH

The current logic is mandibular arch management as the target arch, with orthopedic emphasis (skeletal) to improve jaw proportions, conditions, and relationships. Treatment planning and limitations lie with the restrictions of the mandibular arch. Angle's classification was based on the maxillary molars. However, science has proven that the greatest clinical restrictions lie in the mandibular alveolus and the mandibular dental arch, particularly in the mandibular transverse dimension and its treatment. While the maxillary arch can be significantly widened to correct transverse hypoplasia, the final width determinant is the mandibular arch, with which the maxillary arch must coordinate—much like fitting the lid on a box. The transverse dimension can be altered (orthopedically if early; later by distraction osteogenesis and orthognathic surgery) with stable results. Narrow or transverse restrictions of the maxillae are compensated by narrower mandibular posterior arches or crossbites. Often, one side is more narrow than the other, so maxillary and mandibular asymmetric arch width and lingual tooth angulations are observed. Differential widening and transverse uprighting during treatment must also be administered. Therefore, in planning mandibular molar positions, the changes to be made in the maxillary width are influenced by the mandibular posterior width guidelines. A lingually inclined mandibular posterior arch form can be asymmetric from one side to the other (see Figs 5 and 6).

MODE OF ACTION—BONE PHYSIOLOGY

Mandibular dentoalveolar expansion is usually desired in response to maxillary orthopedic expansion. Arch development while posterior primary molars are still in place produces significant alveolar development, with growth and favorable remodeling. During the mixed dentition stages, development of the intermolar and interpremolar widths (rather than arch reduction by extraction therapy) is favored to unlock mandibular posture for optimal AP growth and development. Treatment to develop the maxillary width permits the mandibular arch to undergo transverse uprighting (lateral decompensation) while uprighting the mandibular posterior teeth transversely and aligning roots underneath the crowns within the periodontal support. As the maxillary arch width increases, more anterior mandibular posturing and placement can occur.[2,4,35,36]

As the mandibular arch is widened and reshaped, the incisors can actually become uprighted (rather than flared) and optimally uprighted within the alveolar support. Significant changes in 3 dimensions can be made in the midface, particularly if started early. If delayed, they must be surgically assisted or corrected later, or the patient is left with impairments and compromises. Obtaining skeletal congruity is a first priority; otherwise, compensations abound. On a practical basis, the greatest transverse skeletal treatment potential lies in the maxillary arch. There exists the ability to: *(1)* affect the palatal suture; *(2)* affect other midfacial sutures; *(3)* change function; and *(4)* modify the maxillary alveolar process.

Untreated Class II cases have apical base deficiencies that can worsen over time. These can vary from right to left sides, which results in lower facial third regional asymmetry. Nice orthopedic and orthodontic changes can predictably occur with appliances that require little compliance from patients. With facial and dentoalveolar symmetry, esthetic and functional occlusal benefits become apparent in the results. The transverse perspective deserves great appreciation and attention with today's 3-dimensional treatments and esthetic emphasis.

MANDIBULAR ASYMMETRY

The asymmetric mandibular short side characteristically has Class II skeletal and dental relationships. The midline is typically off-center and toward the deficient side. The occlusion is usually Class II on the short side, with end-to-end buccal segments as a treatment limitation in the final result. The skilled clinician might equilibrate or provide coronoplasty, as needed, for an improved final functional result. Mandibular canines are often asymmetric in the arch, and the occlusal plane is usually higher on the short side. There are fewer masticatory muscle fibers with less cross-sectional area on the deficient side.

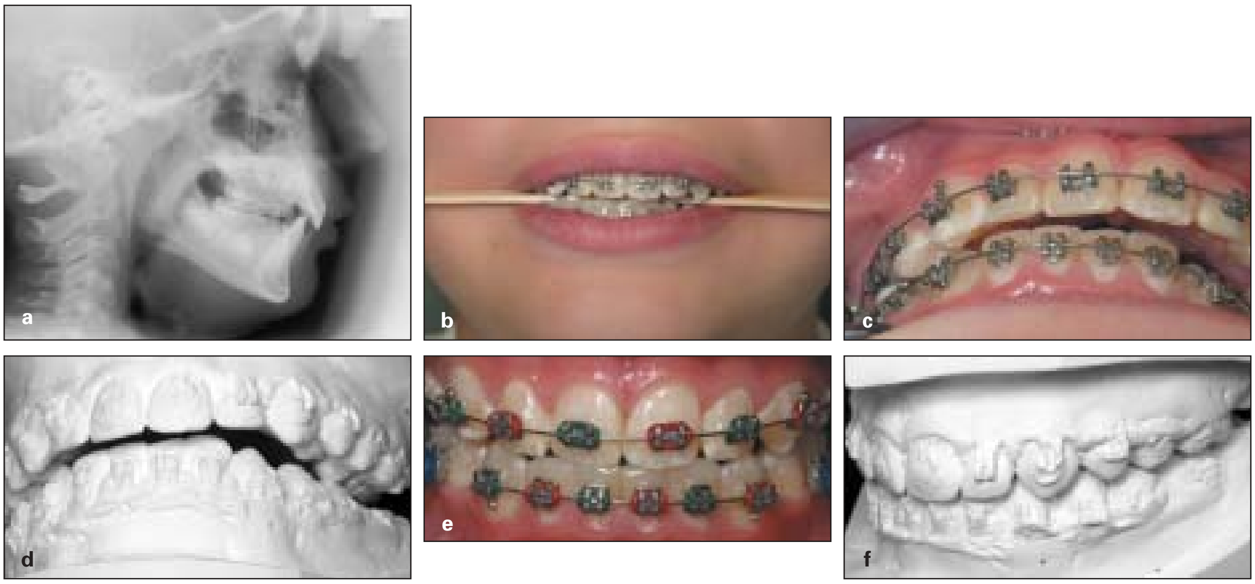


Fig 21 **(a)** Class II mandibular skeletal deficiency. **(b)** Symmetric maxillary occlusal plane. **(c)** Class II, subdivision 1 malocclusion. **(d)** Asymmetric mandibular casts confirm asymmetric Class II relationships. **(e)** Mandibular posture optimized and overcorrected. **(f)** Mandibular growth modification (asymmetric Herbst therapy) yields symmetric and optimized Class I outcome.

Asymmetric mandibular morphology in Class III cases, unilateral condylar remodeling, or TMJ degenerative changes resulting in Class II changes on the affected side, and traumatic cases with Class II malocclusion on the affected side with anterior open bite, can also occur.

Asymmetric extractions are often necessary to camouflage the underlying skeletal Class II or III problems. Surgical intervention for maxillomandibular dysplasia is often indicated and beneficial. This results in more optimal mandibular and dental proportions, stability, and symmetry for best patient benefits. Functional jaw orthopedics or growth modification should be applied early and differentially, with the short side advancing more than the contralateral side. This results in optimal midline placement and 3-dimensional correction. In functional jaw orthopedic therapy, the astute and perceptive clinician will differentially distract and elongate the short side, so the mandibular border, occlusal plane, and midlines become more symmetric. Space within the arches (arch length) can be gained by midsagittal jaw development orthopedics with lateral width increases and from differential Herbst therapy growth modification benefits (Fig 21).[2,35]

Mandibular elongation and hyperplasia

It is important to distinguish between mandibular asymmetry due to unilateral elongation and hyperplasia, since the cessation of growth is different. Elongation involves ongoing growth of the mandible, with excessive length of the body and/or condyle along normal growth lines resulting in a more obtuse gonial angle. Horizontal elongation results in a superimposition of the occlusal planes and the lower borders of the mandible, and it can affect the opposite side.

With vertical elongation, there need be no change in the lower midline nor deviation to the opposite side. A unilateral open bite can occur in patients with elongation in the condylar process. This may also occur in patients treated excessively with a Nance or fixed transpalatal arch with unilateral open bite because compensatory vertical eruption of the molars cannot occur due to prolonged molar anchorage. Elongation tends to stop when growth stops.

Horizontal and vertical components can be combined. With hyperplasia, there is increased bulk of bone that results in a more acute gonial angle. There is also increased distance between the apices of the teeth and the lower border of the mandible on one side. These affect superimposition of the lower borders of the mandible on cephalograms.[1,20]

TMJ AND MASTICATORY DYSFUNCTIONAL ISSUES

It is clear that many patients with dentofacial deformities have coexisting TMJ disorders.[1] Age, gender, dental wear, unilateral posterior tooth contact in the retruded position, and posterior crossbite correlated with TMJ clicking. Jaw movement deflection and asymmetric occlusal slide relate to temporomandibular dysfunction (TMD), mandibular asymmetry, and transverse discrepancy. In children, there can be a relationship between TMD and certain occlusal factors, as well as between TMD and poor posture. In a primary dentition group, the TMD signs of highest incidence were deviation during opening (12.5%), clicking (50%), and posterior condylar displacement (75.5%). These three signs significantly correlate with occlusal factors such as frontal open bite, deviation of soft tissue, midline asymmetry, deep overbite, large overjet, crossbite, and bruxism. TMJ articular surface degenerative and/or remodeling changes occur with resultant mandibular asymmetry to varying degrees, depending upon the pathosis. Functional shifts in older patients should be treated with deprogramming splints to achieve a more reproducible mandibular reference position, and then be reevaluated and treated, using articulated casts to evaluate the dental and skeletal positions. Images should be retaken in centric relation or postural position, so reliable treatment decisions can be made. An individual may appear symmetric in habitual occlusion and asymmetric after deprogramming and stabilization orthotic therapy.

Loss of vertical height of the mandibular ramus may cause hypercontacts of posterior teeth on the affected side. Progressive loss of vertical ramal height usually occurs. A posterior open bite relationship subsequent to an increase of mandibular ramus length may induce loss of posterior teeth contacts on the affected side. If progressive, this may displace the mandible contralaterally with a crossbite or asymmetric relationship. The mechanism of TMJ articular cartilage degeneration is primarily microtrauma (ie, parafunction) with chronic joint overloading common in distress-related repetitive bruxism. Macrotrauma, caused by a direct blow, can also precipitate progressive chondromalacia or softening of articular cartilage. Without favorable remodeling, breakdown occurs, with eventual asymmetric anatomic parts (Figs 22 and 23). When mandibular growth is disturbed on the fractured condylar side, a mandibular deviation and maxillary canting to the affected side results (Figs 23 to 25). Following the completion of growth, the asymmetries can be corrected by combined orthodontic-surgical treatment. Facial asymmetry is common subsequent to early condylar fractures.[4,37]

Mandibular asymmetry secondary to TMJ and/or mandibular dysfunction

When relapses are encountered, an understanding of the biology of the occlusion is employed to explain the reasons for such failures. The underlying causes need investigation from a biologic viewpoint. Homeostasis is the function of various parts and organs to maintain the whole system in equilibrium. When this is disturbed, disease ensues. Because the TMJ is normally suspended and not part of the antigravity system, it usually is not subjected to heavy or prolonged mechanical loading. When normal loading pressure is present, it is of a gliding nature and is relatively intermittent. When clenching of the jaws or continuous forces due to muscular imbalances compress this joint over long duration, it becomes overloaded and disturbed. Displacements of the condyle and disc occur and a new asymmetric equilibrium must be attained over time. A pathologic compression in the joint occurs; destructive or unfavorable adaptive changes ensue. When the conditions become chronic, joint space is lost. The tissues, in an effort to reach homeostasis, reduce and modify and a new muscular status evolves. Advanced resorption of the condyle can be a part of the adaptive process. Soft tissue changes precede hard tissue remodeling; thus the disc remodels first (see Fig 20).[4,38]

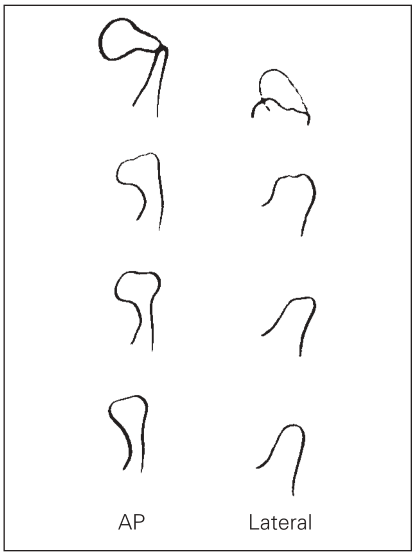


Fig 22 Subcondylar fracture (AP and lateral views) on growing patient and subsequent progressive remodeling and repair to essentially normal conformation.

Adaptation is adjustment to environmental conditions due to localized excessive remodeling; it results in local irregularities of the articular joint tissues. Remodeling is fundamental rebuilding of adult soft and hard tissues; this maintains proportions and relationships between form and function within structures throughout adult life. When growth is completed, remodeling generally takes over. Favorable remodeling is physiology at work and is termed adaptation. Arthrosis (degenerative joint disease,

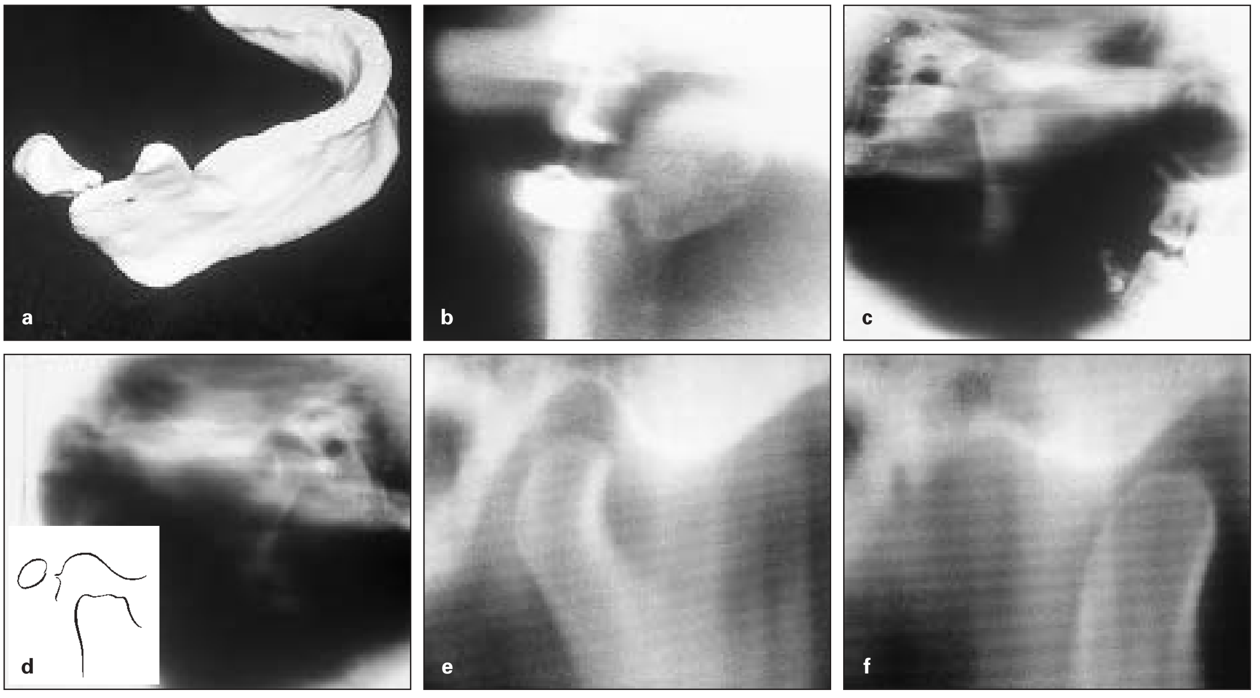


Fig 23 **(a)** Condylar process fractured into the infratemporal fossae. **(b)** Unfavorable medial condylar process displacement. **(c)** Gradual formation of condylar process 1 year later on adolescent patient. **(d)** After 18 months of mandibular unilateral TMJ distraction appliance therapy. **(e)** The condylar process developed in 4 years, and facial symmetry was restored. **(f)** Full range of TMJ motion established.

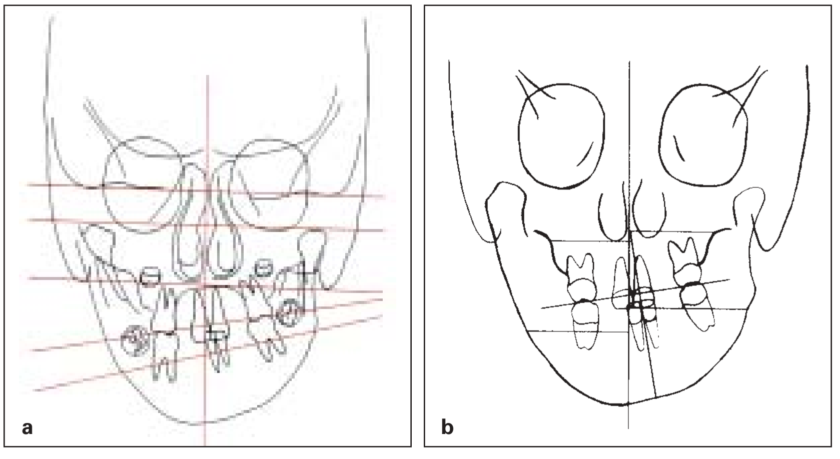


Fig 24 **(a)** Subcondylar fracture resulting in posttraumatic mandibular asymmetry; typical frontal tracing (Ricketts). **(b)** Asymmetric frontal tracing (Grummons) of same skull.

osteoarthrosis) is primarily a noninflammatory joint disease, characterized by a break in the continuity of the articular tissue with negative adaptation or secondary changes in the underlying tissues. Degenerative joint disease is a disease of overloading, leading to articular surface changes and structural asymmetry. At the minimum, today's orthodontist must be informed regarding common TMD with a thorough understanding of pain mechanisms and asymmetric structural consequences.

In most cases of facial asymmetries, the mandible is primarily affected and compensatory changes occur in the maxilla.[39] The goal when treating mandibular asymmetries is to achieve coincident skeletal symmetry. Intercept the problem early when there is a functional asymmetry in the mixed dentition by doing maxillary expansion and permit symmetric neutral mandibular positioning. In young people, functional shifts can lead to disc derangements and asymmetric adaptations in the condylar fossa that may be progressive. A longstanding functional shift creates an environment in the TMJ for future asymmetric growth, even if it is not genetically programmed. Condylar displacement occurs on the non-crossbite side, where the mandible may be positioned anteriorly and inferiorly.[30] Evidence of joint remodeling in cases with functional

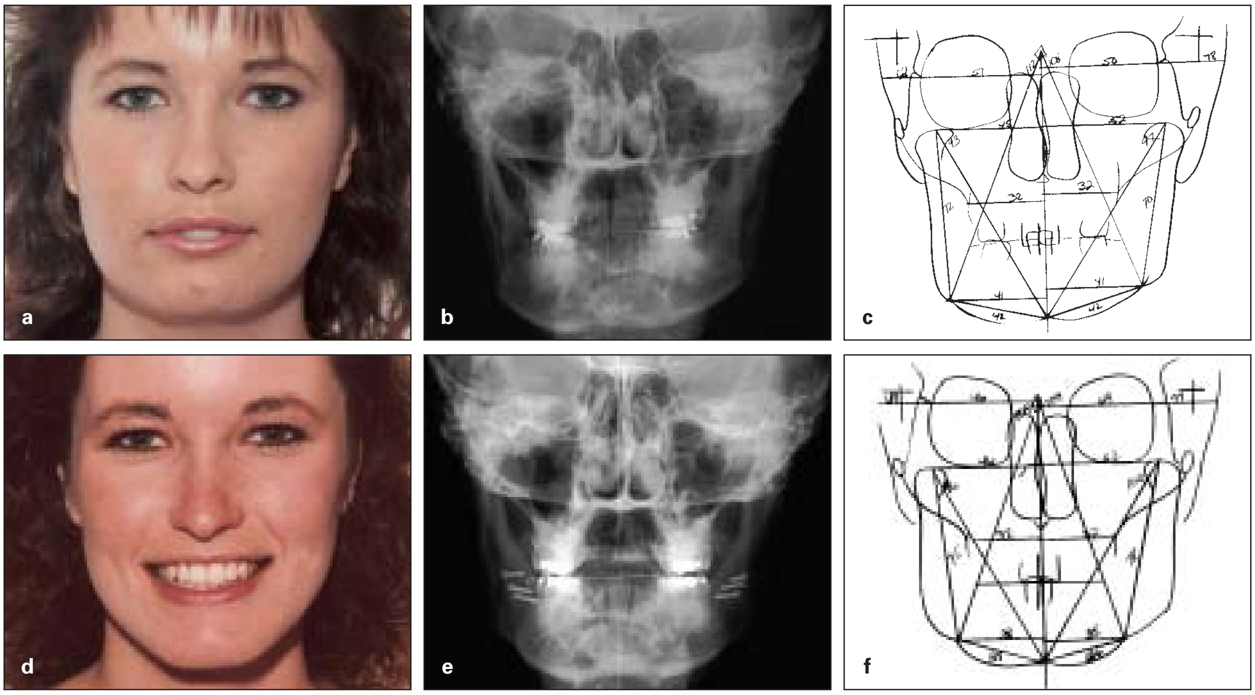


Fig 25 Mandibular border asymmetry. **(a)** Pretreatment mandibular asymmetry. **(b)** PA cephalogram. **(c)** Frontal tracing. **(d)** Posttreatment. **(e)** Posttreatment PA image. **(f)** Frontal symmetry and triangles.

shifts exists in children with crossbites, while more condylar asymmetry exists than in adults with untreated crossbites where the condyles were symmetric.[31] A steeper condylar eminence develops on the crossbite side and a shallower eminence on the non-crossbite side, indicating fossa remodeling.[40] The shape of the fossa affects the growth of the mandible. An alteration in shape of the condylar path induces changes in growth of the mandible. This asymmetric growth may continue even after correction of a crossbite, if the amount of remodeling was significant.

SURGICAL CORRECTION OF FACIAL ASYMMETRIES

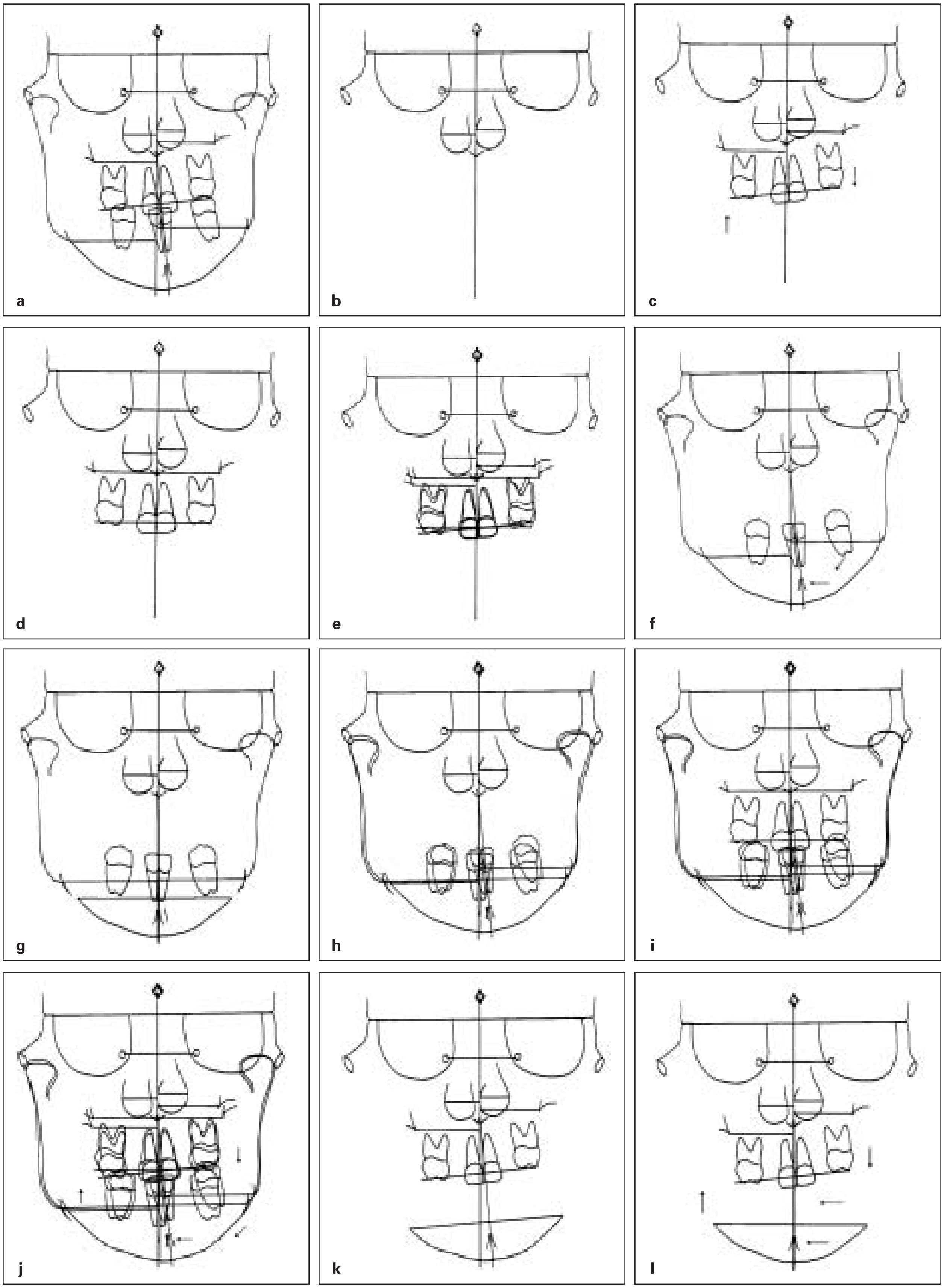
Mandibular elongation involving excessive vertical growth often requires surgery because of the unilateral open bite and necessary changes in the occlusal plane. A mild mandibular body elongation is easier to intercept, with compensatory expansion of the maxilla. Hyperplasias and vertical elongations usually require surgery, whereas body elongation has the possibility of orthodontic correction.

Definitive evaluation of facial morphology (dolichocephalic facial type, divergent jaws pattern; brachycephalic facial type, convergent jaws pattern) and hard/soft tissue assessment includes cephalometrics (lateral and frontal), articulated casts, 3-dimensional data and treatments, facial photographs (frontal, three-quarter, and lateral views), smile dynamics, and animation studies. Functional matrix and neuromuscular findings further influence decisions and treatments. The 4-D functional spatial model includes assessment of the transverse, AP, vertical proportions, range of motion, and time (maturation).

Frontal and lateral cephalometric analyses should interrelate to facial photographs; frontal and lateral animated smile observations become interrelated to information about the functional matrix (breathing, swallowing, muscles, range of motion, posture, and habits). At the finish of therapy, clinicians must locate the dentition in the maxillomandibular static neutral zone in all dimensions (Fig 26).

MANDIBULAR DISTRACTION OSTEOGENESIS

For nongrowing patients, mandibular midline expansion for greater skeletal and dental arch width improvements is being accomplished successfully with mandibular surgicallyassisted distraction osteogenesis (DO).The distance from the molars to a reference line of J-Ag at the level of the frontal occlusal plane can be modified in this way.[41,42]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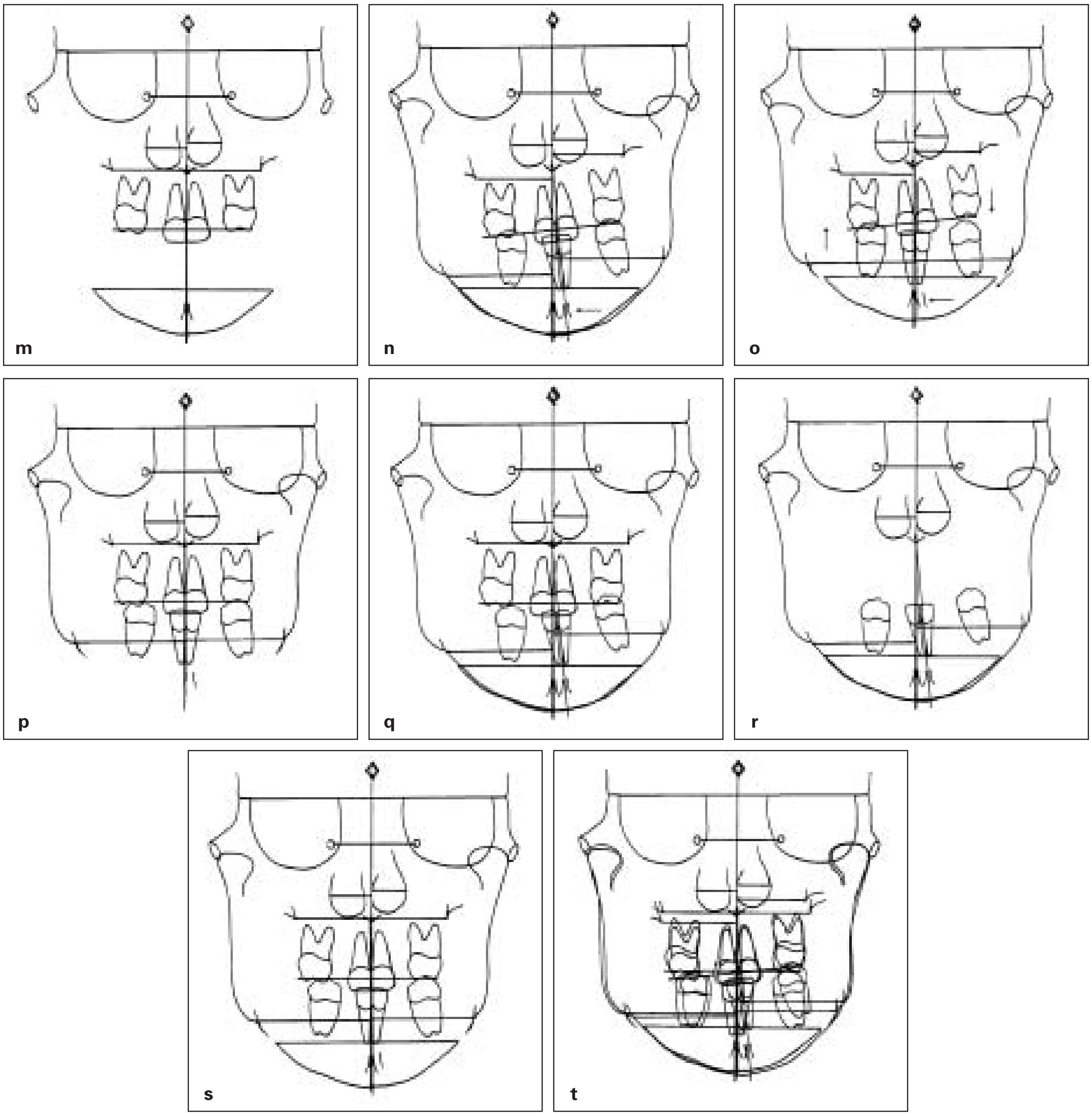

Fig 26 *(a to l facing page)* Steps in analyzing and treatment planning maxillomandibular asymmetry from the frontal perspective. **(a)** Maxillomandibular skeletal asymmetry with dental compensations; baseline frontal asymmetry analysis to establish frontal visualized treatment objectives (FVTO) steps. **(b)** Upper facial third landmarks. **(c)** Asymmetric maxillary component added to frontal tracing. **(d)** The maxillary component is moved to symmetric midline and occlusal plane placement. **(e)** Overlay of asymmetric and symmetric maxillary components. **(f)** Mandibular asymmetric component. **(g)** Mandibular component relocated to symmetric midline placement. **(h)** Overlay of mandibular asymmetric and symmetric components. **(i)** Maxillary jaw leveled, mandibular jaw moved asymmetrically forward and to midline, followed by mandibular posterior teeth erupted to leveled occlusal plane. **(j)** Maxillary and mandibular components in symmetric placement as part of frontal visualized treatment goals (FVTG). **(k)** Asymmetric chin location and maxillary jaw still misaligned. **(l)** Symmetric chin placement as camouflage and maxillary component remains asymmetric. **(m)** Maxillary component and chin made symmetric. **(n)** Both jaws remain asymmetric; chin relocated to appear symmetric at chin midline. **(o)** Both jaws moved to level occlusal plane and to correct midlines and chin. **(p)** FVTG reveals maxillomandibular symmetry with chin location undecided (may be acceptable or may need mentoplasty). **(q)** Maxillary jaw leveled while mandibular jaw and chin remain asymmetric. **(r)** Mandibular jaw body remains asymmetric though chin is moved to symmetric midline position, which disguises the underlying maxillomandibular issues. **(s)** Both jaws and chin optimally symmetric. **(t)** Superimpositions of maxillomandibular and chin treatment changes.

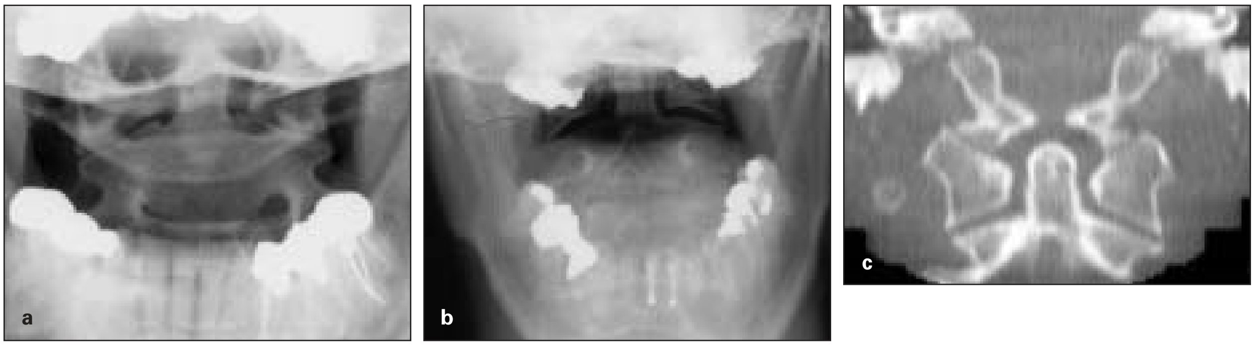

Fig 27 **(a,b)** Craniocervical abnormalities at atlas-axis (C-1, C-2) level evident on PA cephalograms taken with the mouth wide open. **(c)** Odontoid process well visualized (NewTom).

CRANIOCERVICAL ISSUES

The relationships of the cervical vertebrae can alert the clinician to possible abnormalities regarding head rotation or side-bend in the PA radiograph with the mouth wide open.[4,36] Cervical (C2) and odontoid process regions are visible and able to be evaluated in this view (Fig 27).

SUMMARY

The orthodontist must apply the optimal treatment approach for the specific needs and unique asymmetric circumstances of each individual patient, rather than expecting and/or requiring that each patient fit a clinician-preferred treatment approach. Applying such a philosophy and belief system insures that clinicians will be more exacting, and the patient will benefit immeasurably from symmetric results with specific 3-dimensional lifelong advantages. Orthodontists are well-trained regarding sagittal, AP, and vertical discrepancies, but currently less emphasis is placed on the transverse and frontal dimensions. Patients view themselves and shape self-perceptions from the frontal perspective, so this view must have greater significance. Early orthopedic intervention and nonextraction approaches provide for best functional occlusion, symmetric and proportional structural stability, with a final symmetric, esthetic smile and optimized lip support. Man's mind, once stretched by new ideas, can never remain the same.

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