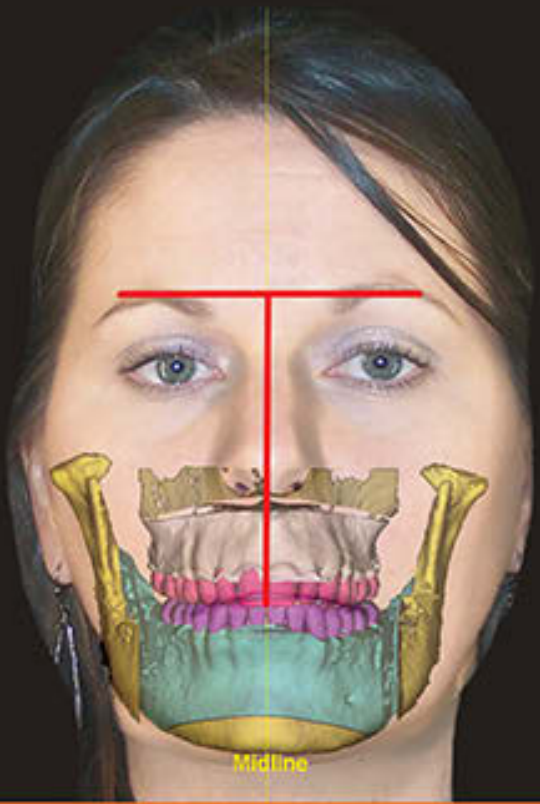
FUNDAMENTALS OF ORTHOGNATHIC SURGERY AND NON SURGICAL FACIAL AESTHETICS

Third Edition



Malcolm Harris
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Contributors

Peter Ayliffe

FDRCS, FRCS (OMFS)
Consultant Oral and Maxillofacial Surgeon
Great Ormond Street Hospital for Children and University College London Hospital
Honorary Senior Lecturer
Eastman Dental Institute and Institute of Child Health, University College London, UK
peter.ayliffe@ucl.ac.uk (p.ayliffe@live.co.uk)

Mohammad Anwar Bamber

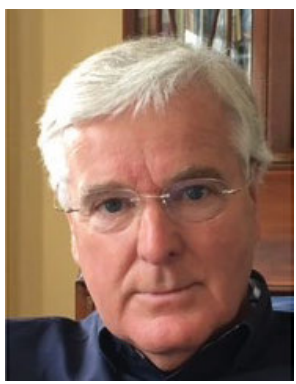
PhD, BA, MSSCh, FIMPT, MBRCP, LFHom, ILTM
Retired Senior Maxillofacial Instructor
Department of Oral and Maxillofacial Surgery,
Eastman Dental Institute,
University College London, UK
bambermn@gmail.com
(ma161@hotmail.co.uk)

d

Tara Brantley

DMD. BSc
Oral and Maxillofacial Surgery Resident
University of California,
San Francisco, USA
tara.brantley@ucsf.edu

Kieran Coghlan



MB, BCh, BDS, FRCS (Edin), FFD, RCSI
Consultant Oral and Maxillofacial Surgeon
Princess Alexandra Hospital NHS Trust, Harlow
Honorary Consultant, Barts & the London, NHS Trust London, UK
kierancoghlan@doctors.org.uk

Susan J. Cunningham

PhD, MSc, BChD, FDS RCS (Eng), MOrth RCS, FDS (Orth) RCS
Professor and Honorary Consultant
Unit of Orthodontics: Eastman Dental Institute, University College London and UCLH NHS Foundation Trust, UK
s.cunningham.ucl.ac.uk

Dan Harris

FCEM, MBBS, BSc, MRCS
Consultant Accident and Emergency Physician
Clinical Associate: Emergency Care Improvement Programme, UK
dndanharris71@gmail.com

Malcolm Harris

DSc, MD, FRCS (Edin), FDSRCS
Emeritus Professor: Oral and Maxillofacial Surgery
University College London, UK
malcolm.harrise@ucl.ac.uk

Rui Ming Ho

MBBS (Monash University, Australia)
MSc Clinical Dermatology (King's College London, UK)
Dip. Aesthetic Medicine (American Academy of Aesthetic Medicine)
Physician Non Surgical Facial Aesthetics
Director of Chrysalis Medical Aesthetics Clinic Singapore
ruimingho@hotmail.com/gmail.com

Nigel Hunt

OBE, PhD, MSc, BDS, FDS RCS (Eng), FDS RCS (Ed), FDS RCPS, DOrth, MOrth RCS
Chairman of Division of Craniofacial and Developmental Sciences
Head of Unit of Orthodontics. Eastman Dental Institute, University College London, UK
n.hunt@ucl.ac.uk

Sabah Kalamchi

BDS., LDSRCS., DDS. FFD. RCS
Professor and Director
Oral & Maxillofacial Surgery Department, Arizona School of Dentistry & Oral Health
Mesa, Arizona, USA
skalamchi@atsu.edu

Fooi Chin NG

BDS (Singapore), MDS (Oral Maxillofacial Surgery), FDSRCS (England)
Oral & Maxillofacial Surgeon
Coden Specialists, Paragon Medical Centre,
Singapore
nfc@codenspecialists.com

Santdeep H. Paun

FRCS (ORL-HNS)
Consultant Rhinologist and Facial Plastic Surgeon
Barts and the London Hospital Trust, London, UK
mail@spaun.co.uk [spaun@me.com]

Edwin Payne

Chief Technical Instructor
Division of Craniofacial Developmental Sciences
Eastman Dental Institute,
University College London, UK

Paul M. Thomas

DMD, MS, FDS [RCS Ed]
Adjunct Professor, Department of Orthodontics,
UNC School of Dentistry, Chapel Hill, North Carolina, USA
Former Senior Research Fellow:
Eastman Dental Institute, University College London, UK
p.thomas@earthlink.net
(p.thomas@dolphinimaging.com)

Mr Tom W M Walker

MBChB BDS DOHNS(RCSEd) MRCSI MFDRCSI AKC
Specialist Registrar & Honorary Clinical Lecturer
Department of Oral & Maxillofacial Surgery
Bristol Royal Infirmary
Children's Hospital & Dental School
University Hospitals Bristol NHS Foundation Trust
Bristol, UK
tom.walker@bristol.ac.uk

Preface and Acknowledgements

The first edition of the "Fundamentals" was published in 1991 by Malcolm Harris and Ian Reynolds shortly after Ian's untimely death and is now coedited for the second time by Nigel Hunt. This 3rd Edition of the "Fundamentals of Orthognathic Surgery has been substantially extended with completely new chapters covering Non Surgical Facial Aesthetics by Rui Ming Ho and Fooi Chin Ng and the application of Cone Beam Computer Scanning for Surgical Planning which was created by Paul Thomas and Sabah Kalamchi with the advice of Tarik Kramcha, a Biomedical Engineer of Healthcare 3D Systems. Although Computer Assisted Surgical Simulation (CASS) may supersede the traditional multi-stage manual orthognathic planning process, this means of record transfer by Mohammad Anwar Bamber and Ed Payne has been retained as an essential clinical skill.

Both fresh disciplines have made the "Fundamentals" an up-to-date operative manual for surgical and orthodontic consultants, their trainees as well as theatre and ward staff.

The important major deformity sections are still the Secondary Management of Clefts by Peter Ayliffe and Tom Walker, the Role of Distraction Osteogenesis by Kieran Coghlan, Rhinoplasty by Santdeep Paun and Temporomandibular Joint Ankylosis*. The

invaluable knowledge of nutrition for the Maxillofacial Surgery patient is by Tara Brantley and Sabah Kalamchi. Susan Cunningham has refined her essential chapter "The Psychosocial Aspects of Facial Deformity" to reconfirm the crucial borderland between the psyche and cosmesis, and warn how the unstable patient can create unexpected problems for the clinician.

The chapter on Emergencies and Complications has been modernised by Dan Harris, and Gemma Harris provided the digital rescue service. The illustration for the cover was produced by Paul Thomas. Many of the drawings from the original text have been retained and were by Mohamed Nour Awang, David Banks, Helen McParland, Daljit S. Gill and Cristina Nacher. There are no references as very few clinicians consult an ever changing scene which is readily available through Google Chrome or Pubmed etc.

Nigel and I must express our gratitude for the continued patience and inspiration of our wives Susan and Naomi and are also grateful to Joy Quek of World Scientific Press for her generous support.

With our best regards to all readers, Malcolm Harris* and Nigel Hunt.

Contents

Chapter 1

General Assessment

Malcolm Harris and Nigel Hunt

Introduction

The overall management of a patient with facial deformity requiring orthognathic surgery is both an art and a science. The management must be based on a team approach. Whilst the team may vary according to local circumstances, the optimum would consist of an orthodontist, an oral and maxillofacial surgeon, a liaison psychiatrist or clinical psychologist, a specialist in restorative dentistry, supported by a maxillofacial technician. A speech therapist is essential for cleft cases and plastic surgery expertise should also be available on an individual patient basis. Whilst a patient may be referred to any of the above specialists, it is important that all patients follow an agreed care pathway to ensure patient satisfaction with the outcome. It is imperative that as part of the initial consultation, patients are encouraged to state precisely what aspects of their facial features or dentition they would like corrected, for what reason and the length of time that they have sought treatment. Whilst the patient can be guided to what constitutes an ideal facial appearance, it is vital that the clinician does not lose sight of the patient's underlying concerns.

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The motivation behind the request for treatment is very important and special consideration is required when psychological factors appear to influence both the diagnosis and the treatment.

The combined orthodontic and surgical treatment goals are:

- Improve facial aesthetics
- Improve dental aesthetics
- A functional, balanced and stable occlusion
- A satisfied patient.

The management protocol for facial deformity should comprise the:

- History
- Clinical examination
- Investigations
- Initial diagnosis
- Treatment plan
- Presurgical orthodontics
- Final treatment plan
- Surgery
- Postsurgical orthodontics
- When appropriate, restorative dentistry, psychological intervention or support and speech therapy will be required.

History

The purpose of the history is to identify the patient's orofacial problems and their cause. This may be a family trait, congenital deformity, or the result of trauma in infancy or adolescence. It is useful to ask the patient to draw up a problem list in order of priority of the specific features they wish to have corrected and for the clinician to note where the drive for treatment has arisen. For example, a patient may complain of having a prominent chin, which they have noticed ever since adolescence and for which they have frequently requested

treatment through the general dental practitioner. This differs from the sudden desire to change minimal deformity as a response to a personal crisis. The long term success in terms of patient satisfaction is far better when driven by the patient than that of a patient seeking surgery driven by a parent, partner or close relative. Many orthognathic procedures have a secondary effect on other aspects of facial appearance. For example, correction of a "gummy smile" with a maxillary impaction will also increase the fullness of the cheeks over the malar region and widen the alar width of the nose It is important to inform the patient of these changes. The overall treatment goals must be to improve facial and dental aesthetics, and to provide a functional and stable occlusion but with the underlying premise that these satisfy the patient's reasonable wishes.

The Medical History

Most orthognathic patients are young and fit to undergo a general anaesthetic and prolonged surgery. Occasional disorders, which require specific attention include:

i) haemophilia or similar clotting disorders which require pre- and intraoperative correction
ii) acromegaly patients may be a cardiomyopathy risk
iii) antibiotic or analgesic idiosyncrasy or allergy
iv) rheumatic or congenital heart valve lesions
v) obstructive sleep apnoea should warrant a sleep study and specific assessment.

Body Dysmorphic Disorder (*Formerly Dysmorphophobia*)

A small but significant proportion of patients may present with varying degrees of concern about one or more aspects of their facial appearance without appropriate clinical signs. This may be a manifestation of the psychiatric disturbance now called the Body Dysmorphic Disorder (formerly dysmorphophobia). This condition

will create problems in surgical management as the patient is often dissatisfied with the final result. The condition invariably raises the conflict as to whether one does,

i) what the patient wants
ii) what the patient needs
iii) or nothing.

It is therefore worth consideration in some detail. See Chapter 16.

Evaluation of the Patient

Patient Evaluation

- Clinical examination
- Radiographic examination and if necessary a Cone Beam Computer Tomographic (CBCT) scan
- Analysis of study models
- Psychological examination where appropriate.

Introduction

The full examination must include the basic scrutiny of the patient, radiographs, cephalometry and study casts. The evaluation should begin with a systematic examination of the patient's facial features from the frontal perspective (vertical proportions) and the lateral profile (horizontal relations). It is important to consider the vertical facial proportions and their balance in relation to the patient's general build, and personality. Examples of patients who may not need surgery are: (i) a young female patient who possesses a vivacious and extrovert personality suited to a mild Class II malocclusion accompanied by a broad smile and marked incisor exposure and (ii) similarly, a well-built male may be suited to a mild Class III malocclusion with a minor degree of mandibular prognathism. It is also important to take

into consideration the overall facial shape, as there is extreme variation from a square shaped facial appearance to one of a long ovoid appearance. In the former case this may fit in well with a shorter stature whereas a longer face may be more suited to a tall individual. At the moment these decisions are based on experience and intuition.

Clinical Examination

The clinical examination should be undertaken with the patient comfortably seated with the Frankfort plane horizontal. Not only is it easy to visualise a line running from the inferior orbital margin to the upper end of the tragal cartilage, but this can be readily compared with the same horizontal plane on the lateral skull radiograph (cephalogram) and photographs.

Frontal Assessment

There are several important facial features to note. These include:

a) *The facial proportions*
The useful classic guide is to consider the face as having three equal vertical components (Figure 1.1): The distance from the hairline to the soft tissue bridge of the nose; from the soft tissue bridge of the nose to the alar base and from the alar base to the lower border of the chin. It is also important to determine whether or not there is a relative excess or deficiency in the vertical height of either the maxillary or mandibular thirds.

b) *The alar base width*
Traditionally in a westernised population it is accepted that the alar base width, as measured from the lateral aspects of the alar cartilages of the nose, should be approximately equal to the distance between the inner canthi of the eyes (Figure 1.2). This measurement has importance when planning a maxillary impaction.

Figure 1.1 The superficial aesthetic proportions of the face can be divided into equal thirds. However the underlying cephalometric proportions of the upper to the lower facial height are 45:55 (see Figure 2.3).

Figure 1.2 The alar base width should approximate the inner intercanthal distance.

c) *Incisor exposure* (*the lip — incisor relationship*)
For a patient with an average upper lip length of 20–25 mm, the standard exposure for orthognathic planning of the upper labial segment with the lips parted at rest should be 2–4 mm of the incisor crown. On smiling, the exposure should increase to the level of the gingival margin of the upper labial segment. This assessment is crucial when planning the vertical height of the mid face where the amount of incisor exposure should be inversely proportional to the length of the upper lip (Figure 1.3). Where the upper lip length is very short then the patient would expect to show more of the upper incisors. Any attempt to reduce the incisor exposure in relation to a short upper lip will lead to an unaesthetic reduced middle face height. Similarly, with a long upper lip, the patient would be expected to show less or no upper incisor, both at rest and during facial animation. The lip incisor measurement should be undertaken with the face at rest. Animation especially smiling will enhance the face and make planning difficult.

The harmony between the components of the lower third of the face is also important, in that the subnasale to the upper lip vermillion border should be a third of the total (i.e. half of the lower lip vermillion border to the soft tissue menton). In those cases where the lower third of the face appears overclosed, it is wise to re-evaluate both the upper lip length and the incisor exposure with the mouth open so that the lips are taken just out of contact.

d) *Facial asymmetry and centre line relationships*
It is important to note any asymmetry of the middle or lower third of the face, including the position and levels of the eyes. This may be facilitated by marking the midlines on the patient's face and also by analysing a clinical photograph or surface laser scan.

The patient's maxillary and mandibular dental midlines may not be coincident nor match their skeletal midlines (Figure 1.4).

Figure 1.3 With an average upper lip length, a useful aesthetic proportion is **(a)** 2–4 mms of maxillary incisor crown visible with the lips apart at rest. **(b)** This increases to the level of the gingival margin on smiling. **(c)** Here the excess incisor exposure of vertical maxillary excess at rest is important for the estimation of the required vertical impaction. **(d)** The aesthetic animated face makes this estimation difficult.

Generally where the maxillary dental midline is displaced to one side of the skeletal midline, there is an indication for orthodontic correction rather than attempting to rotate the maxilla in order to produce a dental midline coincident with the midface. Where a mandibular dental midline discrepancy is noted in

Figure 1.4 **(a)** The facial asymmetry of a left-sided hemimandibular elongation with the chin point displaced to the right. The lower dental midline mirrors the mandibular skeletal asymmetry and will be corrected as part of the surgery. **(b)** The maxillary dental midline is displaced to the left of a symmetrical maxilla and therefore should be corrected as part of the orthodontic preparation of the case. **(c)** Postural camouflage showing tilting of the head to level the lip line, in an asymmetrical face can give a false impression of orbital dystopia. **(d)** Levelling the occlusal plane with bimaxillary osteotomies also "levels" the eyes!

relation to the upper midline, it is important to determine whether it is coincident with a mandibular skeletal asymmetry or of purely dental origin. Where the skeletal asymmetry and dental midlines coincide the centre lines will be corrected as part of the surgical procedure.

Postural camouflage can be a problem with the asymmetrical face as shown in Figures 1.4c and 1.4d. This patient with a marked occlusal cant habitually tilted her head to level the lip line which gave the impression of orbital dystopia. This was corrected by bimaxillary levelling of the occlusal plane.

Profile Assessment

As with frontal evaluation it is important to work down the profile from above to observe key features.

a) *Relative protrusion of the maxilla and mandible*
The relations of the maxilla and mandible to each other and to the skull base will be discussed in greater detail in Chapter 2. It is common for patients to complain of a protruding chin, whereas it is the relationship of the maxilla to the skull base which is at fault, i.e. a hypoplastic maxilla related to a normal mandible. This can be clinically demonstrated by simply padding out the upper lip with soft wax or cotton wool (Figure 1.5) until the lip relationship and facial profile appear normal. Similarly, the surgical correction of a retrognathic mandible may be visualised by asking the patient to slide the mandible forwards (Figure 1.6). Most orthognathic cases require a combination of both maxillary and mandibular surgery and an assessment of the protrusion of the mid third and mandible can be made by assessing their position relative to the coronal facial plane which divides the head into dorsal and ventral (posterior and anterior) portions and passes downwards through the nasion (Figure 1.8). With normal facial proportions the soft tissue profile of the maxilla should be approximately 2–3 mm in front, and the soft tissue pogonion should lie 2 mm behind this facial plane (Figure 1.7). However the face will vary with ethnic norms, giving anterognathic, mesognathic or posterognathic profiles (Figure 1.8b).

Figure 1.5 **(a)** Apparent mandibular prognathism. **(b)** Padding the upper lip suggests a maxillary advancement will harmonise the profile and maintain a "strong chin". **(c)** Masking the mandible facilitates judging the mid face.

Figure 1.6 Forward posturing of the mandible will help to visualize the horizontal and vertical effects of a mandibular advancement to correct a marked Class II deformity.

b) *Position of the infra-orbital margin*
A good indicator of middle third hypoplasia arises from the relative protrusion of the maximum convexity of the globe of

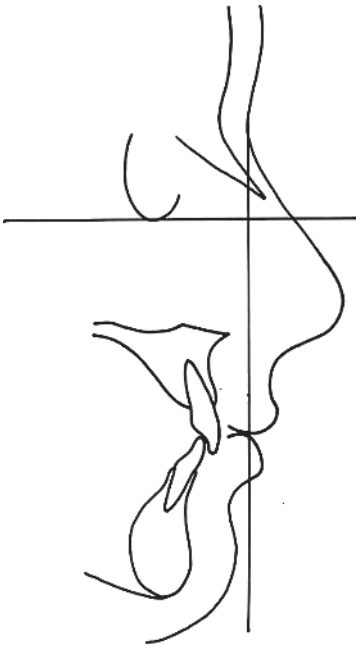

Figure 1.7 The relative projection of the maxilla and mandible can be assessed by the coronal facial plane which is perpendicular to the Frankfort plane passing downwards from the soft tissue nasion. With "normal facial proportions" the soft tissue profile of the maxilla should be 2–3 mm in front of the line and that of the mandible 2–3 mm behind.

the eye in relation to the infra-orbital margin. Ideally the globe should be just 2–3 mm in advance of the infra-orbital margin (Figure 1.9).

c) *Nasal morphology*
The appearance of the nose will often change both relatively and anatomically with many osteotomies. For instance, an apparent large nose may appear more acceptable following a bimaxillary correction (Figure 1.10) due to the change in the adjacent soft tissue drape. Alternatively, a Le Fort I maxillary advancement and/or impaction will tend to raise the nasal tip and straighten a nasal hump unless modifications to the surgical procedure are

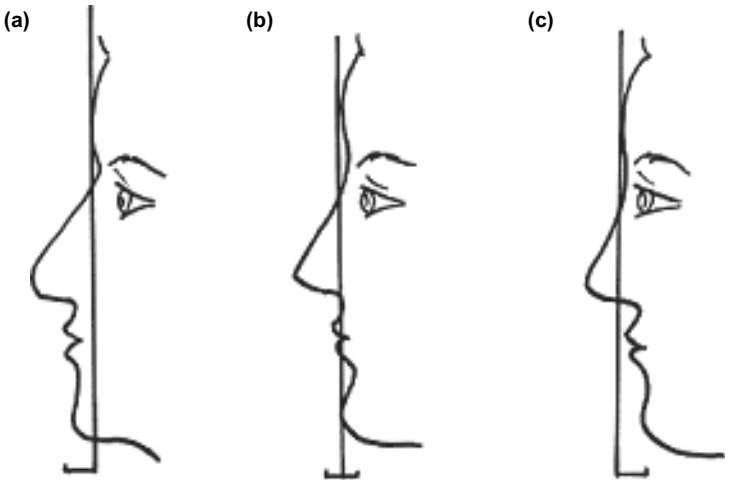

Figure 1.8 The "normal profile" can vary with concepts of beauty and ethnic variation as is seen above showing: **(a)** the anterognathic, **(b)** mesognathic, and **(c)** posterognathic norms.

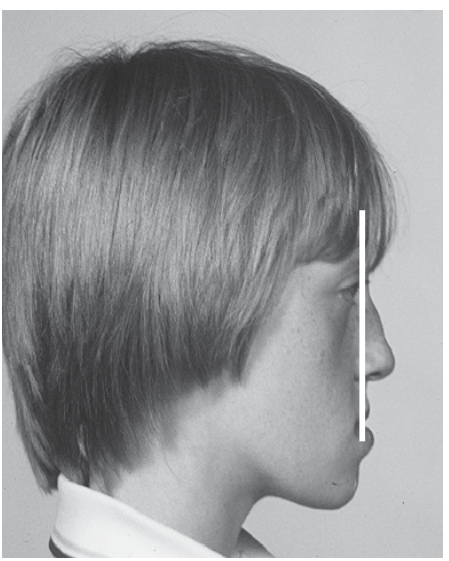

Figure 1.9 A patient with midface hypoplasia. Note the retruded infra-orbital margin relative to the globe of the eye. The globe should only be 2–3 mm in front of the orbital margin.

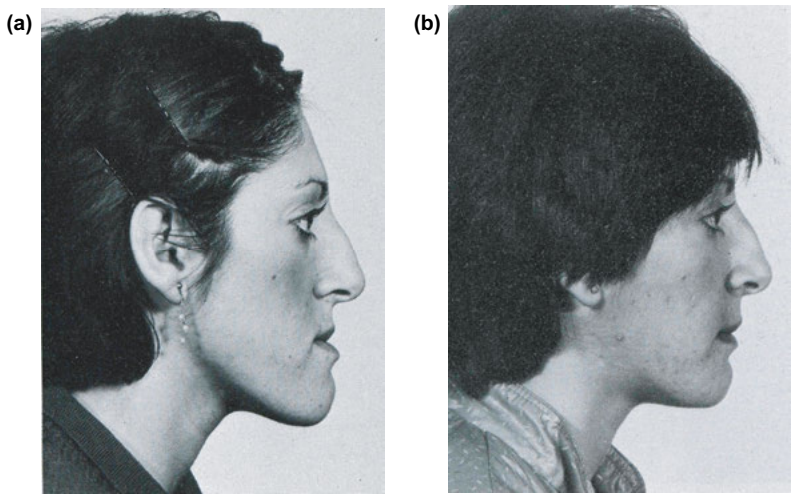

Figure 1.10 **(a)** The relative prominence of the nose seen preoperatively is diminished with a bimaxillary correction, **(b)** which has radically changed the facial soft tissue drape.

included (Figure 1.11). Where a formal rhinoplasty is considered essential, it should always be undertaken as a separate surgical procedure once the changes produced by the jaw surgery have stabilised. See Chapter 14.

The importance of the nasolabial angle in the surgical planning process will be discussed in greater detail in Chapter 5. However it is important to record the nasolabial angle, which is the angle formed by the intersection of tangents to the lower border of the nose and upper lip. Ideally, in Caucasians this angle should be slightly greater than 90 degrees indicating optimum lip support by the maxillary alveolus (Figure 1.12).

d) *Morphology of the ears*

The ears, being first arch derivatives, may concurrently suffer with a gross facial deformity. The ear deformity associated with hemifacial hypoplasia (microsomia) will require reconstruction at a later stage (Figure 1.13). It is not uncommon for the external auditory meati to lie at unequal levels. This creates difficulties

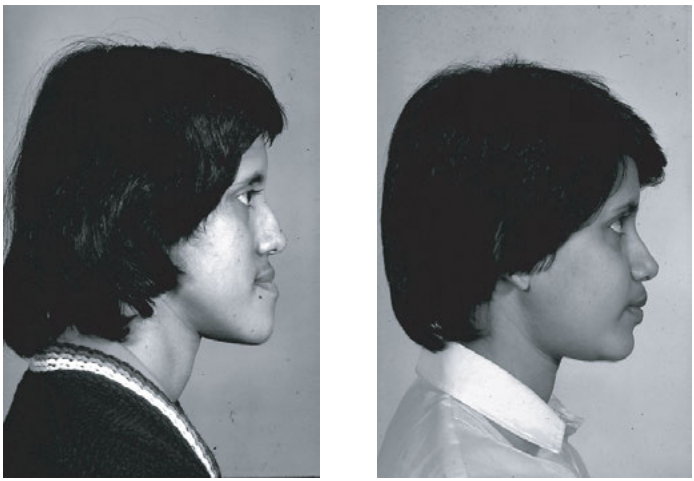

Figure 1.11 This bimaxillary correction consisted of a maxillary impaction with advancement and a mandibular setback. The maxilla has elevated the nasal tip and the combination enhanced the facial tissue drape.

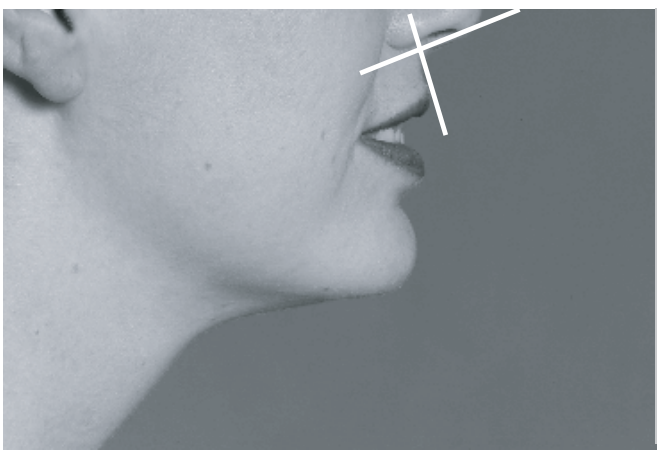

Figure 1.12 The nasolabial angle is assessed at the intersection of tangents to the columella (the lower border of the nasal septum) and the upper lip.

when taking a facebow recording for transfer to the articulator. See Chapter 6. Bat ears appear to be an independent abnormality and do not seem to concern most adults.

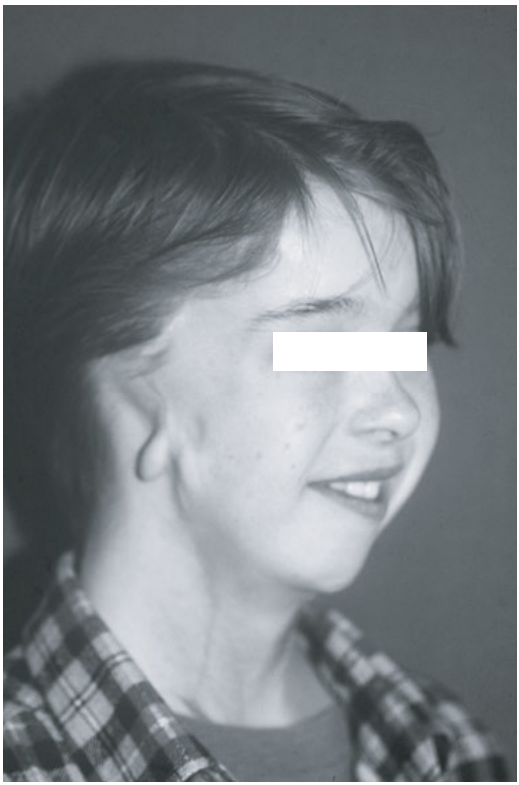

Figure 1.13 Severe ear deformity in a patient with hemifacial microsomia.

e) *Chin depth*
When assessing the facial height in the frontal (coronal) and sagittal planes, the lower facial third can be further subdivided into the upper lip which forms one-third, whilst the distance from the lower lip margin (stomion) to the chin margin (soft tissue menton) should comprise two-thirds of the lower facial height. Taken together with the chin profile this is an important component for correcting jaw disproportion (Figure 1.14).

f) *Chin-Throat angle*
Some patients request cosmetic surgery for an excess fat deposit in the throat region. This should be distinguished from

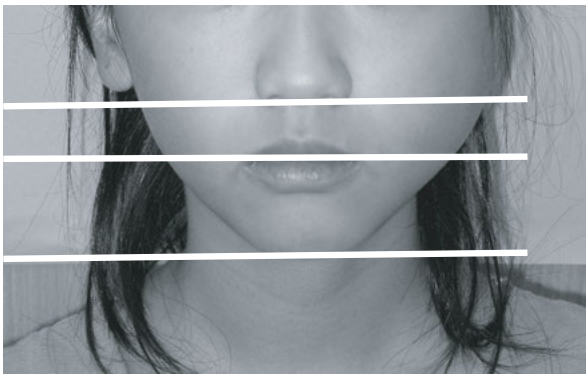

Figure 1.14 The upper lip length should be a third of the lower facial height.

a dewlap which is a fold of loose skin. As a consequence the fat gives a bulky contour below the chin. Surgery to setback the mandible may occasionally accentuate this build up of submental soft tissue, in which case liposuction or plastic surgery procedures may need to be incorporated into the postoperative surgical plan. However in the young patient the submental neck area usually remodels spontaneously following a mandibular setback.

Temporomandibular Joint Examination

Although there is no evidence of malocclusion or jaw deformity causing temporomandibular joint symptoms, it is important to record any abnormalities present in patients considering surgery. The examination of the joint should include observation of the path of opening and closure of the mandible, noting any clicking sounds whilst palpating the joints. If a click is present, it should be noted how this relates to the opening or closing cycle. Also, the extent of maximum opening should be recorded.

Intraoral Examination

The intraoral dental examination must be carried out with the study models and radiographs.

1. Record the teeth that are present or unerupted and any that are impacted, carious, overerupted or periodontally involved. This is often overlooked.
2. The following orthodontic base line notes should include:
   a) A definition of the dental occlusion and dental base relationships.
   b) Any dental centre line discrepancies relative to each other and the facial midline and chin point.
   c) Any crossbite indicating a discrepancy in the transverse relations. This includes both anteroposterior and buccal crossbites. It is important to check and record whether there is any associated displacement or deviation of the mandible on closing. In the buccal segments, it is also important to note whether the segments have attempted to compensate for the discrepancy by tipping of the dentition.
   d) The upper and lower incisor inclinations and in particular, compensatory changes due to the jaw disproportion, e.g. retroclined lower incisors and proclined upper incisors in a prognathous mandible.
   e) The biotype (thickness) of the periodontal attachment and soft tissues overlying the roots of the lower incisors. This is important when considering incisor decompensation. Where there is a thin biotype or signs of gingival recession consideration should be given to a periodontal graft.
   f) The presence of crowding or spacing together with any tooth size discrepancies. Note also any tilting and rotation of teeth.
   g) The levels and shape of the occlusal planes, both the anteroposterior curves of Spee, and the transverse occlusal plane.

A wooden spatula placed across the transverse occlusal plane can help identify any cant in relation to extraoral structures, for example, the interpupillary line.

h) The depth of the overbite and whether it is complete or incomplete. The size of the overjet from the most prominent incisor should also be recorded.

i) Whether the maxillary intercanine width can accommodate the lower arch.

j) The arch form and the coordination of upper and lower arches.

3. Examine and record the tongue size and mobility, and the speech pattern.
4. Enlarged tonsils may jeopardise the patency of the airway. Adenoids are rarely a problem as they have usually regressed in size during early adolescence. However, remember that the micrognathic mandible will create an intubation problem for the anaesthetist.
5. Cleft cases require careful analysis of the cleft site and bony defects that will require grafting. Velopharyngeal competence should be examined by endoscopy and speech recorded by a speech therapist.

Investigations

Radiographic Imaging

Digital radiographic imaging has largely replaced plain film processing. Nevertheless the recorded information should include the following:

1. A panoramic film, e.g. orthopantomograph shows at a glance:
   a) Any unerupted and impacted teeth.
   b) The shape and relative size of each half of the mandible, including the condyles, in two dimensions.

   c) The presence of any pathological condition such as impacted unerupted teeth, caries, periodontal disease, any apical root resorption that may have arisen as a consequence of earlier orthodontic treatment, apical granulomas or cysts.
   d) The trabeculation pattern of the bone, especially at the lingula, which when visible is an indication of adequate thickness of the ascending ramus and ease with which the ramus can be split.
2. The true lateral skull radiograph is taken with the head in a reproducible position with the aid of a cephalostat. The tube is set 1.5 m from the film so that the central parallel rays are used, producing a life-sized image with minimal distortion. Ideally the teeth should be in centric relation (retruded contact position), i.e. the mandible should be gently closed to the natural retruded cuspal contact position to approximate to the supine anaesthetised centric relation during surgery. However, the influence of centric occlusion and centric relation on planning will be discussed in Chapter 6.
3. A cephalostat posteroanterior view of the skull helps to reveal facial bone asymmetry. However, remember that the head may be tilted in the craniostat if the external auditory meati are asymmetrically placed, giving a misleading image.
4. Long cone periapical films are essential for assessing the space between teeth when segmental surgery is required.
5. A maxillary occlusal radiograph defines the bone defect in cleft cases.
6. Unusual anatomy or pathology will require additional investigation using a Cone Beam Computerised Tomograph scan (CBCT).

If the patient elects to have surgery, a preoperative chest radiograph is required by some surgeons but is only justified where a costochondral graft is to be harvested.

Study Models (*Casts*)

The use of intra-oral scanners to record the condition, and relationships of the teeth, and facilitate virtual planning will be covered in Chapter 7. However, traditional methods are still relevant. Impressions are taken for study models, together with a careful interocclusal record ("squash bite") so that the models can be trimmed in centric relation. This is done with the patient in a relaxed supine position. The models must show all the teeth present as well as the sulci. The patient's name, hospital number and the date of taking the impressions must be marked on them after trimming in a standardised manner (e.g. Angle or Tweed).

Initially two replicas are made of the originals and one set is mounted on an anatomical articulator using a facebow recording, although a simple plasterless articulator is suitable for those cases involving mandibular surgery alone. Model surgery is discussed in detail in Chapter 6.

Photographs

The basic orthognathic series of colour images consists of (Figure 1.15):

i) Full face at rest and smiling.
ii) Right profile but both profiles with any asymmetry.
iii) Anterior teeth and right and left buccal segments in occlusion.
iv) Some also include occlusal views of the upper and lower dentition.
v) Cleft cases require a palatal view.
vi) Cleft and rhinoplasty patients also need an inferior view of the alar margins to capture problems of asymmetry.

In addition, some use black and white prints of the patient's profile for treatment planning but the 1:1 object-image profile photograph is not exactly comparable to the lateral skull tracing. These

Figure 1.15 A basic orthognathic series of photographic records.

techniques have been largely superseded by computer imaging and morphing software programmes which are used to simulate surgical changes (Chapter 3).

Photographs should be taken pre- and postoperatively as a surgical audit, for teaching and rarely for medico-legal reasons. If photographs are to be of value, hair must be retracted from the face and moustaches and beards removed.

Lateral Skull Tracing

The "true lateral skull" radiograph is traced manually or digitised by computer for cephalometric analysis.

These will be discussed in detail in Chapters 2 and 3 and in the sections on deformities.

The Diagnosis

With many patients this can be readily stated, for example, "mandibular prognathism requiring a sagittal split osteotomy pushback". However, without more formal scrutiny, bimaxillary, orthodontic, restorative and periodontal problems will be overlooked.

Complex deformities require a detailed appraisal by the surgeon and orthodontist jointly, even then a surgical solution may not suggest itself immediately. Hence it is useful to describe the case under the following headings, in the form of a "problem list".

1. The jaw relationship and facial proportions, including the nose and ears
2. Orthodontic diagnosis
3. Restorative, including periodontal problems
4. Speech
5. Psychological assessment.

Chapter 2

Radiographic Analysis and Imaging

Nigel Hunt

The standard radiographic views which are fundamental to orthognathic surgery planning consist of a panoramic screening radiograph, for example, an orthopantomogram, and a lateral skull radiograph taken in a cephalostat. In addition the posteroanterior skull radiograph may be used in cases where there is clinical evidence of asymmetry. More detailed radiographs, for example, long cone periapical views or an upper standard occlusal radiograph may be taken for clarification of specific areas of pathology. It is not uncommon for surgical patients to have previously undergone some form of orthodontic treatment and therefore it is important to ensure that the roots of the teeth are perfectly sound.

The Need

Cephalometric analysis will establish the relations of:

1. The maxilla and the mandible to the base of the skull.
2. The maxilla to the mandible.

3. The maxillary teeth to the maxilla.
4. The mandibular teeth to the mandible.
5. The upper incisors to the lower incisors.

In order for these measurements and relationships to be meaningful it is important that the radiograph is taken in the standardised centric relation position (retruded contact position) with the patient's Frankfort Plane (the line from the lower border of the orbital rim to the upper border of the cephalostat ear post) horizontal. It is also important to ensure that the soft tissues are at rest when the radiograph is recorded.

Modern radiological guidelines require that intensifying screens should be used and that the radiographic beam has undergone appropriate collimation so as to avoid excessive exposure of structures considered unnecessary in the planning process.

Ethical approval is also required for repeated radiographs used for research purposes.

The Tracing

A sheet of clear, matt acetate paper is fixed securely with adhesive tape to the lateral skull radiograph placed on a horizontal viewing box. The radiographic image is enhanced by tracing in a darkened room with any peripheral light from the viewing box masked off. Many operators will have their preferred landmarks and analyses but the following outlines and points are commonly registered (Figure 2.1).

Outlines:

1. The soft tissue profile including glabella, nasion, nasal tip, upper lip, lower lip and the soft tissue chin.
2. The inner outline of the sella turcica, the anterior aspect of the nasal bones together with the frontonasal suture and the outline of the lower bony margin of the orbit.

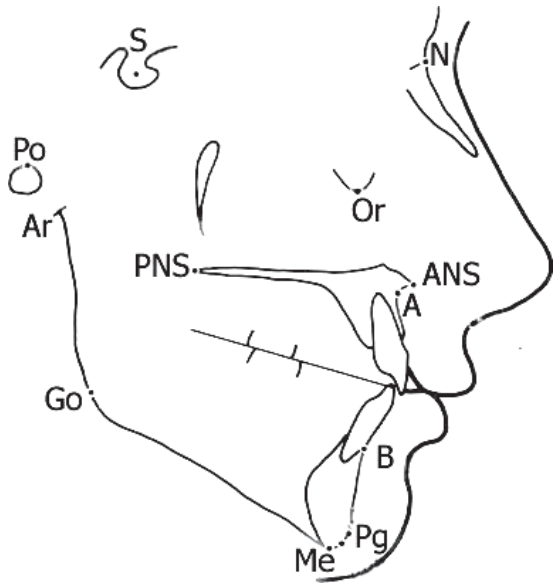

Figure 2.1 Cephalometric outlines and landmarks: A, point A; ANS, anterior nasal spine; Ar, articulare; B, point B; Go, gonion; Me, menton; N, nasion; Or, orbitale; PNS, posterior nasal spine; Pg, pogonion; Po, porion; S, sella.

3. The maxillary outline, upper incisors and upper first molar.
4. The mandibular outline with the mandibular incisors and first molar and articulare. As a result of superimposition it is often difficult to identify the head of the condyle but it is easy to register the articulare where the posterior margin of the ramus crosses the cranial base. In general, where bilateral landmarks present two images, the average of the two should be drawn. The exceptions to this are those cases where there is an obvious asymmetry of the mandible, which has resulted in two distinct lower borders to the mandible. From the point of view of measurement, it is normal practice to take the lower border which conforms to the normal side of the face, as assessed clinically.

Points:

- S Sella: The centre of the sella turcica determined by visual inspection.

- N Nasion: The anterior point of the frontonasal suture.
- ANS. Anterior nasal spine: Where the tip of the anterior nasal spine deviates markedly upwards or downwards, it is taken as the mid-point of the upper and lower spine outlines where it is 2 mm wide.
- PNS. Posterior nasal spine.
- Point A. The deepest midline point on the maxillary alveolus outlined between the anterior nasal spine and the maxillary alveolar crest.
- Point B. The deepest midline point between the mandibular alveolar crest and pogonion.
- Me Menton: The most inferior point on the lower border of the bony symphysis.
- Pg Pogonion: The most anterior point on the bony symphysis.
- Go Gonion: Is determined by bisecting the angle formed by tangents to the lower and posterior borders of the mandible. It is the point where the bisector cuts the angle of the mandible.
- Ar Articulare: The intersection of the posterior border of the ramus and the temporal bone.
- Co Condylion: The superior point on the condylar head.
- Or Orbitale: The most inferior point on the orbital margin.
- Po Porion: The upper margin of the bony external auditory meatus. The upper margin of the condylar head (Co) may also be used as it is often more easily determined.
- UMC. The tip of the mesio-buccal cusp of the upper first permanent molar.
- LMC. The tip of the mesio-buccal cusp of the lower first permanent molar.
- UIA. The tip of the most prominent maxillary incisor root apex.
- UIE. The most prominent maxillary incisor crown edge.
- LIE. The most prominent mandibular incisor crown edge.
- LIA. The tip of the most prominent mandibular incisor root apex.

The following lines are then drawn (Figure 2.2):

- S-N (the anterior cranial base).
- S-Ar.

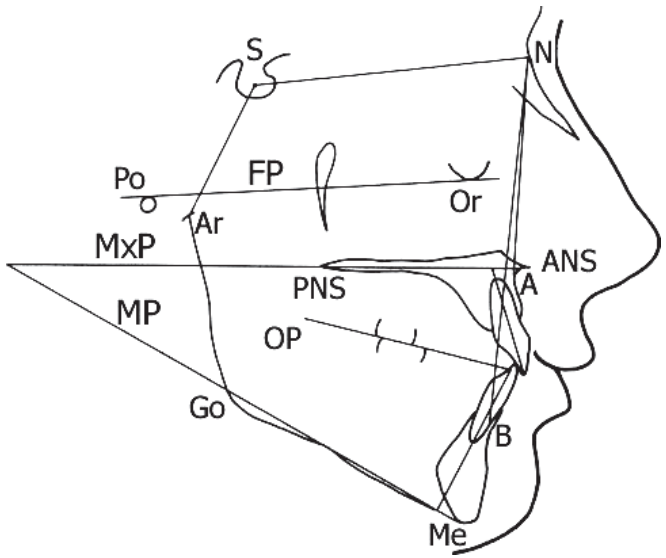

Figure 2.2 The planes and angles. Using the cephalometric points the following planes are constructed; SN plane (SN), mandibular plane (MP), maxillary plane (MxP) and Frankfort plane (FP). The long axes of the maxillary and mandibular incisors are considered relative to the maxillary and mandibular planes respectively. The important cephalometric angles can be readily derived from these points and planes. For key, see Table 2.1.

- N-A.
- N-B.
- Or-Po (the Frankfort plane-FP).
- ANS-PNS (the maxillary plane-MxP).
- Me-Go (mandibular plane-MP).
- Long axes of the upper (UI) and lower (LI) incisors.
- The occlusal plane (OP) is drawn through the occlusal outline of the buccal segment teeth, including the premolars. However, it may be difficult to determine the outline of the molars due to superimposition. Therefore for simplicity, the tips of the upper and lower mesial cusps (UMC and LMC) and the upper and lower distal cusps only are drawn.

The Analysis

The accuracy when undertaking a cephalometric tracing of a radiograph by hand and its analysis only permits linear and angular measurements to be expressed to the nearest whole millimetre or degree. The values obtained can then be compared with the population normal values to determine the patient's problems (Tables 2.1–2.3). It is important to appreciate that they will vary with age, sex and ethnic origin. Table 2.1 presents the mean angular cephalometric values based on a Caucasian population. As can be seen from these tables, there is considerable variation for all values.

Although cephalometric analysis is helpful in providing information for diagnosis and treatment planning, it has to be borne in mind that the ultimate goal is not necessarily to achieve ideal values near to the mean but to produce a proportional and harmonious

Table 2.1 Mean angular cephalometric values (Caucasians)

Measurement	Mean ^{0} ± SD
SNA	81 ± 3
SNB	78 ± 3
ANB	3 ± 2
SN/MxP	8 ± 3
SN/MP	35 ± 4
FP/OP	8 ± 4
NSAr (saddle angle)	125 ± 5
SArGo (articular angle)	140 ± 6
ArGoMe (gonial angle)	128 ± 7
MxP/MP	27 ± 4
UI/MxP	109 ± 6
UI/LI	130 ± 6
LI/MP	93 ± 6

For explanations of abbreviations, see text.

Table 2.2 Mean linear cephalometric values (Caucasians)

Measurement		Mean mm ± SD
Facial Heights		
Total anterior	TAFH (N-Me)	124 ± 8
Lower anterior	LAFH	68 ± 8
Total posterior	TPFH (S-Go)	79 ± 6
Lower posterior	LPFH	34 ± 5
	Ar – Go	54 ± 4
Lower anterior face height ratio	LAFH/TAFH%	55 ± 2
Lower posterior face height ratio	LPFH/TPFH%	44 ± 1
Dentoalveolar Heights		
Lower posterior	LPDH (LMC-MP)	38 ± 3
Lower anterior	LADH (LIE-MP)	40 ± 2 (females)
		44 ± 2 (males)
Upper anterior	UADH (UIE- MxP)	33 ± 3
Upper posterior	UPDH (UMC-MxP)	28 ± 3

For explanations of abbreviations, see text.

Table 2.3 Angular cephalometric values (Negroes and Chinese)

	Value[0]	
Measurement	Negroes	Chinese
SNA	85	83
SNB	80	80
ANB	5	3
MxP/MP	28	28
UI/MxP	118	113
LI/MP	98	96

For explanation of abbreviations, see text.

These figures may be used for Negro and Oriental patients instead of those in Table 2.1 but should be regarded as a broad guide, rather than an exact ideal, bearing in mind that numbers in some surveys are small and may be the average of a wide range. Because of natural incisor proclination, the aesthetic nasolabial angles are invariably acute, i.e. significantly less than the Caucasian range.

facial structure. To that end, where there are discrepancies between clinical observation and cephalometric values, the analysis of the clinical presentation is always more important.

Vertical Values

Vertical cephalometric analysis is of great value in orthognathic planning.

Linear

The total anterior face height (TAFH) is the sum of the upper anterior face height (UAFH), measured from nasion to the maxillary plane, and the lower anterior face height (LAFH), maxillary plane to menton. The lower anterior face height is usually 55 ± 2% of the total anterior face height.

Posterior face height is similarly measured from sella to gonion using the maxillary plane to divide the upper posterior face height (UPFH) from the lower posterior face height (LPFH). The lower posterior face height being approximately 44 ± 1% of the total posterior face height (Figure 2.3).

The anterior dentoalveolar heights are measured from the incisal edges of the upper and lower incisors (UIE and LIE) to the maxillary plane and mandibular plane respectively. It should be noted that these measurements reflect the components of the lower face height. In other words, if the lower anterior face height value is high, then the upper and lower anterior dentoalveolar heights (UADH and LADH) will also be increased, except in some cases of anterior open bite.

The upper and lower posterior dentoalveolar heights (UPDH and LPDH) can be recorded from the tips of the mesial cusps of the upper and lower molars (UMC and LMC) to the maxillary and mandibular planes respectively.

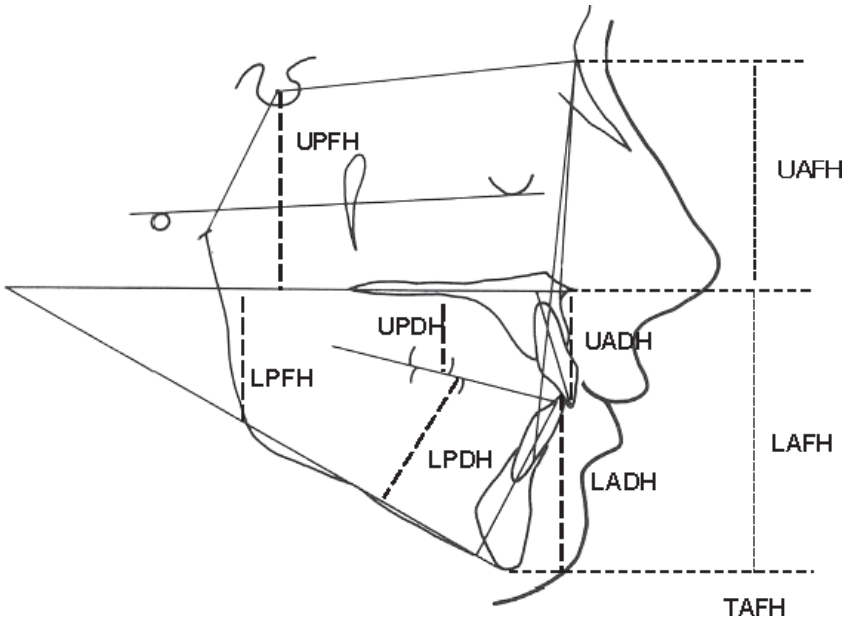

Figure 2.3 Linear measurements for the vertical dimensions. See Table 2.2 for details.

Angular

The relationship of the anterior and posterior face heights is reflected by the angles between the skull base and the maxillary and mandibular planes.

The angle of the maxillary to the mandibular plane (MxP/MP) is normally 27 ± 4°. This angle is important because as with the posterior face height measurement, it reflects the surgically important pterygomasseteric sling length (muscle, fascia and ligaments). For instance, a patient with a high angle, i.e. greater than 35°, tends to have a relatively short posterior face height and therefore posterior musculo-ligamentous height. Any attempt to stretch this posterior connective tissue by rotating the anterior body of the mandible upwards, in an anticlockwise direction, around a fulcrum produced

by the posterior molar occlusion, is doomed to failure and will lead to early surgical relapse.

Anteroposterior Relationships

In clinical practice anteroposterior lengths are rarely measured or used to relate the jaws to each other. It has become conventional to study the angular relationship of the jaws to the cranial base (SN). Orientation to the Frankfort plane is also used to compare these structures. However, in extremes of skeletal variation some angular measurements may be misleading. A typical example is the problem of SNA and SNB to analyse the anteroposterior relationship of the maxilla to the mandible (Figure 2.4). In the normal Class I patient, SNA is 81° with a standard deviation of 3°, and the normal maxillary-mandibular relationship (ANB) is 3°. An increased ANB angle suggests a Class II relationship, whereas a negative ANB angle suggests a Class III case. However, variations in the positions of N will influence both the SNA and SNB. For example, with a shorter anterior cranial base length (SN) increasing SNA by 10° alters the ANB angle to 7° giving the impression of a skeletal Class II jaw relationship (Figure 2.4). These variations, due to an "abnormal" SNA, may be corrected by subtracting 0.5° from the ANB angle for every degree by which SNA exceeds the normal value of 81°. In the above example, applying the conversion would reduce the apparent ANB angle from 7° to 2°. Conversely, where the SNA is below the normal value of 81°, 0.5° should be added to the ANB angle for every degree that SNA is below the normal figure. This conversion is only possible providing the SN/MxP values are within the normal range of $8^0 \pm 3^0$. If the SN/MxP value is outside this range then alternate analyses of the anteroposterior skeletal pattern should be employed as detailed in cephalometric specific texts.

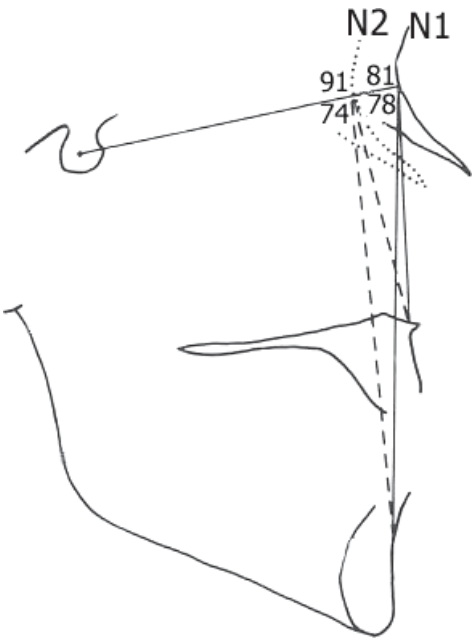

Figure 2.4 Cephalometric idiosyncrasies. The tracing shows how variations in skull base length (SN) can influence the angular values relating to A point and B point. With SNA 81° and SNB 78°, ANB is 3° indicating a Class I skeletal pattern (continuous line). With an unchanged jaw relationship, a shorter skull base SN (from N1 to N2) changes the SNA and SNB angles, i.e. SNA 91°, SNB 74° and ANB becomes 7°, suggesting a Class II skeletal pattern (broken line).

Analysis of the Incisor Angulations to the Maxillary and Mandibular Bases

Skeletal deformity with its disturbed muscular skeletal pattern will lead to changes in the angles of the upper incisor to the maxillary plane (UI/MxP) and the lower incisor to the mandibular plane (LI/MP) adding a degree of secondary deformity (dental compensation) to any underlying skeletal discrepancy (Figure 2.5). Thus with a mandibular prognathism the lower incisors tend to be retroclined and the maxillary incisors proclined. In some severe Class II deformities the lower lip may become trapped behind the maxillary

Figure 2.5 Dental compensation in a Class III case with proclination of the maxillary incisors and retroclination of the mandibular incisor teeth. See also Figures 4.8 and 4.9.

incisors with the effect that the upper incisors may actually procline, whilst the lower incisors may be retroclined. This "compensation" requires correction, i.e decompensation, as part of the overall treatment plan.

The Surgical Application of Cephalometry

Caution must be used in the interpretation of precise linear measurements such as the anterior face height. Measurements from different samples can vary by as much as 10 mm. This problem is diminished when the components are expressed as a percentage. In addition, too many measurements may cause confusion, defeating the purpose of the analysis. However, the exercise is an important means of studying the clinical problem. The geometry can also be checked by the use of diagnostic templates.