Orthognathic and Obstructive Sleep Apnea

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Indications for Orthognathic Surgery

When dentofacial deformities cannot be corrected by conventional orthodontic compensation, including growth modification and camouflage techniques as well as for treatment of OSA.

Anterior-Posterior Discrepancies

- Over jet 5 mm or more or a zero to negative value (normal 0–2 mm).
- Molar relationship discrepancy of 4 mm or more (normal is 0–1 mm).

Vertical Discrepancies

- Skeletal facial deformity of two or more standard deviations from published norms.
- Open bite: no vertical overlap of the anterior teeth or posterior open bite of 2 mm or more.
- Deep overbite with irritation of tissues.
- Supraeruption of dentoalveolar segment due to lack of occlusion.

Transverse Skeletal Discrepancies

- Presence of skeletal transverse discrepancy of two or more standard deviations from published norms.

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- Maxillary palatal cusp to mandibular fossa relationship that is 3 mm or greater for a unilateral or 4 mm or greater for a bilateral relationship. Of note, one must differentiate between dental tipping and skeletal deficiencies in this deformation.

Other Indications for Orthognathic Surgery

- 3 mm or greater of asymmetry in any vector with 3 mm associated occlusal asymmetry.
- Patients with severe class II and class III problems, anterior open bite, markedly increased overbite, and facial asymmetries.
- Once the skeleton and dentition are aligned, the surgery may lead to improved speech, esthetics, function, and social interactions, and alleviate temporomandibular joint dysfunction.
- Cleft lip and palate patients with maxillomandibular skeletal disharmony.
- Facial syndromes and congenital anomalies.

Presurgical Orthodontic Goals

Decompensation of Teeth

- Dental compensation is nature's attempt to camouflage a jaw deformity.
- Orthodontic decompensation aims to reverse the natural compensation of teeth and move them into their appropriate axial inclination within the upper or lower jaw so they are housed within the alveolus.
- Remember that the upper and lower incisor angulations drive the anterior- posterior position of the maxilla and mandible into their final position.
- The orthodontic decompensation will exaggerate the malocclusion and thus make the skeletal deformity more noticeable.
- In class II skeletal patients, the retroclined upper incisors should be aligned over the alveolar bases (proclined to 102 degrees to SN) to maximize the overjet while at the same time maintaining a normal angulation. Caution must be used so that the transverse position of the maxillary canines does not block out the mandibular incisors as the mandible is advanced surgically. The lower incisors are typically proclined in this population and the goal should be to have the lower incisors at 90–95 degrees to the mandibular plane. This may require removal of the first or second bicuspids or reproximation (stripping) if very significant crowding exists.
- In class III skeletal patients, the lower incisors are usually found to be retroclined and upper incisors proclined. The lower incisor dentition in these patients should be proclined so that the lower incisor is at 90–95 degrees to the mandibular plane. The upper incisors should be retracted to obtain and angle near 102 degrees to SN.

Arch Alignment and Leveling

- All teeth are aligned when gross crowding, spaces, or rotations are corrected.
- Adjustments for tooth size discrepancy (TSD) – calculated with Bolton's analysis (see below).
- Create divergence of roots adjacent to interdental osteotomy sites.
  - To perform interdental osteotomies, space should be created between the lateral incisors and the cuspids or between the cuspids and first bicuspids ideally.
- Lingual cusps of the mandibular posterior teeth should be 1 mm below the buccal cusps.
- Palatal cusps of the maxillary posterior teeth should be 1 mm below the buccal cusps. Plunger cusps create open bites post-op as the dentition relapses.

Bolton Analysis

- Determines the disproportion of the size of the permanent maxillary and mandibular teeth (tooth size discrepancy between the upper and lower teeth). Two ratios are calculated (overall ratio and anterior ratio).
- The overall ratio is calculated by taking the sum of the mesiodistal width 12 mandibular

teeth (first molar to first molar) divided by the sum of the mesiodistal width of the 12 maxillary teeth. According to Bolton, the overall ratio should be 91.3%. A ratio less than 91.3% indicates maxillary tooth excess.
- The anterior ratio is calculated by the sum of the mesiodistal widths of the anterior mandibular teeth divided by the sum of the mesiodistal widths of the anterior maxillary teeth (canine). According to Bolton, the overall ratio should be 77.2%. A ratio less than 77.2% indicates maxillary tooth excess.
- Tables are available in multiple orthodontic textbooks with calculated ratios easily obtainable.

Arch Coordination

- Teeth may not interfere with planned skeletal movement.
- Both dental arches should be reasonably compatible with one another at the time of surgery to allow maximum intercuspation post-surgically.
- Arch form must be changed to expand the constricted areas in the more tapered arch or change narrow arches into more rounded form.
- As a general rule, orthodontic expansion should be limited to 4–5 mm total, although this depends on angulation of the posterior teeth. In many cases, there is dental compensation (vertical position of maxillary posterior teeth) that can easily be corrected with orthodontic treatment up to 6–7 mm. However, if the position of the posterior teeth is angulated facially with narrow basal bone surgical expansion is indicated.
- For severe maxillary transverse discrepancy surgical correction greater than 5 mm, surgically assisted rapid palatal expansion (SARPE) or segmental osteotomy should be considered.

Final Presurgical Orthodontic Preparation

- At the conclusion of presurgical orthodontic goals, the patient should be in full dimension rectangular steel arch wire that fills the bracket slot.
- There should be absolutely no movement of the teeth for at least four weeks before taking presurgical models: either stone or virtual.
- The stabilizing wire must fit passively to be effective.
- Surgical hooks attached to the brackets or arch wires are usually necessary to facilitate maxillomandibular fixation and to provide a means of using postsurgical elastic guidance or traction.
- Fixtures attached to the brackets include ball hooks or K (Kobayashi) hooks (Fig. 5.1).
- They may distort or break during the surgery.
- Fixtures attached to the arch wire include crimped-on hook and soldered pins.
- The use of postsurgical elastics may activate the arch wire, possibly creating unwanted orthodontic movements.

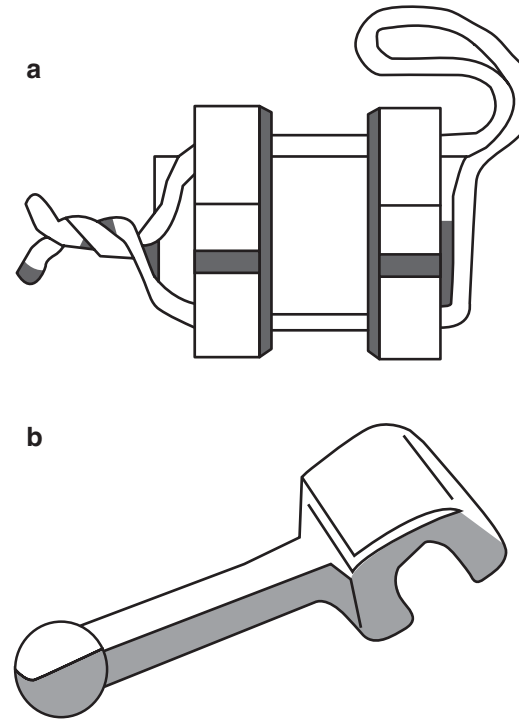

Fig. 5.1 A. Kobayashi hook B. Ball hook. (Image courtesy of Erik Steenberg)

Surgical Workup

Traditional Model Surgery

- Clinical data collection
  - Facial measurements
  - ROM/TMJ findings
  - Cranial nerve exam
- Photographic records
  - Extraoral front relaxed and smile (natural head position), lateral with lips in repose, ¾ view. If you are using the GALL line, then lateral with smile is needed, and ensure no hair is covering forehead.
- Facial measurements
  - Look for position of orbits
  - Position of ears
  - Alar width
  - Asymmetries and Cants.
- Inter-occlusal records or bite registration in centric relation (CR)
- Diagnostic casts that are mounted on an anatomic fully adjustable articulator in CR
- Facebow transfer to mount maxilla
- Radiographic exam

Virtual Surgical Planning

- Clinical data collection
- Photographic records
- Facial measurements
- Diagnostic casts/digital dental scan
- Centric relation record with fiducial markers
- Cone beam computed tomography (CBCT) or CT scan
- Final occlusion established by surgeon
- Data transfer to service center
- Planning specifics – order form (osteotomy design, order, and anticipated movements)

Radiography

Lateral Cephalogram

- Used to aid in making a skeletal diagnosis. Patient is held in adjusted natural head position.
- Lips relaxed, mandible in retruded contact position, and teeth lightly in occlusion.
- Assess the inclination of the various facial planes.
- Used to assess the AP position of the maxilla and mandible.
- May show asymmetries of condylar ramal height/size between the left and right (inferior borders do not coincide). Ensure radiograph taken correctly, verify with AP cephalometric.
- Can be used to assess the relationship of the maxilla to the cranial base.
- Can visualize the posterior airway space.
- Can assess growth by looking at the cervical vertebrae along with a growth chart.
- The goal of surgery is not to give patients cephalometric normal values, instead it is used as a guide to treat the clinical picture.

Orthopantogram

- Used to examine the dentition.
- Can assess the temporomandibular joint anatomy.
- Assess for presence of third molars.
- Assess for pathological lesions/entities.
- Can assess the inclination of roots (could be supplemented with periapical radiographs to view interdental osteotomy sites).
- Used to assess the position of the inferior alveolar canal and entry to ramus.
- Degree of sinus pneumatization.

Computed Tomography

- Used for gross facial asymmetries and for planning surgical treatment. Scan should be obtained at a high spatial resolution with no motion artifact.
- The patient's CT/CBCT scan is reoriented by the computer engineers to reflect their NHP for more accurate planning. To produce accurate CAD/CAM splints, occlusal surfaces from CT or CBCT scans are replaced with a high-resolution laser scan from stone models

or an intraoral scanner to create a composite model.
- CT/CBCT can be reformatted into orthopantogram. Also allows assessment for TMJ, third molar, interdental osteotomy site, and IAN nerve canal position.

Posteroanterior Cephalogram

- Will highlight significant facial asymmetry and can quantify excess or deficiency with tracing and measuring films. This film also allows the surgeon to further evaluate for skeletal cants of maxillae, mandible, and chin point.

Submental Vertex

- Evaluate for U or V shape mandible, may have combination. V shape favors IVRO for setback. U shape favors BSSO for setback.

Presurgery Records

- An ideal time to obtain presurgical records is 2 weeks prior to the planned surgery date. If custom plates (patient-specific plates) are to be used, then at least a month of lead time is needed to have time to plan and manufacture them.
- Don't take models until after the final rectangular orthodontic arch wire has been in place to be passive – ideally 4 weeks or more.

Dental Casts or Scanned in Dentition (STL Files)

- To be used in model surgery itself.
- Facilitates fabrication of occlusal wafer splints.

Facial Photographs

- Frontal full face with lips in repose.
- Frontal full face with animation.
- 45-degree oblique (three-quarter) with lips in repose.
- Right and left profile view in natural head position (NHP), in repose, full smile, and lips together.
- Additional – submental view.
  - To document mandibular and/or midface asymmetry.
  - To allow detailed analysis of nasal tip form in patients with abnormalities.

Intraoral Photographs

- Right, center, and left view with teeth in occlusion.
- Maxillary and mandibular occlusal view.

Facial Examination

- An examination of the face is performed with the patient in adjusted NHP.

Frontal View

Vertical Facial Proportions

- Facial thirds – The ideal face in both males and females is horizontally divided into equal thirds by horizontal lines at the hairline (Tr), glabella, the subnasale (Sn), and menton (Me') (Fig. 5.2).
- Upper third of the face, measured from trichion to glabella.
  - Deformities may indicate craniofacial deformity.
  - Assess eyebrow shape, position, and symmetry.
- Middle third of the face, measured from glabella to subnasale.
  - Includes eyes, nose, and cheeks.
  - Scleral show and flattening of cheek bones/paranasal region may indicate midface deficiency.

Fig. 5.2 Facial thirds. (Courtesy of Dr. Damian Findlay)

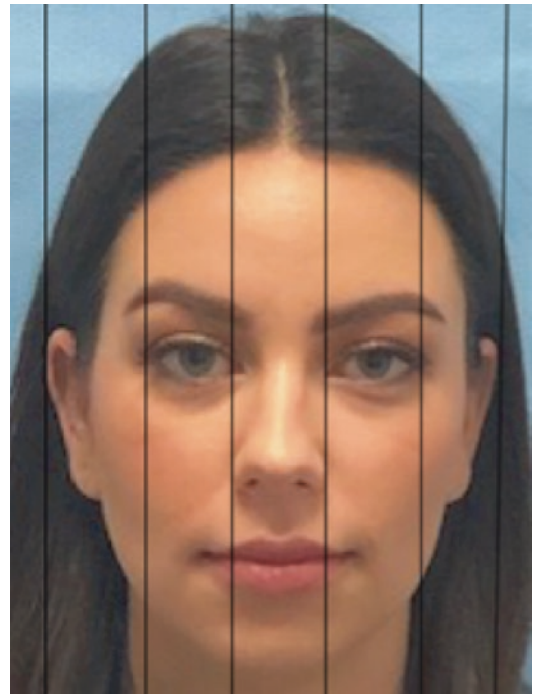

Fig. 5.3 Facial fifths. (Courtesy of Dr. Damian Findlay)

  - The nose, center of the lips, and middle of the chin should fall along the true vertical line.
  - The cheek bone-nasal base-lip contour line evaluates harmony of the structures of the midface with paranasal area and upper lip.
- Lower third of the face measured from subnasale to menton.
  - Lower third is further subdivided into upper one-third from subnasale to stomion superius (Sn-Sts) and lower two-thirds from stomion inferius to menton (Sti-Me').
- The ratio of middle third to lower third vertical height of face should be 5:6.
- Racial differences need to be considered.

Transverse Facial Proportions

- The "Rule of Fifths" – the face is divided sagittally into five symmetric and equal parts and each of the segments should equal the width of one eye (Fig. 5.3).
- The outer canthi should coincide with the gonial angles.
- The medial canthi should coincide with the alar bases of the nose.
- The inter-pupillary distance should coincide with the corners of the mouth.

Facial Symmetry

- Maxillary and mandibular dental midlines should be coincident to facial midline.
- Important midline structures are glabella (G), nasal bridge (NB), nasal tip (Pn), the midpoint of the philtrum of the upper lip (F), dental midline (DM), and the midpoint of the chin (Pog').
- Assess maxillary and mandible dental midlines in relation to each other.
- Mandibular dental midline in relation to the mid chin point should coincide.
- Smile and tooth-lip relationship.
- Upper lip should expose full crown length in males and with 2 mm gingival show in females.
- Normal tooth exposure on repose is 2–4 mm. Greater than 4 mm indicative of lip incompetence. Patient may display mentalis strain and have a tendency for mouth breathing.

- Excessive tooth display at rest may be from:
  - Short philtrum height. Look for this in the cleft population.
  - Vertical maxillary excess.
  - Excessive crown height/length.
  - Lingually tipped maxillary incisors.
- Inadequate incisor display may be from:
  - Excessive philtrum height; subnasale to upper lip is >22 mm.
  - Vertical maxillary deficiency.
  - Inadequate crown height.
  - Flared maxillary incisors.

Profile View

The Upper Third of the Face

- Supraorbital rim projects beyond the most anterior projection of the globe of the eye.
- Glabella should be coincident with the base of the nose.

The Middle Third of the Face

- Assess nose, cheeks, and paranasal area.
- Nose:
  - Lower nose projection can be affected by the anteroposterior (AP) position of the maxilla.
  - Alar base shape resembles isosceles triangle from worm's view.
- Cheek:
  - The lateral orbital rim lies 8-12 mm behind the globe.
  - The globe projects 0-2 mm ahead of infraorbital rim.
  - Malar eminence should be located 10-15 mm lateral and 15–20 mm inferior to the lateral canthus.
  - Cheekbone-nasal base-lip curve contour should be smooth, uninterrupted curve.
- Paranasal Area:
  - Paranasal deficiency represented by flatness of cheeks is often present in patients with maxillary deficiency.
  - The nasolabial angle is normally 100 degrees ±10 degrees; it is greater in females than in males.

The Lower Third of the Face

- Lower third face height: subnasale to soft tissue menton
  - Lower third divided into two portions:
    Subnasale to wet line of upper lip (1/3)
    Wet line of lip to soft tissue menton (2/3)
- Lips:
  - Subnasale-pogonion line (lower facial plane) – the upper lip should be 3 ± 1 mm and lower lip 2 ± 1 mm ahead of the line
  - Interlabial gap normally 0–3 mm in repose
  - Upper lip length: 20 +/− 2 mm in females, 22 +/− 2 mm in males
  - Lower lip length: 40 +/− 2 mm in females, 44 +/− 2 mm in males
- Labiomental Fold:
  - S-contour
  - Angle – 130°.
- Chin-Throat Angle:
  - Normally 110 degrees – provides chin definition.
  - Chin adiposity and hyoid bone position effect angle.

Cephalometric Analysis

Soft Tissue Analysis

Maxillary and Mandible AP Evaluation

- A vertical line perpendicular to constructed horizontal is drawn through soft tissue glabella (G').
- Pog' should be 1-4 mm behind this line.
- For maxillary AP position, Sn should be 6 ± 3 mm ahead of the line.
- For mandible AP position, Pog' should be 1-4 mm behind the line.

Nasolabial Angle

- Angle formed by tangent line to columella and upper lip. Normal range is 85–105 degrees.
- More acute in males and obtuse is more attractive in females.
- Acute in class III.
- Obtuse in class II.
- Influenced by lip support, lip thickness, lip strain, and magnitude of the overjet.

Lip Prominence

- A line drawn from subnasale (Sn) to soft tissue pogonion (Pog').
  - The perpendicular distance of upper lip ahead of this line should be 3 ± 1 mm, while lower lip should be 2 ± 1 mm.
  - The AP position of upper lip is an indication of soft tissue support by maxillary incisors.
- Another way to measure it is by using subnasale vertical (SnV) – a vertical line drawn from subnasale perpendicular to true horizontal line.
  - The upper lip should be 1-2 mm ahead of this line.
  - Lower lip should be on or just posterior to SnV.

Chin Prominence (Fig. 5.4)

- A line drawn through N′ perpendicular to FH is 0-degree meridian line.
  - Pog' 0 ± 2 mm ahead of 0-degree meridian and 3 ± 3 mm behind SnV (subnasale vertical).

Lower Lip-Chin-Throat Angle

- Angle formed by a line drawn from Li to Pog' and submental tangent line – 110 ± 8 degrees.
  - Acute in patients with mandible AP excess and/or macrogenia.
  - Obtuse in patients with mandible AP deficiency and/or microgenia.

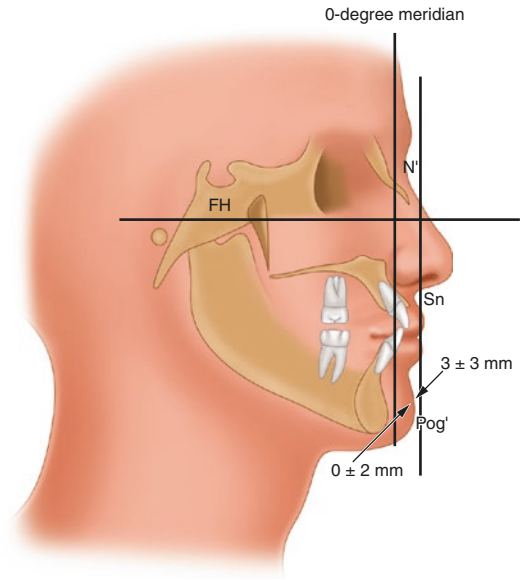

Fig. 5.4 Chin prominence can be evaluated in relation to Frankfort horizontal (FH). A line drawn perpendicular through FH through soft tissue nasion is known as (0-degree meridian); soft tissue pogonion should be 0 ± 2 mm ahead of this line. A line perpendicular through FH through subnasale is known as subnasale vertical. Soft tissue pogonion should be 3 ± 3 mm behind subnasale vertical. (Image courtesy of Erik Steenberg)

- Chin Throat Length
  - Measured from angle of the throat to Me' (normal value 42 ± 6 mm).
  - Helps differentiate between mandibular excess and maxillary deficiency.
- Facial Contour Angle
  - Formed by lines drawn from G' to Sn (upper facial plane) and from Sn through Pog' (lower facial plane).
  - Mean angulation is −12 degrees (Fig. 5.5).
  - Males tend to have a straighter profile (−11 ± 4 degrees), while females have slightly more convex profile (−13 ± 4 degrees).
  - Various facial deformities may produce the same facial contour angle.

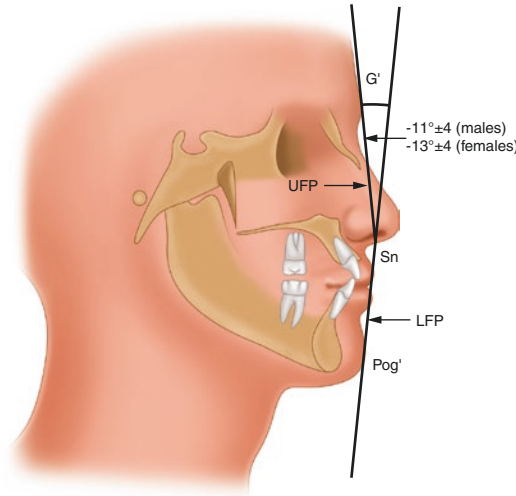

Fig. 5.5 The facial contour angle describes facial convexity or concavity. It is formed by the angle of the upper and lower facial planes. Averages are −13 ± 4 for females and 11 ± 4 for males. (Image courtesy of Erik Steenberg)

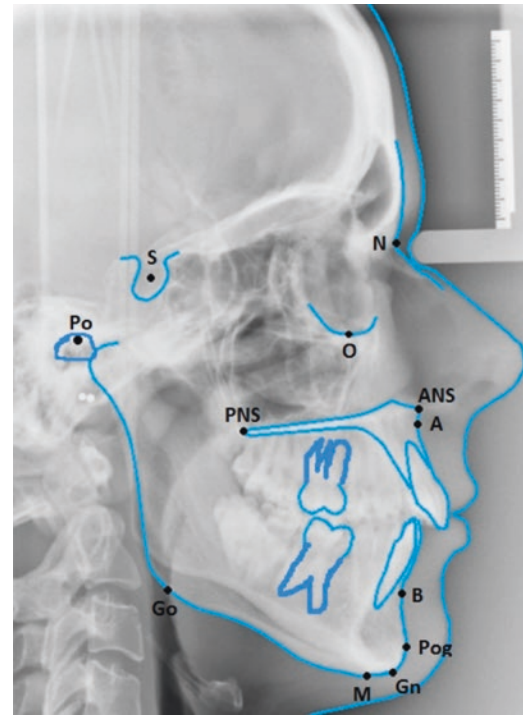

Fig. 5.6 Cephalometric hard tissue points

Skeletal Analysis

- Tracings of lateral cephalograms utilize stable hard and soft tissue points to aid in diagnosis, changes in growth, and treatment of dentofacial deformities (Fig. 5.6).

Assess Maxillary AP Position

- Steiner Analysis
  - Maxillary anteroposterior positions in relation to the anterior cranial base (S-N).
  - SNA of 82° is considered normal. An angle <82° indicates maxillary AP deficiency, while >82° indicates maxillary protrusion.
- Ricketts Analysis
  - Ricketts analysis uses maxillary depth.
  - Measures angle at the intersection of FH line and the NA line.
  - An angle of 90 ± 4 ° is ideal. An angle less than 86° indicates retrognathia, while an angle greater than 94° indicates prognathism.
- McNamara Analysis
  - Measures the distance from A point to Nasion perpendicular (a line that crosses N and is perpendicular to FH), normal range is 0-1 mm.
  - A negative number indicates retrognathia, while a positive number greater than 1 indicates prognathism.

Assess Mandibular AP Position

- Steiner Analysis
  - Mandibular anteroposterior positions in relation to the anterior cranial base (S-N).
  - SNB of 80° is considered normal. SNB <80° indicates mandibular AP deficiency and a greater angle indicates mandibular excess.
- Facial Angle (Downs Analysis)
  - Indicates relative AP position of mandible to cranium.

  - An angle formed by the intersection of the facial line, N-Pog' line and FH line.
  - Mean is 82–95°.
- McNamara Analysis
  - Measures the distance from Pog to N perpendicular (a line that crosses N and is perpendicular to FH).
  - An ideal number for mixed dentition is −8 to −6 mm, adult female is −4 to 0 mm, and adult male −2 to +2 mm.

Assess AP Maxillomandibular Relationship

- Steiner
  - Provides an idea of anteroposterior relationship between maxilla and mandible.
  - A normal maxillomandibular relationship is indicated by ANB of 2°.
  - In class III cases, angle is <2 or even negative. In class II cases, angle is >2.
- Wits Appraisal
  - Linear relationship between maxilla and mandible not influenced by cranium.
  - Points BO and AO are established by dropping perpendicular lines from A point and B point, respectively, onto the occlusal plane (OP) (Fig. 5.7).
  - The mean in male is BO 1 mm ahead of AO. In females, AO and BO coincide.
  - The measurement between AO and BO indicates the AP discrepancy between maxilla and mandible.
  - Small discrepancy between AO and BO indicates that the case can be treated orthodontically, while large discrepancy may indicate surgical correction.
- Mandibular Plane Angle (Steiner)
  - Formed between mandibular plane (Go-Gn) and anterior cranial base (S-N), normal value is 32 degrees.
  - An angle ≥39° is considered high, ≤ 28° is a low angle.

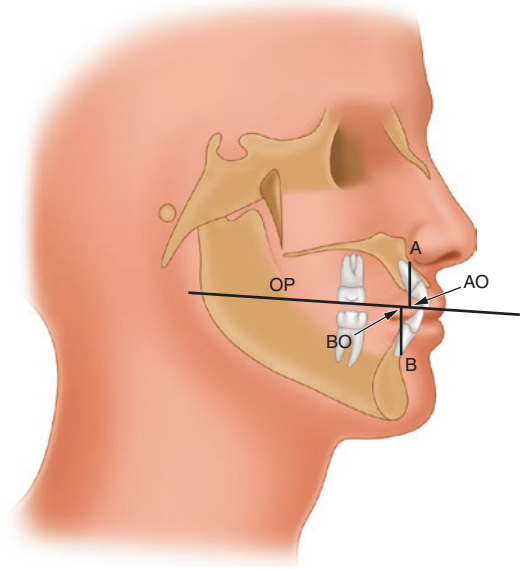

Fig. 5.7 Wits appraisal

  - Interprets the difference between anterior and posterior facial heights.
  - Increase in mandibular plane angle tends to have dolichocephaly, class II malocclusion, vertical maxillary excess, and apertognathia.
  - Decrease in angle is associated with brachycephaly, skeletal deep bite, and notched gonial angles.

Analysis of Dental Relationships

Maxillary Incisor Position

- Steiner
  - AP position of incisor to maxilla.
  - The axial inclination should be 22° to NA and the most anterior point of maxillary incisor should be 4 mm ahead of NA.
  - The facial surface of maxillary incisor should be 4-6 mm ahead of the vertical line through A point.

Mandibular Incisor Position

- Steiner
  - AP position of incisor to mandible (NB line).
  - Mandibular incisor angulation to NB line should be 25 ° and the most labial point of incisor should be 4 mm anterior to the line.

Occlusal Plane Angle

- Steiner Analysis
  - Angle between the occlusal plane (OP) and anterior cranial base (S-N) – 14°.
  - High-angle individuals have relatively long anterior facial height, while low-angle individuals have vertically short anterior facial height.

Chin Assessment

- Holdaway Ratio
  - Extend NB line to the inferior border of the mandible and compare the distance between L1 (incisal edge of mandibular incisor) and Pog from this line.
  - A ratio of 1:1 is ideal in males and 0.5–1 in females.
  - REMEMBER, this is only of value if lower incisors are in the proper position. Predictions for chin correction must be made with this in mind.

Growth Evaluation

- Skeletal age – serial hand-wrist radiographs.
- Deceleration of growth – serial cephalometric radiograph.
- Six stages of cervical vertebrae maturation on lateral cephalometric radiograph.
  - The peak of mandibular and craniofacial growth corresponds to the peak in statural height growth, which corresponds to stages 3 and 4 of cervical vertebral maturation.
  - As cervical vertebrae mature through six stages, they develop a concavity on the inferior border and assume a more rectangular shape in both boys and girls.

LeFort (LF) Osteotomy

The LeFort osteotomy has a long history and has become the standard of care when performing maxillary osteotomies to achieve a change in maxillary position. The maxillary position can be changed in any one of three dimensions or a combination thereof. When deciding on maxillary position, we must be sure to have the correct diagnosis, which ultimately will guide our surgical plan and produce the best surgical result for the patient. Maxillofacial deformities are always determined by the physical exam which then may or may not be supported by radiographic findings.

The following list of maxillary diagnoses includes important physical findings that exemplify the specific diagnosis.

Maxillary hyperplasia can be one of the following or a combination thereof:

Posterior vertical excess

- Open bite

Anterior vertical excess

- Excessive gingival show and/or excessive incisal show (resting and/or smiling)

Anterior posterior excess

- Acute nasolabial angle
- Excessive gingival show and/or excessive incisal show (resting and/or smiling)
- Maxillary protrusion

Maxillary hypoplasia can be one of the following or a combination thereof:

Posterior vertical deficiency

- Steep mandibular plane
- Posterior open bite

Anterior vertical deficiency

- Incisors not visualized at rest
- Minimal to no incisor show with smiling

Anterior posterior deficiency

- Midface deficiency
  - Poor piriform rim support (flat to concave maxillary appearance)
- Incisors not visualized at rest
- Minimal to no incisor show with smiling

LeFort Osteotomy Technique

- General anesthesia with nasal intubation.
- Place K wire at nasofrontal suture and take measurement to lower edge of maxillary incisor orthodontic bracket. This is an external vertical reference marker that can be used when complicated movements are to be done.
- Full-thickness maxillary vestibular incision from one zygomatic maxillary buttress to the other (leave at least 5 mm of nonkeratinized mucosa to facilitate closure).
- Bony exposure superiorly via this full thickness mucoperiosteal flap.
- Bluntly dissect to the nasal aperture and protect the nasal mucosa by lifting it up with a freer elevator, stay just shy of the infraorbital nerve and tunnel to the pterygoid plates bilaterally. The soft tissue posteriorly can be protected with a neuro-patty soaked in local anesthesia and a small retractor.
- Dissect anterior nasal spine free, dissect nasal floor off the palatal shelf using a freer.
- Bone markings can be used to measure subsequent maxillary movement (internal reference marks).
- Horizontal cut (or stepped cut) from posterior maxilla to piriform rim bilaterally.
- If impacting, use a caliper to measure bone to be removed and cut a wedge out.
- Lateral nasal wall osteotomies completed with guarded osteotome.
- Nasal septum separated with nasal-guarded osteotome.
- Pterygoid plate osteotomies with pterygoid osteotome (vector should be anterior and inferior).
- If multiple-piece LeFort planned, place vertical interdental osteotomies at this time (cut arch wire if not already segmentalized by the orthodontist).
- Induced hypotension (50–65 mm Hg MAP) is helpful to control bleeding. Patient must have an A-line.
- Down fracture with simple digital pressure or gently with Rowe maxillary disimpaction forceps or Tessier mobilizers.
- Check fractures and trim bony interferences of the septum and lateral walls.
  - Ensure complete mobility of the maxilla in three planes of space, should be able to passively move.
- If multi-piece is planned, cut palatal paramedian osteotomy just lateral to nasal septum. This region represents thin bone and thick palatal tissue, reducing the chance of palatal tear.
- Place splint securely to the dentition.
- Intermediate or final splint used to position maxilla with maxillomandibular fixation (MMF).
- Rotate the maxillomandibular complex up. Use a single finger to lift up complex to first point of contact. Grind as needed to achieve the correct vertical position. Do not force up or will pull condyles down out of fossae and bite will be open once you release the MMF.
- Plate maxilla into new position (plates should be at the piriform and zygomaticomaxillary buttresses).

Complications with LeFort Osteotomy

- *Bleeding* – sources include the pterygoid plexus, posterior superior alveolar artery, greater palatine artery, terminal branches of the maxillary artery. The internal maxillary artery is normally 25 mm superior to the base of the junction of the pterygoid plates in a normal maxilla. The pterygoid osteotome is 15 mm in height, leaving a 10 mm margin of safety. Treatment: attempt pressure packing with gauze and/or hemostatic agent. If no resolution, try to identify vessel for cautery. If bleeding continues consider an interventional radiology intraoperative consult for emboliza-

tion. With an extremely small maxilla, like in a cleft child or syndromic patient, a preoperative CT angiogram may be useful to identify these vessels.

- *Anterior Open Bite After MMF Release* – etiology: condyles not seated in fossa or area of premature bony contact. Remove fixation and check for bony interferences. Ensure passive condylar positioning into fossa. Replace fixation.
- *Dental Iatrogenic Injury* – recommend placement of osteotomies 5 mm above apices of roots. Observe, root canal therapy if symptomatic, or extract. Teeth may remain insensate up to around 5 years.
- *Cut Palatal Mucosa During Multi-Piece* – For a small tear, perform a simple suture repair and continue with the case. For large tear, consider replacing maxilla to original position. Do not attempt to raise flap of defect as it may further compromise blood supply and lead to avascular necrosis. The treatment in this case requires local irrigation and cover with a noncompressive splint. Formal closure is performed when revascularization is confirmed if the region has not closed spontaneously.
- *Vertical Posterior Maxillary Wall Fracture* – check globe for increased pressure. Fracture of the pyramidal process of the palatine bone can cause injury to vessels or contents of the globe. Intraoperatively redirect fracture with osteotome. Postoperatively check globe pressure, changes in visual acuity, proptosis of the globe, and pupillary response. Ophthalmology consult may be indicated. If pressures are high, may require CT orbit with contrast for evaluation or emergency lateral canthotomy.
- *Anterior Maxillary Wall Fracture* – attempt plating.
- *Midline Discrepancy* – etiology: error introduced into workup/mounting/or splint fabrication. Reposition maxilla by utilizing facial midline or dental midline or stable jaw.
- *Decrease in Maxillary Perfusion* – as denoted by poor capillary refill or purple gingiva. Replace and fixate maxilla to original position, check to ensure stents are not impinging tissue. Keep area clean to prevent infections with chlorhexidine and antibiotics until resolved. For severe delayed vascular compromise, consider hyperbaric oxygen.
- *Cut Endotracheal Tube* – tube transfer/reintubate. Consider tracheostomy or submental intubation.
- *Nosebleed (Postoperative)* – pack nose with nasal packing. If not controlled with packing, then return to the operating room to take maxilla down and control bleeding. Consider embolization.
- *Trigeminocardiac Reflex* – stop stretch on maxillae. Further anesthetize soft tissue to decrease sensitivity of CN V. Atropine or glycopyrrolate may be required to complete surgery.
- *Epiphora* – more common in high LeFort osteotomies due to damage of nasolacrimal system, nasoseptal deviation, or swelling. If no resolution after 6 weeks, CT scan to r/o source. May require dacryocystorhinostomy or nasoseptoplasty depending on etiology.
- *Pseudoaneurysm* – patient may complain of build-up pressure with release. Bleed may be early or late. CT angiogram with interventional radiology consult.
- *Nasal Septum Deviation or Buckling* – suture septum to the ANS to prevent deviation. Trim cartilaginous septum or maxillary crest for buckling.
- *Infection* – obtain imaging. Antibiotics, incision and drainage, debridement. If hardware is source of infection, then remove appropriate hardware, replace if clinically acceptable.
- *Hardware Failure* – replace hardware and consider more rigid fixation.

Surgically Assisted Rapid Palatal Expansion (SARPE)

While this section covers surgically assisted rapid palatal (or maxillary) expansion (SARPE or SARME), a brief overview of other related procedures to increase the maxillary transverse dimension is necessary for completeness.

Dental Tipping

For small transverse discrepancies up to 5 mm with healthy periodontium and upright teeth, the maxillary dentition may be tipped to facilitate expansion.

- Orthodontic rapid palatal expansion (RPE) takes advantage of growth potential in growing children and adolescents.
- A transpalatal, dental-borne, and/or microimplant borne (MARPE) orthopedic expander opens the midpalatal suture, tips teeth, and bends and remodels the alveolus.
- Older patients have more sutural resistance that results in less expansion and more dental tipping, lateral tooth displacement, and periodontal defects.
- Children have a 50% tipping and 50% expansion.
- Adolescents have 65% tipping and 35% expansion.
- High relapse (40–60% depending on age) with up to 50% overcorrection recommended.
- More widening occurs at the canines than molars (3:2).

Up to 18% of adult patients that present for orthodontic treatment have a transverse discrepancy >5 mm that cannot be corrected with orthodontics alone. After palatal suture fusion and for patients who failed RPE, two primary options for palatal expansion exist: SARPE or segmental (LF) osteotomy.

Segmental LeFort

- This is part of the definitive orthognathic surgery and treats multiple planes of occlusion and when more expansion is needed posteriorly versus anteriorly. Surgery includes interdental osteotomies to create multiple dental bearing segments that are independently mobilized, repositioned, and fixated. While this has the benefit of a single stage procedure, it is more complex, time consuming, has more minor and major complications, higher relapse (if >7 mm expansion), and less expansion potential than a SARPE.

SARPE Alone or Before Single-Piece LF

- This involves creating osteotomies in the maxilla and application of an expander for distraction osteogenesis. This may be performed alone or to obtain transverse expansion prior to a single-piece LF.
- Indications:
  - >7 mm expansion
  - Desire to avoid segmental maxillary surgery
  - Thin, delicate soft tissue with gingival recession in the bicuspid-canine region
  - Significant nasal stenosis
  - Level occlusal plane
  - Constricted V-shaped arch form

Benefits of SARPE

- Greater arch expansion
- May avoid extractions
- Better orthodontic alignment before definitive orthognathic surgery
- Improved periodontal health, esthetics, and buccal corridor

Segmental LF vs SARPE and Single-Piece LF

- For expansion >7 mm, SARPE stability (30% relapse at canine and molars) far exceeds segmental LF and RPE (50% relapse) (1).
- More expansion at the canines than the molars due to lateral nasal wall and palatine bone resistance.

Preoperative Preparation

- After determining a patient is appropriate for SARPE, the patient should stop nicotine at

least three weeks preoperatively and stop NSAIDs 1 week prior. Nutritional supplements that predispose patients to bleeding should be stopped at least two weeks preoperatively, and oral hygiene should be optimized.
- The orthodontist should tip teeth at the site of the interdental osteotomy with 3 mm between the apices, decompensate the curve of Wilson, stop all orthodontic forces, remove or segment the maxillary arch wire, provide the surgeon with the expander key, and preferably, apply the tooth or bone-borne expansion device (usually a Hyrax, Haas, or microimplant supported) prior to the OR.

SARPE Surgical Procedure

- Maxillary vestibular incision from one zygomaticomaxillary buttress to the other.
- Full thickness mucoperiosteal flap.
- Identify piriform rims, infra orbital nerve, and the pterygoid plates bilaterally.
- Bilateral maxillary osteotomies from the piriform rim to the pterygomaxillary junction that is parallel to the occlusal plane and 5 mm above dental apices.
- Release of nasal septum to avoid septal deviation during expansion (optional).
- Dissect mucosal tunnel between 8 and 9 with thin periosteal elevator to expose the facial cortex and root projections.
- Small fissure bur (#701) or sagittal safe blade to score the cortex at the osteotomy site between 8 and 9 from the alveolar crest to the nasal floor.
- Use a thin spatula osteotome between 8 and 9 and extend the osteotomy to the PNS.
  - Variation: stop midline osteotomy after 1.5 cm to avoid injury to the palatal tissue.
  - Variation: do not release the nasal septum, incise along the palatal midline, elevate two conservative midpalatal flaps, create two paramedian (2 mm lateral to the suture) osteotomies that connect posterior to the incisive foramen, suture palatal tissue closed, and cement expander.
- Perform an osteotomy of the anterior portion of the lateral nasal walls for 1.5 cm.
  - Variation: stop after 1.5 mm as the bone posteriorly is thin and offers minimal resistance to transverse expansion.
- Bilateral pterygoid plate osteotomies.
- Activate the distractor to allow passive expansion of 3–4 mm. Then, decrease the expansion to a total bony gap of 0.5–1.5 mm at the end of the procedure.
- Any perforations of palatal tissue should be closed without undermining.
- Close with an alar base cinch and V-Y closure.
- 5–7 days of latency.
- Rate and rhythm of 0.25 mm twice/day (0.5 mm/day).
- Palatal expansion must occur within 4 weeks of surgery. Allow 4 months of retention before removing the expander to get bone fill.

Complications of SARPE

- Complications similar to the LeFort procedure.
- *Periodontal Compromise Between the Central Incisors* – decrease the appliance back a few notches and reduce the rate of expansion.
- *Asymmetric Expansion* – this is the most common expansion complication and results from incomplete release of pterygomaxillary junction on one side. Half of the time, the asymmetry self-corrects. Others may require a segmental osteotomy to correct the asymmetry at least 4 weeks after the SARPE.
- *Inadequate Expansion* – inadequate surgical mobilization results in pain, dental tipping, periodontal breakdown, palatal tissue impingement by the expansion device, and post-orthodontic relapse. Treat with adequate mobilization and removal of bony interferences.

Mandibular Osteotomies

- There are various osteotomy techniques that have evolved over time. The most common osteotomy techniques are sagittal split osteotomy and the vertical ramus osteotomy.
- The workhorse of the group is the sagittal split procedure. This is followed by the vertical ramus osteotomy being the second most common technique performed.
- The mandibular position can be changed in any one of three dimensions or a combination thereof; however, it is important to realize that the final mandibular position should be governed by the maxillary position to get a functional and cosmetic result.
- When deciding on mandibular position, we must be sure to have the correct maxillary and mandibular diagnosis, which ultimately will guide our surgical plan and produce the best surgical result of the patient.
- Maxillofacial deformities are always determined by the physical exam, which may or may not be supported by radiographic findings.
- The following list of diagnoses includes important physical findings that exemplify the specific diagnosis:

Mandibular Hyperplasia

- Class 3 skeletal appearance

Mandibular Hypoplasia

- Class 2 skeletal appearance
- Micrognathia
- Short mandibular ramus
- Short mandibular body

Condylar Hyperplasia

- Mandibular asymmetry deviating the chin point to the contralateral side
- Posterior open bite on the ipsilateral side
- Maxillary cant on the ipsilateral side

Condylar Hypoplasia

- Mandibular asymmetry deviating the chin point to the ipsilateral side
- Posterior open bite on the contralateral side
- Maxillary cant on the contralateral side

Bilateral Sagittal Split Osteotomy (BSSO)

- The BSSO is the predominant workhorse procedure for various mandibular movements in orthognathic surgery.
- For mandibular setback, the BSSO is a good choice if the setback is less than 8 mm. While it is possible for larger setbacks, there is greater potential for bony interference and a posterior border step defect if the proximal end of the distal segment is passed beyond the posterior border of the proximal segment. Must always be cognizant of the posterior airway space during planned setbacks.
- BSSO can also be used for mandibular advancements. Advancements of 12 mm or more are unstable/more prone to relapse. Regardless of the vector of movement, the basic operation is the same with minor variations.
- Hunsuck modification – the medial osteotomy does not extend to the posterior ramus as opposed to the original Obwegeser medial cut. This modification allowed for a shorter split, less soft tissue stripping, and improved mandibular contour.
- Dal Pont modification – advanced the vertical osteotomy on the buccal cortex between the first and second molars. This allowed for greater advancement by allowing more bony contact surface area.
- Epker-Schendel modification – reduced stripping of the masseter and soft tissue of the medial ramus. Cut at inferior border to extend to lingual side, including entire inferior border in the proximal segment. This led to decreased postoperative swelling, hemorrhage, and reduced manipulation of the neurovascular

bundle. This also allows for easier repositioning of TMJ, reduction of relapse, and more blood flow to the proximal segment.

BSSO Surgical Technique

- Incision over the anterior border of the ramus into the mandibular vestibule to the second molar region, leave 5 mm of a non-keratinized tissue cuff to aid in closure.
- Dissection begins laterally with a full thickness mucoperiosteal flap over the body of the mandible proceeding toward the inferior border. Avoid aggressive stripping of the pterygomasseteric sling.
- The dissection proceeds up the anterior ramus to the coronoid process, and the fibers of the temporalis muscle are prudently freed.
- Medial dissection is completed subperiosteally above the lingula and the mandibular foramen to identify the entrance of the nerve. Dissection should be limited to prevent overstripping of the attached muscles, reducing blood supply to the mandibular segments. If difficulty identifying the lingula or nerve, then osteotomy should be done above the level of the mandibular occlusal plane (remember that the lingula usually is at the level of the occlusal plane).
- Make the medial corticotomy just above the lingula.
- Extend the osteotomy anteriorly through the ramus paralleling the buccal plate to the medial aspect of the second molar region.
- Drop a vertical corticotomy in the second molar region to the inferior border.
- Chisels are carefully used to slowly expand the corticotomies to split the mandible. Make sure the inferior alveolar nerve is in the distal segment.
- Medial pterygoid attachment must be released on the distal segment for advancement – best accomplished with a J stripper. In setbacks, the medial pterygoid must be dissected from the medial aspect of the proximal segment creating a pocket for distal segment positioning.
- Interim/final splint is placed and the mandible is moved to the new position.
- May use pickle fork or condylar seating instrument to push proximal segment posterior and superior. Also may evaluate alignment of inferior borders.
- Place fixation with plates or screws. L configuration for screws is more stable than a straight line. Plates allow for less nerve compression, less torque on condyle, and can be used to aid positioning of condyle.

Complications

- *Nerve Transection* – epineural repair with a 7-0 non-resorbable suture.
- *Bad Split (Buccal/Lingual Plate Fracture)* – complete osteotomies and set to planned occlusion. Fixate fractures with plates and screws as you would a traumatic fracture (single bicortical positional screw for a lingual plate fracture). Stabilize as planned to new position. If segment is small and attached to the periosteum, consider leaving it.
- *Subcondylar Fracture* – complete osteotomies. Set to planned occlusion. Fixation with plates and screws or consider IMF.
- *Infection* – imaging to review if hardware/screw loosening. Antibiotics, incision and drainage, debride, or hardware removal if appropriate.
- *Bleeding* – most likely due to damage of the inferior alveolar artery. Attempt packing as normally this will spontaneously correct. Important to stay in periosteal pocket to prevent retromandibular vein or facial artery damage.
- *Bite Discrepancy/Malocclusion* – remove fixation. Ensure that the condyles are seated in the fossae and replace fixation.
- *Condylar Sag* – manifests as unilateral malocclusion after removing IMF. Remove fixation, reposition condyle in the fossa, and reapply fixation (3).
- *Condylar Resorption* – associated with skeletal class 2 deformities with high mandibular planes (higher incidence in female patients)

that require large advancements. Treatment involves bite splint therapy and anti-inflammatory medications. More severe cases may warrant synovectomy, costochondral grafting, or TMJ replacement.
- *Non-union* – reoperation of the sites. Freshen bony margins and remove fibrous tissue. Apply more rigid fixation and consider bone grafting the sites. Consider period of IMF.

Bilateral Intraoral Vertical Ramus Osteotomy (BIVRO)

- When mandibular set back is considered, in addition to BSSO, the surgeon and patient also have the option of BIVRO.
- There are nuances of the BIVRO that need to be taken into account.
  - Best operation for V-shaped mandible (divergent ramus pattern).
  - Incidence of both short- and long-term paresthesia is less with BIVRO based on osteotomy location and design.
  - Also, when evaluating the anatomy of the mandible, a very thin mandibular ramus with little marrow space may be more suited for BIVRO over BSSO, given the increased risk of unfavorable split with the latter osteotomy in this circumstance.
  - This operation should also be considered with large mandibular asymmetrical prognathism. As the mandible is rotated, a vertical ramus osteotomy may reduce the incidence of segmental interference on the setback side.
  - Lastly, in patients who have symptomatic TMD preoperatively that have not been addressed either non-surgically or with TMJ surgery, an IVRO may be of benefit, given less potential pressure on the intracapsular tissues.
  - Some potential downsides to BIVRO are the need for a period of IMF.
  - If there is a large counterclockwise movement planned, the proximal end of the distal segment will rotate inferiorly lengthening the pterygomandibular sling and potentially pulling on the proximal segment. Accommodations are necessary if this is the case including possibly wiring the segments together to counteract this force.
  - Can create splaying of the proximal bony segment creating fullness in the region of the mandibular angle, more prominent with larger setbacks.

IVRO Technique

- Incision is made over anterior border of the ramus into the mandibular vestibule.
- Full-thickness mucoperiosteal flap is developed exposing the lateral ramus from the inferior border up to the sigmoid notch.
- A J stripper is used to release attachments of the inferior border.
- Bauer retractors are then inserted into the sigmoid notch and along the inferior border to provide retraction. Some surgeons use the Merrill-Levasseur retractor along the posterior border.
- Identify the antilingula as this marks the anterior limit of the osteotomy.
- Make vertical cut utilizing an oscillating saw blade beginning in the midramus region posterior to the antilingula to the inferior border. (If you cannot identify the antilingula, a cut 7–10 mm anterior to the posterior border provides safety.)
- The superior osteotomy is completed last as there is a risk for insult to the masseteric artery. This will provide quicker access upon completion of the osteotomy to manage the bleeding.
- On the medial aspect of the mandible, judiciously dissect a subperiosteal pocket to accept the overlapping segment.
- Manipulate the proximal segment laterally.
- Trim excess inferior portion of the bony proximal segment.
- Establish occlusion with MMF (6 weeks of MMF, then training elastics).
- If segments are passively positioned and in approximation, rigid fixation with two or three screws can be done easily through a transfacial trocar.

Complications

- *Infection* – antibiotics, incision and drainage, debridement as needed.
- *Bleeding* – injury to internal maxillary artery branches (most commonly the masseteric branch) at sigmoid notch. Direct pressure with gauze. Consider application of hemostatic agents. If can identify bleeding vessels, consider hemoclips. If uncontrolled, consider embolization. The masseteric artery on average is 8 mm above the sigmoid notch and 25 mm from the anterior border of ramus.
- *Displaced Proximal Segment* – distract mandible anteriorly and reposition. Evaluate for medial bony interferences and reduce as necessary.
- *Distraction of Condylar Segment* – may occur early in treatment or weeks after surgery. Aggressive elastic traction treatment should be attempted. May require revision and placement of fixation/wire placement.
- *Inadvertent Subcondylar Osteotomy* – place patient in 6-week of IMF and complete surgery after establishment of bony union.

Genioplasty

- Genioplasty is occasionally necessary to help balance the patient cosmetically.
- When the genial tubercles are included in the osteotomy, anteriorly repositioning the bone can help in opening up the lower airway in sleep apnea patients. This is usually referred to as anterior mandibular horizontal osteotomy with genioglossus advancement.
- Careful examination of each of the facial units is critical to obtain optimal outcomes both functionally and aesthetically.

Genioplasty Surgical Technique

- The incision should not be done in the depth of the vestibule but rather half of the distance between the vestibule and the wet line of the lower lip. Incision from canine to canine through the mucosa and submucosa.
- Incision is carried through the mentalis muscle down to the bony mandible.
- A subperiosteal dissection proceeds to the most inferior portion of the bony chin and laterally identifying the mental nerves and foramina bilaterally.
- Mark the midline of the chin with a hand-piece (other measured markings are occasionally used). A prefabricated cutting guide created with virtual surgical planning (VSP) can increase accuracy of the chin repositioning.
- Using a reciprocating saw to make a cut beneath the mental foramen (5 mm below the foramina and 5 mm below the apices of the teeth) at the inferior border of the mandible to a point at least 10 mm above the inferior border at the midline; this is done bilaterally. (Bone wedges or an osteoplasty can be performed for asymmetric movements.)
- Bony chin is mobilized and separated from the mandible and repositioned using a measured bone plate or fixation screws (a surgical guide can be used to position the bony chin if necessary).
- Closure should be accomplished in two layers. It is important to reapproximate the mentalis muscle to prevent ptosis of the chin. The mucosa is then closed with resorbable sutures.

Complications

- *Ptosis* – avoided by aggressive soft tissue dissection and ensure reapproximating the mentalis muscle. Reopen wound and reapproximate mentalis muscle. Placement of pressure dressing.
- *Malposition of Chin* – remove plate and realign.
- *Injured Root Apices* – observe or possible root canal in the future.
- *Nerve Injury* – ensure during dissection that osteotomies are 5–6 mm away from mental foramina. Epineural repair with 7-0 suture for observed transection.

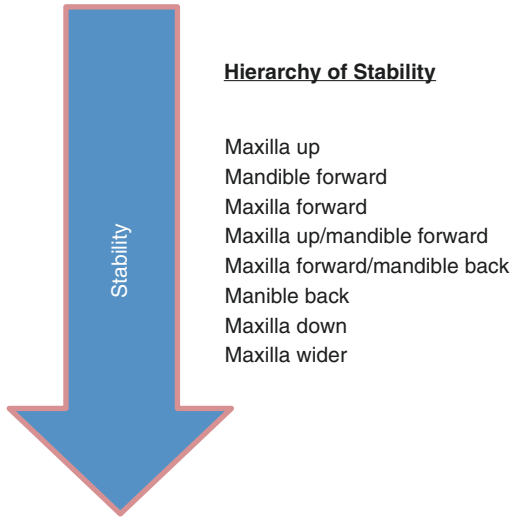

Fig. 5.8 Stability of orthognathic movements. It is important to note that this hierarchy deals primarily with changes and stability of the occlusion rather than close evaluation of skeletal changes. (Modified from Proffit et al. [2])

- *Malunion* – debride interposing fibrous tissue and reposition with new hardware. Consider adjunctive bone grafting.
- *Infection* – incision and drainage, antibiotics, debridement, or remove hardware.
- *Hardware Failure* – remove hardware and replace if no evidence of union.

Hierarchy of Stability

There is a hierarchy of stability as it relates to movements accomplished with orthognathic surgery. In 1996, Turvey, Profitt, and Phillips conducted a study that has become an established paradigm for the hierarchy of stability (Fig. 5.8). In 2007, the aforementioned authors wrote a paper that updated this hierarchy to include procedures where rigid fixation is used (2).

Orthognathic Surgery Considerations in Cleft Lip and Palate Patients (CLP)

Management of patients with orofacial clefts requires a multidisciplinary approach in order to provide optimal care. Listed below are members of the CLP team that are part and parcel to successful management of these patients.

- Patient care coordinator
- Pediatrics/primary care/geneticist
- Surgeon (oral and maxillofacial surgery, plastic surgery, or otolaryngology)
- Pediatric dentistry/general dentistry
- Orthodontist
- Speech pathology
- Audiology
- Psychology
- Social work

Orthognathic surgery is performed when growth is complete prior to secondary nasal revision. Contemporary orthognathic treatment of cleft patients is aimed at correcting the hypoplastic abnormality. A mandibular setback procedure should be avoided if the maxilla is hypoplastic. Orofacial cleft patients oftentimes can present with large anterior-posterior discrepancies. A decision must be made if the patient is a candidate for a traditional orthognathic procedure or if they require distraction osteogenesis. After careful evaluation of the physical and radiographic findings, an appropriate treatment plan can be formulated and surgery undertaken.

As it is not the topic of this section to review orthognathic surgery, only the important aspects involved in treating orofacial cleft patients will be reviewed. Specific areas to consider include the following:

- Intubation
- Incision design in the maxilla and vascularity
- Osteotomy and down fracture
- Management of residual oronasal fistulas and altered nasal anatomy
- Rigid fixation and bone grafting

Intubation

Oftentimes orofacial cleft patients may have previously undergone pharyngeal flap procedures in order to address velopharyngeal insufficiency. This must be recognized and discussed with the anesthesiologist. Different techniques can be

used to ensure atraumatic placement of the nasal endotracheal tube through a lateral port of the pharyngeal flap without trauma to the flap or the posterior pharyngeal wall.

- Red-rubber catheter placement and visualization in the posterior pharynx with which the nasal endotracheal tube is then guided through a lateral port of the flap.
- Endoscopic or fiberoptic guidance.
- Nasopharyngeal airways can be used to guide a bougie into the appropriate position, which the endotracheal tube is then passed over.

Incision Design in the Maxilla and Vascularity

The vascular supply to the maxilla and premaxilla is critical. Due to previous surgeries and scarring, it can be more fragile than in a non-cleft patient. Most of the blood supply to the mobilized maxilla is derived from the palatal tissues.

Alterations in incision design that can be considered include the following:

- Shortened circumvestibular incision leaving a large buccal soft tissue pedicle.
- An anterior midline pedicle can be left with a vertical incision at the midline and two lateral vestibular incisions.

It is ideal to attempt to preserve the descending palatine vessels if possible and care should be taken during separation of the lateral nasal walls and down fracture to avoid unnecessary trauma. Maxillary segmentation should be approached with caution. A compromise in the posterior occlusion and finishing with a slight posterior crossbite or edge-to-edge occlusion may be more desirable than the risk of avascular necrosis of a segment. If segmentation is planned to address a severe transverse discrepancy, the best location is the cleft site.

Remember, the cleft patient has no bone in the midline. The only transverse stability is from a well-healed alveolar cleft bone graft. Once that needs to be cut to achieve better arch form, a transpalatal device is needed (splint, Hyrax, TPA) to allow for the alveolus to heal again.

Osteotomy and Down Fracture

- The greatest areas of buttressing in the maxilla are the pyriform and pterygomaxillary buttresses. Care must be taken when completing the osteotomy to ensure careful separation in these areas.
- Failure to do so can lead to unfavorable fractures into the skull base or superiorly into the orbit. In addition, leaving an anterior pedicle in the incision design can make down fracture more difficult, making it even more crucial to ensure that the osteotomy is completed and buttresses weakened sufficiently.
- Too much pressure during down fracture can lead to fracture at a thin alveolar graft site and lead to transverse instability.

Management of Residual Oronasal Fistulas and Altered Nasal Anatomy

- Once down fracture is achieved, the nasal floor and nasal cavity must be examined for the following:
  - Residual oronasal fistulas
  - Septal deviation
  - Enlarged inferior turbinates
  - Alar support
- Closure of any residual fistulas should take place as well as any needed additional bone grafting.
- If significant septal deviation is noted, a septoplasty may be indicated.
- Inferior turbinectomy can be considered at this juncture as well if they are large or may impinge on the nasal floor.
- Time should be spent stretching the soft tissues to allow for planned vertical and anterior-posterior movements passively.

Rigid Fixation and Bone Grafting

- Soft tissues must be stretched to allow for planned vertical and anterior-posterior movements without tension.

- Bone contact is paramount to achieve union in this patient population. Bone grafting may be considered at buttress regions.
- This can be autogenous for large gaps or allogeneic for smaller gaps.
- Fixation should be achieved with the largest or strongest possible rigid fixation system to reduce relapse.

Final Considerations

With a small alveolar cleft graft, the area of the graft may be weak and prone to fracture during mobilization and down fracture of the segment. Consider a palatal splint preoperatively or plan for a final splint with holes to allow it to be wired into place to stabilize the mobile segments. If an alveolar cleft graft was not undertaken, then a palatal splint and/or occlusal splint will be necessary. In addition, the splint may assist in repositioning of the lesser segment to minimize the size of the cleft for bone grafting.

Cleft Distraction Osteogenesis

- Distraction osteogenesis is considered in patients with large anterior-posterior discrepancies that would not be possible to correct in a single orthognathic procedure or which would require unnecessary mandibular setback procedures.
- There are two commonly employed methods of distraction osteogenesis at the LeFort I level:
  - Rigid external maxillary distraction
  - Internal maxillary distraction

Rigid External Maxillary Distraction

- The orthodontist will start by fabricating an intra-oral splint that will attach to the orthodontic appliances with extra-oral extensions. The extension sits in the paranasal regions. These are used to deliver the distraction forces.
- The LeFort I osteotomy is completed in the same manner and consideration as described above.
- Adequate mobilization is critical.
- A cranial halo is placed with an external adjustable distraction screw system. A rigid down-rod is attached to the halo, which is used to attach wires to the extra-oral component of the orthodontic splint.
- Using the principles of distraction osteogenesis including a latency period of about 5–7 days, activation phase, and consolidation phase, advancement of the maxilla is undertaken.

Advantages:

- Adjustable vector of distraction throughout the activation phase.
- Does not require secondary surgery for removal; removal is complete in the office.

Disadvantages:

- Psychosocial aspects of wearing a large extra-oral appliance.
- Does not offer retention and requires the use of reverse pull headgear after removal.

Internal Maxillary Distraction

- Typically, a stereolithographic model is obtained preoperatively and the planned Lefort I osteotomy is marked on the model.
- The intra-oral appliances are then pre-bent and modified preoperatively to achieve the most appropriate distraction vector.
- The devices are sterilized and again the LeFort I osteotomy is completed as previously described.
- The intra-oral device is anchored superiorly in the region of the zygomatic buttress and inferiorly to the osteotomized segment via circumdental wires. The same principles of distraction are employed.

Advantages:

- Lack of a large extra-oral halo device.

- Reverse pull headgear is not necessary as the devices can be left in place after consolidation with removal of the activation arm.

Disadvantages:

- Unidirectional vector that cannot be altered after placement.
- A second surgery is required for removal of the device; this may provide an opportunity for placement of rigid internal fixation plates if desired.

Orthognathic Case

The patient is a 22-year-old male patient with no past medical history. He denies any medication use and has no allergies. The patient's chief complaint is, "It is hard for me to bite my food because of my underbite."

Describe your clinical workup for this patient.

Patient will need photos, dental models with CR records, and clinical measurements.

*Describe what you see in the photos below (*Fig. 5.9*).*

- In the frontal repose image, you can appreciate that the overall facial profile is dolichocephalic. The facial thirds appear congruent. The maxillary dental midline is coincident with facial midline. The mandibular dental midline is deviated to the left. There is an appropriate amount of incisor show at rest and the interlabial gap is within normal limits. There is increased scleral show and paranasal flatness. There is no appreciable asymmetry of the eyes or ears. The bigonial width appears to be less than the bizygomatic width.
- On the profile view, the patient appears to be prognathic. There is volume deficiency of the midface with a negative vector of the orbit. There is a break in the cheek bone-nasal base-lip curve contour. The nasolabial angle appears within normal limits.
- In the animation image, there is an appropriate amount of incisor show. The nasolabial folds deepen during animation, which suggests midface deficiency. There is no appreciable occlusal cant and the mandibular dental midline appears coincident with the mandibular skeletal midline.

Fig. 5.9 Facial and intraoral photos of orthognathic case patient. (Courtesy of Dr. Gregg Jacobs)

- Intraorally, there is a class I cuspid and molar occlusion on the right and a class III on the left with a midline discrepancy. There appears to be a biplanar maxillary occlusal plane. There is a crossbite relationship (transverse discrepancy) on the left side. There appears to be excessive interdental spacing in the mandibular canine-premolar-canine region. There is appreciable apertognathia with mamelons present on the anterior teeth. The periodontium appears healthy and oral hygiene appears appropriate.

How would you like to proceed next?

- At this stage, you may request to see radiographs (orthopantogram, lateral cephalogram, and possibly a PA cephalogram if necessary).

Here you are provided with the orthopantogram and lateral and PA cephalogram. Describe what you see (refer to Figs. 5.10, 5.11, and 5.12 *below).*

- In the orthopantogram, you can appreciate a dental midline discrepancy. The condyles are seated within the fossae; however, the left condyle is seated slightly forward on the eminence indicating that in the image the patient is in centric occlusion and perhaps not centric relation. There are mild degenerative changes noted in the condylar heads. The maxillary sinuses appear well pneumatized. The inferior alveolar nerves are proximal to the inferior border in the second molar region. Third molars are present and erupted. There is no overt dental pathology noted (no radiographic evidence of periodontitis or caries). There are intracoronal restorations noted.
- The lateral cephalogram demonstrates a class III facial-skeletal malocclusion with nearly edge-to-edge anterior occlusion. The inferior borders are well aligned and there is slight flaring of the maxillary and mandibular incisors.
- The PA cephalogram reveals a true mandibular skeletal asymmetry to the left (mandibular skeletal midline is rotated to the left of the facial and maxillary midline).

What is your diagnosis?

This patient's skeletal diagnosis includes AP and vertical maxillary hypoplasia, mandibular prognathism, and mandibular asymmetry with dental compensation. There is a slight microgenia. The dental diagnoses include an angle class 3 malocclusion and apertognathia.

***Author's Note:** At this stage, you should be able to establish a diagnosis list even without a cephalometric tracing.

What is the next step?

You would suggest that this patient undergo presurgical orthodontics to level, align, and coordinate his arches and place teeth over basal bone in preparation for definitive orthognathic surgery.

What is your surgical treatment plan?

Given that the skeletal diagnosis involves both arches, prior to orthodontic preparation, you may suggest that this patient requires a LeFort I osteotomy for maxillary advancement, possibly in segments should a two-plane maxillary arch still be present, and a BSSO or IVRO for asymmetric mandibular setback.

Fig. 5.10 Orthopantogram of orthognathic case patient. (Courtesy of Dr. Gregg Jacobs)

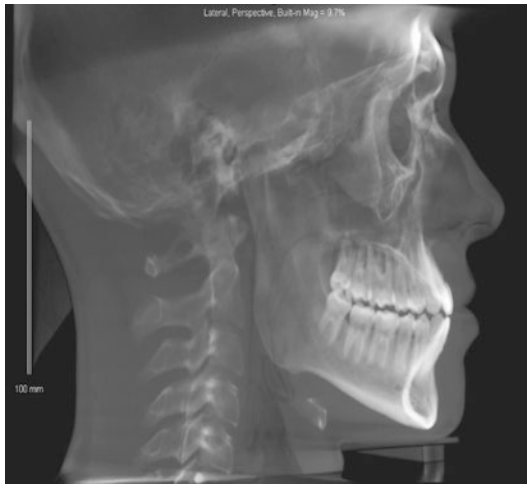

Fig. 5.11 Lateral cephalogram of orthognathic case patient. (Courtesy of Dr. Gregg Jacobs)

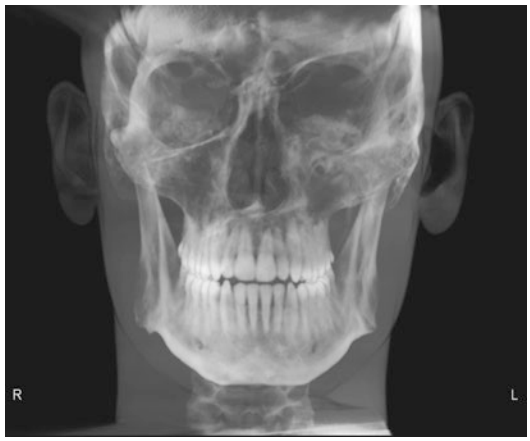

Fig. 5.12 PA cephalogram of orthognathic case patient. (Courtesy of Dr. Gregg Jacobs)

Patient has completed presurgical orthodontics and has surgical wires and hooks in place. Patient returns to your office and is now ready for surgery. Your final treatment plan is for a LeFort I osteotomy and a BSSO. Today is the day of surgery and the patient is in the preoperative holding area. What would you want to discuss with the anesthesiologist?

I would request a nasal intubation. In anticipation of blood loss, I would request a type and cross in addition to an accurate blood loss and fluid count. An arterial line would be important for accurate blood pressure intraoperatively. I will be requesting hypotensive anesthesia during down fracture of the maxilla. With a long operating time and high blood loss possibility, I would request placement of a Foley catheter. I would warn them about possible maxillomandibular fixation on waking up. Patient may require an overnight stay in the ICU or step down unit.

What is the difference between a type and screen and a type and cross?

Type and screen determines blood type, Rh factor, and antibodies in case a blood transfusion is required. A type and crossmatch tests determines the same information but matches a unit of blood to be prepared for immediate transfusion.

A patient returns to your office for a second opinion following orthognathic surgery with a posterior open bite on the right. You take a CBCT and you see this (Fig. 5.13). *What happened and how do you manage it?*

During seating of the proximal and distal segments, the mandibular condyle is torqued laterally

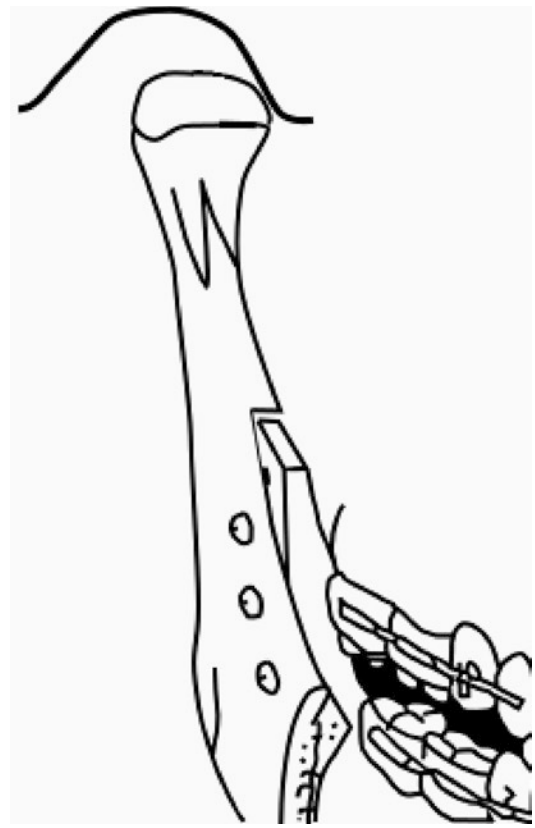

Fig. 5.13 Orthognathic complication. (Modified from Reyneke and Ferretti [3])

out of the fossa because of bony interferences along the ramus while fixation is taking place; once the IMF is released, the condyle will reseat itself into the fossa and the occlusion will deviate to that side.

This should be noticed immediately and corrected by removal of the plates and screws, reapplication of the IMF into the splint, and re-fixation with the condyle (proximal segment) seated appropriately within the fossa. The surgeon can avoid this issue by ensuring there are no bony interferences as the condyle is seated and the proximal segment is laid flush with the distal segment prior to plating. Very little pressure should be necessary to achieve flush seating. If this is not recognized and a maxillary osteotomy is performed after the mandible, the final occlusion may fit well into the splints but will be off from a facial perspective with the midline deviating toward the side of the condylar dislocation. This may, in severe cases, necessitate revision of both osteotomies. It is best to look for this at the time the IMF is released and addressed immediately. If a single jaw surgery is being performed and the deviation is small, then this may be able to be compensated for with postsurgical orthodontics.

Obstructive Sleep Apnea (OSA)

The surgeon needs to be familiar with the diagnosis, key points of the physical examination, questionnaires, analysis of diagnostic imaging, and the use of polysomnography. Treatment is multidisciplinary and consists of both nonsurgical and surgical modalities that should be familiar to the oral and maxillofacial surgeon.

Definitions of Basic Terms

- Obstructive Sleep Apnea – a sleep disorder characterized by obstructive apneas and hypopneas caused by collapse of the upper airway during sleep.
- Central Sleep Apnea – the absence of respiration associated with an absence of respiratory effort.
- Polysomnography (PSG) - a diagnostic test used for the evaluation of sleep disorders. Components include EEG, EOG, EMG, ECG, and pulse oximetry with or without a video recording of the subject. It measures several variables indicative of sleep apnea. The PSG is considered the gold standard in the diagnosis of sleep apnea.
- Apnea – a cessation of airflow at the nostrils and mouth for at least 10 seconds while sleeping.
- Hypopnea – a reduction of airflow resulting in a drop-in oxygen saturation followed by an arousal.
  - 50% reduction in airflow for 10 seconds with a 3% drop in oxygen saturation or
  - 30% reduction of airflow for 10 seconds with a 4% drop in saturation.
- Apnea Index – the apnea index is the average number of apneic events per hour.
- Hypopnea Index – the average number of hypopnea events per hour.
- Apnea/Hypopnea Index – the average number of apnea and hypopnea events per hour (Table 5.1).
- Respiratory Disturbance Index – the average number of apnea events, hypopnea events, and respiratory event related arousals (RERAs) per hour.
- RERA – an event that causes an arousal or a decrease in oxygen saturation, without qualifying as apnea or hypopnea.
- Cheyne Stokes Breathing – a breathing pattern marked by crescendo-decrescendo changes in airflow and respiratory effort that often ends with apnea (typical of central sleep apnea syndrome).
- Mueller's maneuver – inhalation with the nasal passages occluded and the mouth closed with an endoscope inserted through one nostril to observe the location of airway collapse.
- Fujita Classification – a classification system developed to indicate the level of obstruction identified by nasopharyngoscopy in conjunction with a Mueller's maneuver or during sleep-induced nasopharyngoscopy. It can be used as a

Table 5.1 AHI values

0–4	Normal
5–15	Mild OSA
15–30	Moderate OSA
>30	Severe OSA

guide as to what surgical interventions may be useful in alleviating the source of obstruction:
- Type I – upper pharynx to include the palate, uvula, and tonsils.
- Type II – upper and lower pharynx.
- Type III – lower pharynx to include the tongue base, lingual tonsils, and supraglottic region.

Functions of Sleep

- Sleep serves a variety of functions that are essential to human physiology. Secretion of growth hormone peaks during sleep, which is particularly important to growing children. During sleep, the body repairs damage, clears waste products, and revitalizes. It is crucial for proper brain function, as sleep promotes brain plasticity through synapse formation and maintenance.
- Conversely, those suffering from lack of sleep suffer from slow reaction time, difficulty in problem-solving, and problems with short-term memory as well as a host of systemic problems outlined below.
- There are two cycles of sleep (non-REM and REM sleep).
- The first cycle of sleep starts with wake, transitioning to N1, then to N2, then to N3, and finally to REM. As the cycles progress throughout the night, the percentage of REM sleep in each cycle gradually increases. Conversely, the percentage of stage N3 tends to decrease over the course of the night, with the largest amount of N3 in the first half of the night.
- It appears that REM sleep appears to be the most important in maintaining vitality, as interruption of REM sleep appears to have the greatest impact on health.

Stages of Normal Sleep

Non-rapid Eye Movement Sleep

- *N1* – (5–10% of sleep time) the lightest stage of sleep. Characterized by slow rolling eye movements and low–amplitude, mixed EEG frequencies.
- *N2* – (45–50% of sleep time) marks the first appearance of sleep spindles and K-complexes.
- *N3* – (10–20% of sleep time) deep sleep characterized by low-frequency, high-amplitude EEG waves. Tends to occur more in the beginning of the night and sleepers are difficult to arouse.

Rapid Eye Movement (REM) Sleep

- (18–20% of sleep time) Characterized by a low-voltage, mixed EEG pattern (saw-toothed waves), rapid eye movements, and muscle atonia.
- Consists of two phases:
  - *Phasic* – bursts of rapid eye movements, respiratory variability, and brief EMG activity.
  - *Tonic* – limited motor activity with few eye movements.
- REM sleep may be delayed or suppressed by alcohol, sedative-hypnotic drugs, barbiturates and other antiepileptic drugs, beta antagonists, monoamine oxidase inhibitors, selective serotonin reuptake inhibitors, and stimulants.

Pathophysiology of OSA

- OSA causes the patient to have an increased sympathetic tone, which leads to autonomic arousals.
- The hypoxia associated with OSA leads to sleep fragmentation and restriction.
- Hypoxia followed by oxygenation can also lead to production of free radicals and endothelial damage via hypoxia-reperfusion injury. There is also activation of PMNs and the release of inflammatory mediators that cause further damage.
- Over time, this leads to a chronic inflammatory state.
- OSA is much more common in males aged 18–60 years old.

Medical Conditions Associated with OSA (Table 5.2)

Table 5.2 Medical conditions associated with OSA

Cardiovascular	*Hypertension* *Arrhythmias* (sinus bradycardia most common, also PVCs and other more serious in advanced disease) *Congestive heart failure (right sided heart failure)* *Myocardial ischemia/infarction* (probably due to endothelial damage)
Neurological	*Stroke* (strong statistical correlation) *Parkinson's disease* (some PD patients show obstructive breathing patterns) *Seizure disorders*
Endocrine	*Diabetes and insulin resistance*
Psychiatric	*Cognitive function* (decreased reaction time, concentration, memory) *Depression* (strong evidence of overlap)
Pulmonary	*Pulmonary hypertension* (strong correlation)
Digestive	*Acid reflux*
Other	*Decreased wound healing* *Morning headaches* *Immune system impairment* *Secondary polycythemia* *Erectile dysfunction and impotence*

Diagnosis and Workup for Sleep Apnea

Health History

In patients with known OSA, the health history should focus on those medical comorbidities strongly associated with OSA. Many symptoms can be elicited from the STOP BANG (4) or Epworth Sleepiness (5) questionnaires and, therefore, they are useful screening tools.

STOP-BANG Questionnaire (Score out of 8)

STOP

Do you **S**NORE loudly (louder than talking or loud enough to be heard through closed doors)?

Do you often feel **T**IRED, fatigued, or sleepy during the daytime?

Has anyone **O**BSERVED you stop breathing during your sleep?

Do you have or are you being treated for high blood **P**RESSURE?

BANG

BMI more than 35 kg/m^2?

AGE over 50?

NECK circumference >16 inches (40 cm)?

GENDER: Male?

Interpretation

High risk of OSA: Yes 5–8.

Intermediate risk of OSA: Yes 3–4.

Low risk of OSA: Yes 0–2.

Epworth Sleepiness Scale

Age (Yrs.): _____.

Sex (Male = M, Female = F): _____.

Use the following scale to choose the **most appropriate number** for each situation:

0 = would **never** doze

1 = **slight chance** of dozing

2 = moderate chance of dozing

3 = high chance of dozing

It is important that you answer each question as best you can.

Chance of Dozing (0–3)

Sitting and reading - _____

Watching TV - _____

Sitting, inactive in a public place - _____

As a passenger in a car for an hour without a break - _____

Lying down to rest in the afternoon when circumstances permit - _____

Sitting and talking to someone - _____

Sitting quietly after a lunch without alcohol - _____

In a car, while stopped for a few minutes in the traffic - _____

Interpretation

0–5 Lower Normal Daytime Sleepiness

6–10 Higher Normal Daytime Sleepiness

11–24 Excessive Daytime Sleepiness

Pertinent Physical Exam Findings

Body Habitus

- Obesity (BMI >30 kg/m^2) has a strong causative correlation with OSA. Many obese patients have OSA, and weight loss can result in alleviation or resolution of symptoms. Neck and waist circumferences are more relevant than BMI alone.
- Obesity results in fat deposition in the uvula, tonsils, tongue, aryepiglottic folds, lateral pharyngeal wall, and between the medial and lateral pterygoids. The most frequent site of

collapse, as well as the area of greatest fat deposits, is the lateral pharyngeal wall.
- There is a strong correlation between OSA and neck greater than 16 inches in females and 17 inches in males.
- Lung volumes are reduced due to fat deposition and decreased compliance. There is decreased FRC and expiratory reserve volume due to displacement of the diaphragm into the chest by visceral fat. Ventilation is shifted to the upper portions of the lungs resulting in a worse V:Q mismatch and lower PaO_2.

Airway Examination

- Examination of the occlusion via clinical exam and lateral cephalogram is essential.
- A class II dentoskeletal malocclusion resulting from retrognathia can be associated with a narrow posterior airway space and OSA.
- Micrognathia can also be a source of obstruction in the OSA patient. Macroglossia can be caused by obesity as well as some genetic abnormalities (i.e., Down's syndrome) and can be a source of obstruction.
- Other sites of obstruction may be due to an elongated uvula/soft palate nasal septal deformities, enlarged turbinates, and tonsillar/adenoid hypertrophy.
- Evaluation should include Mallampati score (Table 5.3). For each increase in class, the odds ratio of having OSA increase by 2.5 (6).

Diagnostic Aids

Nasopharyngoscopy

- Nasopharyngoscopy is the use of a flexible fiberoptic laryngoscope to examine the lumen of the nasal passages, oropharynx, and vocal cords.

Table 5.3 Mallampati classification

Class I	Complete visualization of the soft palate, uvula, and fauces
Class II	Complete visualization of the uvula and soft palate
Class III	Only base of uvula visible
Class IV	Soft palate not visible

- When used in conjunction with a Mueller's maneuver, it can identify potential sites of obstruction and can be performed both in the supine and in the sitting positions.
- In experienced hands, it can easily be performed in an office setting with only topical or aerosolized local anesthetic.

Drug-Induced Sleep Endoscopy (DISE)

- DISE is nasopharyngoscopy performed on a patient that is undergoing sedative-induced sleep.
- Anesthetic agents blunt the negative pressure reflex, thus mimicking the conditions of REM sleep.
- It is usually performed in the operating room in a controlled environment where airway intervention can be safely performed if necessary.
- This technique can identify the areas of collapse in the pharynx and direct site-specific surgical intervention.

Polysomnography

- Full night, in-laboratory, attended polysomnography (PSG) is considered the gold standard for diagnosis of obstructive sleep apnea.
- Those patients who are diagnosed with OSA and elect CPAP therapy are brought back for another night of PSG during which their device is titrated.
- Split night PSG is similar except that PSG is performed during the first half of the night, and as OSA is diagnosed, a CPAP is titrated during the second part of the night.
- Despite the fact that it is considered the gold standard of OSA diagnosis, a negative result should be viewed with skepticism in patients that have a high suspicion of OSA.

Home Sleep Apnea Testing (HST)

- An alternative to in-laboratory PSG is home sleep apnea testing (HST). This has been tested and validated against standard PSG and has been shown to have high sensitivity and specificity in appropriate patients.

- It is useful in patients who have a high probability of having moderate to severe sleep apnea, patients who do not have associated medical comorbidities, or patients that are suspected of having components of central sleep apnea.
- It is limited in that it can only detect breathing-related sleep disorders and it often underestimates AHI.

Imaging

Cephalometric Analysis

- The lateral cephalogram is a valuable tool in assessing various aspects of the maxillofacial skeleton that are positively correlated with obstructive sleep apnea.
- Its advantages are that it is relatively inexpensive, easily obtained, and widely available.
- It is important to recognize that cephalograms are useful in identifying potential sources of obstruction but are not useful in predicting surgical success.

Concerning Cephalogram Signs (Fig. 5.14):

- Retrognathia – a posteriorly positioned mandible can be indicative of a narrow posterior airway space making the patient susceptible to airway collapse.
- Posterior Airway Space (PAS) – a measurement of the airway along a line that bisects B point and gonion through the posterior airway space. A PAS of less than 11 may indicate a base of tongue obstruction, making the candidate a poor candidate for UPPP.
- Increased dimension of the soft palate (P to PNS) – the length of the soft palate as measured from the posterior nasal spine to the tip of the soft palate. Normal measurement is 37 ± 3. Increased length is associated with OSA.
  - Position of the hyoid (H to MP) – the distance of the hyoid bone to the inferior border of the mandible along a line perpendicular to the mandibular plane angle. An inferiorly positioned hyoid (greater than 15 mm) is indicative of a longer airway and is correlated with UPPP failure.

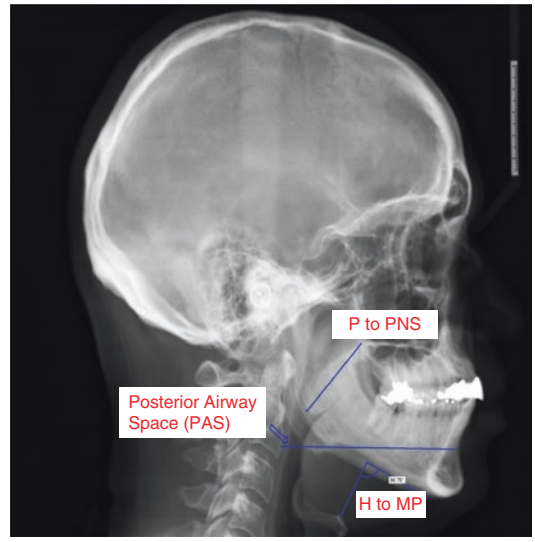

Fig. 5.14 Illustration of PAS, P to PNS, H to MP on lateral cephalogram. (Courtesy of Dr. Joseph Ivory)

Cone Beam Computed Tomography (Fig. 5.15)

- CBCT can be performed on OSA patients to identify the examination of the airway in sagittal, axial, and coronal planes.
- Certain programs allow volumetric, three-dimensional reconstruction of the airway.
- Most programs allow reconstruction of a panoramic radiograph, lateral cephalogram and PA cephalogram as well, making it useful for examination and planning of surgery.
- In addition, postoperative CBCT can be performed to examine the effects of global airway procedures if desired.

Magnetic Resonance Imaging

- Like DISE, MRI can be done under sedation to detect site of obstruction and plan surgery.
- It gives excellent anatomic detail of the soft tissues surrounding the airway and can detect fatty deposits around the pharynx.
- It can be useful in patients with obesity, craniofacial syndromes, and neuromuscular disorders.

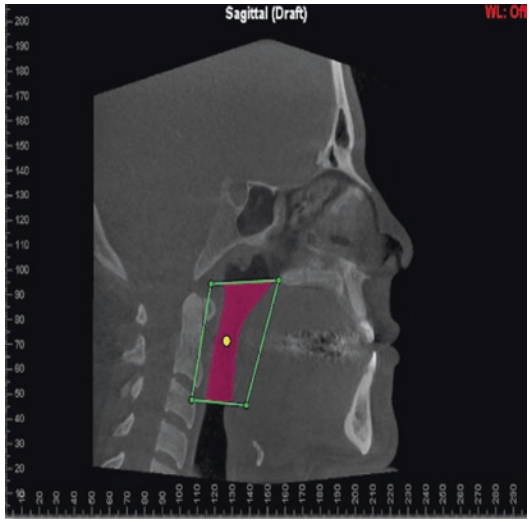

Fig. 5.15 Volumetric analysis of CBCT. (Courtesy of Dr. Joseph Ivory)

Nonsurgical Therapies

- Weight Reduction – can result in reduction in the severity of OSA, lower pressure requirements for CPAP, and in some cases offer resolution.
- Oral appliances can be used as a first-line therapy for patients who snore and have mild to moderate OSA. They can be used as second-line therapy for patients who have severe OSA after initiation of CPAP. Adverse effects of oral appliances can include backward movement of the maxillary anterior teeth and forward movement of the mandibular anterior teeth. Other adverse effects include bruxism, dry mouth, dental discomfort, excessive salivation (at the initiation of therapy), TMJ disease, and gingival irritation. All patients fitted for oral appliances need to be followed up both by their dentist and by a sleep physician. Dental follow-up should be every six months for the first year and afterward should be annual. The dentist needs to monitor for comfort, occlusal changes, adherence, and device deterioration and should question the patient about symptoms of OSA.

Surgical Therapies

- The Stanford Protocol was created as an attempt to standardize the surgical approach to OSA among surgeons and prevent excessive operations. While it is important to be familiar with the Stanford Protocol for historical purposes, it should not be followed as a rigid algorithm for all patients. The author of the protocol, Nelson B. Powell, was very clear about this fact. Powell himself recognized that there is no "cookbook" approach to the surgical treatment of OSA (7).
- Surgery should be addressed to the site of obstruction, which is why diagnosis and treatment planning are critical in identifying the site(s) of obstruction to prevent unnecessary surgery.
- The Stanford Protocol is divided into two phases. The first phase consists of soft and hard tissue procedures that address specific sites of obstruction. Those who fail Phase I treatments are either referred for CPAP or are offered MMA as a global airway surgery. The original protocol did not include nasal procedures, which are a more recent addition.
- Phase I (directed to site of obstruction) – 61% success
  - Nasal Obstruction – Septoplasty, turbinectomy, alar collapse, valve deformities, etc.
  - Retropalatal Obstruction – UPPP with tonsillectomy if present
  - Retrolingual Obstruction – Genioglossus advancement
- Phase II
  - Maxillomandibular advancement
  - Tracheostomy

Many patients presenting to the oral and maxillofacial surgeon for MMA have been previously treated according to the Stanford Protocol, and thus will have undergone significant soft tissue procedures that can affect MMA. It is important to at least be familiar with these procedures, though it is doubtful that the candidate will be required to give an in-depth discussion. They are listed and briefly explained below for familiarization.

Uvulopharyngopalatoplasty (UPPP)

- This surgery involves the reduction, tightening, and/or repositioning of the soft palate and related oropharyngeal structures as well as removal, reduction, or reconfiguration of the uvula.
- It is usually done in conjunction with a palatine tonsillectomy if present.
- Adenoidectomy in conjunction with a UPPP should be done with caution because it can lead to circumferential velopharyngeal scarring.
- Laser-assisted UPPP (LAUPPP), while once popular, has fallen out of favor because it can lead to abnormal palatal scarring leading to nasopharyngeal stenosis.
- The procedure has approximately a 50% success rate for OSA overall.
- Complications can include significant pain, postoperative bleeding up to 2 weeks out from surgery, symptomatic dysphagia, nasal regurgitation, velopharyngeal incompetence (VPI), and subjective globus sensation.
- Of particular interest to the oral and maxillofacial surgeon is that the scarring caused by UPPP and tonsillectomy can have a significant effect on the ability to move the maxilla forward during MMA. Additionally, these patients are at risk for postoperative VPI after MMA.

Tonsillectomy

- This can be done in patients with tonsillar hypertrophy as an isolated procedure or in conjunction with UPPP.
- An extra capsular tonsillectomy involves the removal of the entire palatine tonsils along with the surrounding fascia.
- An intracapsular tonsillectomy involves the removal of the bulk of the palatine tonsils. While an intracapsular tonsillectomy reduces the risk of postoperative bleeding and allows for a more rapid recovery, it does allow for tonsillar regrowth in 0.5–16.6% of patients.
- When done in isolation, it is frequently done in conjunction with adenoidectomy.

Hyoid Suspension

- In patients with a low-lying hyoid bone, a hyoid suspension may be performed in isolation or in conjunction with other procedures (such as UPPP).
- The procedure involves the advancement and stabilization of the hyoid bone to the thyroid cartilage or the inferior border of the mandible. This advances the hyoglossus muscle and increases the posterior airway space.
- The procedure can have the effect of stabilization of the base of the tongue and other pharyngeal musculature.
- Adverse effects include dysphagia, infection, rupture of the hyoid suspension sutures with relapse and voice changes.

Tongue Reduction

- Patients with retrolingual obstruction stemming from macroglossia may benefit from reduction in tongue volume. Reduction in tongue volume can open the posterior airway space and the scar formation can have the added benefit of stiffening the base of the tongue to prevent collapse.
- There are a variety of techniques available with multiple modalities including electrocautery, irrigating/suctioning bipolar instruments, and radiofrequency ablation.
- It may also be done in conjunction with lingual tonsillectomy.
- Adverse effects include hemorrhage, infection, airway compromise, dysphagia, neurosensory changes, and paresis. Radiofrequency techniques have fewer complications but are less effective.

Genioglossus Advancement

- This procedure can be used in isolation of MMA or in conjunction with it.
- It involves creating an osteotomy around the genial tubercle and advancing the bone, pulling the genioglossus forward and opening the posterior airway space.

- There have been several different techniques developed to include a traditional horizontal osteotomy or variations of a window technique (square or trephine).
- Complications of genioglossus advancement include infection, anesthesia or paresthesia of the chin and anterior teeth, swelling and bruising of the floor of the mouth, tooth injury, mental nerve damage, and mandible fracture.

Maxillomandibular Advancement/ Telegnathic Surgery

- The surgical technique for maxillomandibular advancement is identical to that for orthognathic surgery. However, there are additional considerations for MMA for the treatment of OSA that bear special attention and should be kept in mind.
- The patient may or may not have an existing dentoskeletal malocclusion (class II or class III malocclusion, cross bite, transverse discrepancies, etc.) but can be addressed simultaneously.
- Patients may or may not require orthodontic treatment prior to MMA.
- Patients who are going to receive telegnathic surgery need to be counseled that their facial profile may be significantly different after surgery.
- The surgical goal is to advance the mandible as far as possible, to maximize the volume of the hypopharynx. This can result in a bimaxillary protrusive profile that the patient may find unappealing.
- The maxillomandibular complex is brought forward and can be rotated in a counterclockwise fashion to maximize the anterior movement of the mandible. This puts significant soft tissue strain on the osteotomies, which in turn can lead to relapse. Additional measures should be taken to prevent relapse. The use of bicortical screws to reinforce osteotomies, heavier plates than in traditional orthognathic surgeries, and bone grafts in the mandible and the maxilla to stabilize the segments and prevent soft tissue ingrowth can help prevent relapse.
- Often, patients may present for MMA after having underwent UPPP with unsatisfactory results. It is important to obtain a thorough history and even ask for the operative report from the UPPP if available prior to going to surgery. Scarring from UPPP and other pharyngeal procedures can limit the amount of advancement that can be obtained during surgery.
- MMA following UPPP may result in VPI as evidenced by dysphonia while speaking and occasional nasal regurgitation. This is usually transient and can often be managed by a "watchful waiting" approach instead of rushing to surgery.
- If a patient has known hypopharyngeal obstruction, performing MMA prior to attempting a UPPP can make global airway procedures easier as well as spare the patient unnecessary pharyngeal procedures.
- Postoperatively, these patients need to be monitored in the ICU with continuous pulse oximetry. Often, the facial swelling of this procedure can be dramatic, but does not usually affect the pharynx.

Tracheostomy

- Historically, tracheostomy was performed on patients suffering from severe OSA. While a tracheostomy provides an almost 100% cure for OSA (as it completely bypasses the entire upper airway), it is generally not favored by patients.
- Tracheostomy still has a role in children with severe craniofacial malformations (i.e., Pierre-Robin syndrome) and may still be used for OSA patients whose comorbidities may preclude global airway procedures but who still require surgical intervention (e.g., morbidly obese patients with severe medical comorbidities).
- The cannula remains capped during the day and the patient can eat and drink normally. However, the site must be vigilantly maintained to prevent mucus plugging, stomal granulation tissue, bronchitis, and peristomal infections.

Case

The patient is a 42-year-old African-American male referred to your practice for the management of his obstructive sleep apnea. He has undergone previous treatment and was referred to your practice by a colleague in ENT. The patient is being consulted for telegnathic surgery.

Medical History

- PMHx – HTN, HLD
- PSHx – UPPP, tonsillectomy, hernia repair
- RX – lisinopril, labetalol, simvastatin
- ALL – NKDA
- SOCHx – denies tobacco, 1–2 drinks/week, no illicit drug use
- Vitals – BP, 140/89; HR, 82; R, 15; T, 37.2°C

- *What information do you want?*
  History of present illness including onset, symptoms, and previous treatment details.

HPI – The patient reports that he has a long history of snoring and that he was diagnosed with OSA approximately 10 years ago. His initial management included CPAP therapy and weight loss. His wife reports that he was still snoring loudly, choking, and waking up frequently whenever he tried to take the CPAP off. He was referred to an ENT surgeon and underwent a UPPP with tonsillectomy. He is still snoring loudly per his wife and is unable to tolerate CPAP therapy. His ENT sent him for a follow-up PSG and he remembers that his AHI was "about 50." He still has morning headaches and feels tired all day.

- *What do you want to do now?*
  Conduct a physical examination including inspection of body habitus, intranasal inspection, airway assessment, dental exam, and occlusion.

The patient is a muscular 42-year-old African American male. His current weight is 198 lbs and his BMI is 27 kg/m^2. He is orthognathic with submental lipomatosis and neck circumference of 18 inches. A nasal exam shows nares patent bilaterally, negative Cottle test, no evidence of polyps, and no evidence of turbinate hypertrophy. Intraorally, the patient has evidence of his previous UPPP with an MP I airway. He has class I molars and canines and the tongue appear to be of normal size.

- *Is there any other diagnostic procedures or imaging that you would like to obtain?*
  A nasopharyngoscopy with a Mueller's maneuver will show obstruction at the base of the tongue. Obtain a lateral cephalogram or CBCT (Fig. 5.16).
- *What cephalometric measurements would you evaluate?*
  SNA, SNB, P to PNS, PAS, H to MP

His measurements are as follows:

- SNA – 91
- SNB – 90
- P to PNS – 40
- H to MP – 27
- PAS – 5

* **Author's Note.** Requesting a CBC and an ECG would be required in such a patient given his history of severe OSA and medical comorbidities. If you request labs during this section, you will most likely be told that they are within normal limits. Do not think that you wasted your time. It is important to remember that this is not the medicine section of the board. While it is important that you know there are several medical comorbidities associated with OSA and that you should get appropriate labs, it is unlikely that the examiners are going to take you down the rabbit trail of chasing all of the patient's medical comorbidities.

- *Do you want any other information?*
  Results of the previous PSG.

The report shows an AHI of 49 with the lowest O_2 saturation of 84%. His ECG shows occasional PVCs and two runs of sinus bradycardia.

- *What is your assessment?*
  The patient is a 42-year-old, ASA 3, male with severe OSA due to obstruction in the hypopharynx.

Fig. 5.16 Preoperative lateral cephalogram. (Courtesy of Dr. Joseph Ivory)

- *What is your plan?*
  The patient is a candidate for maxillomandibular advancement surgery which would include LeFort I advancement, mandibular advancement, and genioglossus advancement.
- *What is the amount of recommended advancement?*
  It is important to maximize the mandibular advancement to ensure the most gains in the volume of the posterior pharynx. The patient is class I, so the degree of mandibular advancement is directly related to the maxillary advancement. A maxillary advancement of about 10 mm with some impaction would be ideal. Counterclockwise rotation in this particular case would probably not be warranted because the patient already has a flat occlusal plane angle. This would give a mandibular advancement of about 10 mm coupled with a genioglossus advancement (cortex to cortex).

*__Author's Note.__ Be aware that you should remember that the patient had a UPPP prior to surgery. You should anticipate difficulty advancing the maxilla during your surgery due to scarring from the UPPP and consider making an alternative intermediate splint with a smaller advancement.

- *What are your considerations for hardware placement?*
  For this degree of advancement, it is important to utilize heavy, 2.0 plates on the piriform rims, shorter 2.0 L-plates for the zygomatic buttresses. Grafting may also be necessary to optimize bony contact in the LeFort osteotomy sites. The mandible is secured with bicortical screws in an inverted L with plates along the osteotomy with monocortical screws. The genioglossus advancement is secured with prebent chin plates and grafted with cortical wedges when necessary.
- *Intraoperatively, there is difficulty advancing the maxilla 10 mm as planned. What is the most likely etiology and how do you manage this?*
  This patient had a UPPP, and difficulty in advancing the maxilla the full 10 mm should be anticipated due to scarring. I would use the Rowe disimpaction forceps to stretch the maxilla to try to achieve the ideal advancement (anticipate reflex bradycardia when you do this). If you cannot achieve the ideal advancement, then the maxilla advanced as possible manually and should be fixated in this position. The osteotomized mandible is then set to the new position of the maxilla.

Appendix 1. Cephalometric Analysis

Measurement	Description	Normal values
SNA	Relation of the maxillae to the anterior cranial base	82 ± 2°
SNB	Relation of the mandible to the anterior cranial base	80 ± 2°
ANB	AP discrepancy between the maxillae and mandible in relation to the cranial base	0–2°
FH-NA	Maxillary depth AP position of the maxillae	90 ± 3°
FH-NB	Mandibular depth AP position of the mandible	88 ± 3°

(Continued)

Measurement	Description	Normal values
MPA (FH-MP)	A line from the menton through the gonion (mandibular plane) relative to the FH. Gives you the direction of the facial growth. Low angle of high angle	25 ± 5°
OPA (FH-occlusal)	Occlusal plane angulation: a line tangent to the buccal grooves of the mandibular second molar through the cusp tip of the premolars and the angle of this line relative to FH	8 ± 4°
U1:NA	Upper incisor angulation: long axis of the maxillary incisor to the NA line	22 ± 2°
U1:NA distance	Measurement from the labial tip of the upper incisor tip to the NA line should be 4 +/− 2 mm anterior to the NA line	4 ± 2 mm
L1:NB	Lower incisor angulation: long axis of the mandibular incisor to the NB line	20 ± 2°
L1:NB distance	Measurement from the labial surface of the lower incisor tip should be 4+/−2 mm from NB	4 ± 2 mm
L1:MP	A line from the lower incisor to the mandibular plane. Shows the inclination of the lower incisor	90–95°
N-ANS	N to anterior nasal spine, measure the middle facial height. It is measured perpendicular to FH	54 ± 3 mm
ANS-Me	Measures lower facial height. It is measured perpendicular to FH	65 ± 4 mm
Upper lip tooth	Amount of incisal show. This measurement is correlated with the upper lip length	1–4 mm
Wits appraisal	Expression of AP position between maxillae and mandible without taking into consideration the cranial base. Points BO and AO are established by dropping a line from A and B point to the occlusal plane	BO is 1 mm ahead in males and AO should coincide in females

Appendix 2. Chin Measurements

Measurement	Description	Normal values
Pog-NB = L1-NB	Pogonion projection: Most protrusive point of bony pogonion to the NB line. Mandibular balance achieved when the labial surface to the lower incisors and pogonion are in a ratio of 1:1 anterior to the NB line	4 ± 2 mm
Subnasale vertical	Distance from the soft tissue chin to a line perpendicular to FH through subnasale	3 ± 3 mm behind line
0° Meridian	Distance of soft tissue chin to a line perpendicular to FH through soft tissue nasion	Chin should be 0 ± 2 mm
E-line	A line drawn from the tip of the nose to the tip of the chin	Lower lip should be 2 mm behind it and upper lip 4 mm behind the line

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