

## ***Introduction***

Cephalometric radiography is a standardized method of production of skull radiographs, which are useful in making measurements of the cranium and the orofacial complex. This method aims to study various components of the face and relate them to each other and to the cranium to see whether there is balance and harmony between these components or not. In 1931, Hofrath in Germany and Broadbent in USA simultaneously developed standardized methods for the production of cephalometric radiographs, using special holder known as cephalostat.

Nowadays digital cephalometrics can be used to provide a very quick way of analysis and allowed a great advancement in the field of orthodontic diagnosis and growth prediction. There are two main types of cephalometric radiography:

1. *True lateral cephalometric: it is commonly used for orthodontic analyses.*
2. *Frontal cephalometric (posteroanterior): usually used to assess the symmetry of the face.*

A cephalometric apparatus consists of an X-ray source, a cephalostat or head holding device, and a cassette holder/sensor. They should be at a fixed distance to each other to achieve the standardization which is necessary in order to be able to compare the cephalometric radiographs of one patient taken on different locations, or those of different individuals.

The Cephalostat consists of two ear rods designed to fit into the patient's external auditory meatus to prevent movement of the head in horizontal plane and so that the central beam of the machine is directed toward the ear rods. The position of the head in the vertical axis is standardized by ensuring that the patient Frankfort plane is horizontal. This can be done manually by positioning the subject with the aid of the nasal rod or, alternatively, by placing a mirror some distance away leveled with the patient's head and asking him to look into his own eyes. This is termed the natural head position.

The patient should be in centric occlusion and the distance from the X-ray source to the subjects' midsagittal plane is kept at 5 feet. The distance from the midsagittal plane to the cassette/sensor can vary in different machines (0.5-1 foot), but must be the same for each patient every time. Some magnification usually of the order of 7-8% is inevitable with a lateral cephalometric film.

To give a better definition of the soft tissue outline of the face, either thin layer of barium paste can be placed down the central axis of the face or an aluminum wedge positioned so as to attenuate the beam in that area.



Figure 1: cephalometric x ray.



Figure 2: Cephalometric arrangement.

## **Indications for Cephalometric Evaluation**

### ***1. An Aid to Diagnosis and Treatment Planning***

It is possible to carry out successful orthodontic treatment without taking a cephalometric radiograph, particularly in Class I malocclusions. However, cephalometric analysis may provide useful information for assessing the etiology of malocclusion and for planning treatment, especially the differentiation between skeletal and dental malrelationships. The benefit to the patient in terms of the additional information gained must be weighed against the radiation dose. Therefore, pre-treatment lateral cephalometric radiograph may be best limited to patients with a skeletal discrepancy and/or where anteroposterior movement of the incisors is planned.

In a small proportion of patients, it may be helpful to monitor growth to aid the planning and timing of treatment by taking serial cephalometric radiographs and whether the case can be treated by growth modification or orthognathic surgery. Although again, the dosage to the patient must be justifiable. In addition, a lateral view is often helpful in the accurate localization of unerupted displaced teeth and other pathology.

### ***2. A Pretreatment Record***

A lateral cephalometric radiograph is useful in providing a baseline record prior to the placement of appliances, particularly where growth modification or movement of the upper and lower incisors is planned.

### ***3. Monitoring the Progress of Treatment***

In the management of severe malocclusion, where tooth movement is occurring in all three planes of space (e.g. treatments involving functional appliances, or upper and lower fixed appliances), it may be helpful to take a lateral cephalometric radiograph during treatment to monitor incisor inclinations and anchorage requirements.

A lateral cephalometric radiograph taken during treatment to assess treatment progress may also provide information about the movement of unerupted teeth and upper incisor root resorption. However, intra-oral images are preferred as greater detail is gained with lower radiation dose.

### ***4. End of Orthodontic Treatment***

For patients with severe malocclusions, a lateral cephalometric radiograph may be taken near the end of active treatment to check all treatment objectives have been met and to aid planning of retention. Post-treatment lateral cephalometric radiographs are usually restricted to patients where there is uncertainty around the stability of the outcome as a result of the treatment methods used, or a concern around future unfavorable growth.

## **5. Research Purposes**

A great deal of information has been obtained about growth and development by longitudinal studies which involved taking serial cephalometric radiographs from birth to the late teens or beyond. While the data provided by previous investigations are still used for reference purposes, it is no longer ethically possible to repeat this type of study due to the risks associated with ionizing radiation. However, views taken routinely during the course of orthodontic diagnosis and treatment for clinical care may be used to study the effects of growth and treatment if the necessary consent and ethical approval are obtained.

### **Tracing Technique and Digitizing**

Before starting a tracing, it is important to examine the radiograph for any abnormalities or pathology. For example, a pituitary tumor could result in an increase in the size of the Sella turcica.

Hand tracing: acetate tracing sheet should be secured onto the film with masking tape. The tracing should be carried out in a darkened room on a light viewing box, and a sharp pencil used for the tracing. It should begin with a general inspection of the cephalogram and then locate and identify standard landmarks. This is followed by tracing the anatomic structures in a logical sequence, and finally constructing derived landmarks and lines.

Digitization: for digital radiographs the points can be entered directly by a mouse click. Specialized software can then be employed to utilize the information entered to produce a tracing and/or the analysis of choice.

Note: For landmarks which are bilateral, an average of the two should be taken unless they are directly superimposed.

### **Cephalometric Analysis: General Points**

There are different cephalometric analyses, but no single method is sufficient for all purposes and that all have their drawbacks.

Cephalometric analysis is often based upon comparing the values obtained for certain measurements for a particular individual (or group of individuals) with the average values for their population (e.g. Caucasians). Cephalometric analysis is also of value in identifying the component parts of a malocclusion and probable etiological factors - it is useful when a tracing is finished to reflect why that individual has that particular malocclusion. However, it is important not to fall into the trap of giving more credence to cephalometric analysis than it actually merits, it should always be remembered that it is an adjunctive tool to clinical diagnosis, and differences of cephalometric values from the average are not in themselves an indication for treatment, particularly as variations from normal in a specific value may be compensated for elsewhere in the facial skeleton or cranial base. In addition, cephalometric errors can occur owing to incorrect positioning of the patient and incorrect identification of landmarks.

A lateral cephalometric radiograph is a slightly magnified, two-dimensional representation of three-dimensional object (the patient). For this reason, angular measurements are generally to be preferred to linear measurements, as the element of magnification is less important.

#### Cephalometric Norms for Caucasians (Eastman Standard)

Measurements	Value
SNA	$81^{\circ} \pm 3^{\circ}$
SNB	$78^{\circ} \pm 3^{\circ}$
ANB	$3^{\circ} \pm 2^{\circ}$
U1/Maxillary Plane	$109^{\circ} \pm 6^{\circ}$
L1/Mandibular Plane	$93^{\circ} \pm 6^{\circ}$
Inter-incisal angle	$135^{\circ} \pm 10^{\circ}$
MMPA	$27^{\circ} \pm 4^{\circ}$

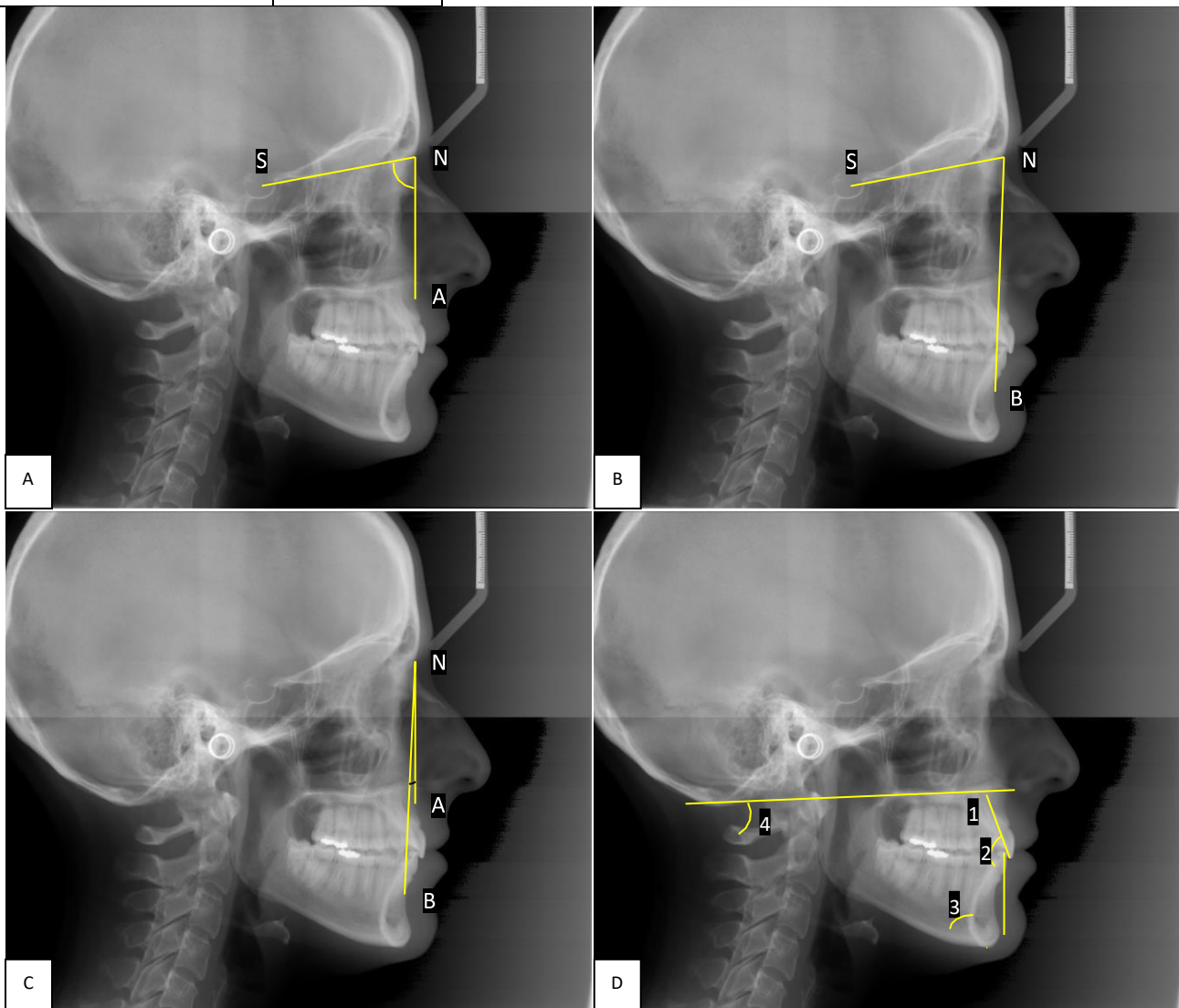


Figure 3: A: SNA. B: SNB. C: ANB. D: (1) U1/Maxillary plane angle, (2) Inter-incisal angle, (3) L1/Mandibular plane angle, (4) Maxillary/Mandibular plane angle.

## Commonly used Cephalometric Points and Reference Lines

### **Points**

- 1) Point A (A): the point of deepest concavity on the anterior profile of the maxilla. It is also called subspinale. This point is taken to represent the anterior limit of the maxilla. It is located on alveolar bone and is liable to change in position with tooth movement and growth.
- 2) Point B (B): the point of deepest concavity on the anterior surface of the mandible. It is also called supramentale. It is also located on alveolar bone and is liable to change in position with tooth movement and growth.
- 3) Anterior nasal spine (ANS): the tip of the anterior process of the maxilla, situated at the lower margin of the nasal aperture.
- 4) Posterior nasal spine (PNS): the tip of the posterior nasal spine of the maxilla. This point is often obscured by the developing third molars, but lies directly below the pterygomaxillary fissure.
- 5) Gonion (Go): the most posterior inferior point on the angle of the mandible. This point can be determined more accurately by bisecting the angle formed by the tangents from the posterior border of the ramus and the inferior border of the mandible.
- 6) Menton (Me): the lowest point on the mandibular symphysis.
- 7) Pogonion (Pog): the most anterior point on the mandibular symphysis.
- 8) Nasion (N): the most anterior point on the frontonasal suture. If it is difficult to locate the nasion, the point of deepest concavity at the intersection of the frontal and nasal bones can be used instead.
- 9) Orbitale (Or): the most inferior anterior point on the margin of the orbit. It can be a little tricky to determine radiographically.
- 10) Porion (Po): the uppermost outermost point on the bony external auditory meatus. This landmark can be obscured by the ear rods of the cephalostat and some advocate tracing these instead (mechanical porion).
- 11) Sella (S): the midpoint of the sella turcica.

## Horizontal Reference Lines

- SN line: the line connecting the midpoint of Sella turcica with Nasion, taken to represent the cranial base.
- Frankfort plane: the line joining Porion and Orbitale. This plane is difficult to record accurately because of the problems inherent in determining Orbitale and Porion.
- Maxillary plane: the line joining the ANS with the PNS. Where it is difficult to determine ANS and PNS accurately, a line parallel to the nasal floor can be used instead.
- Mandibular plane: the line joining Gonion and Menton.
- Functional occlusal plane (FOP): the line drawn between the cusp tips of the permanent molars and premolars (or deciduous molars in mixed dentition).

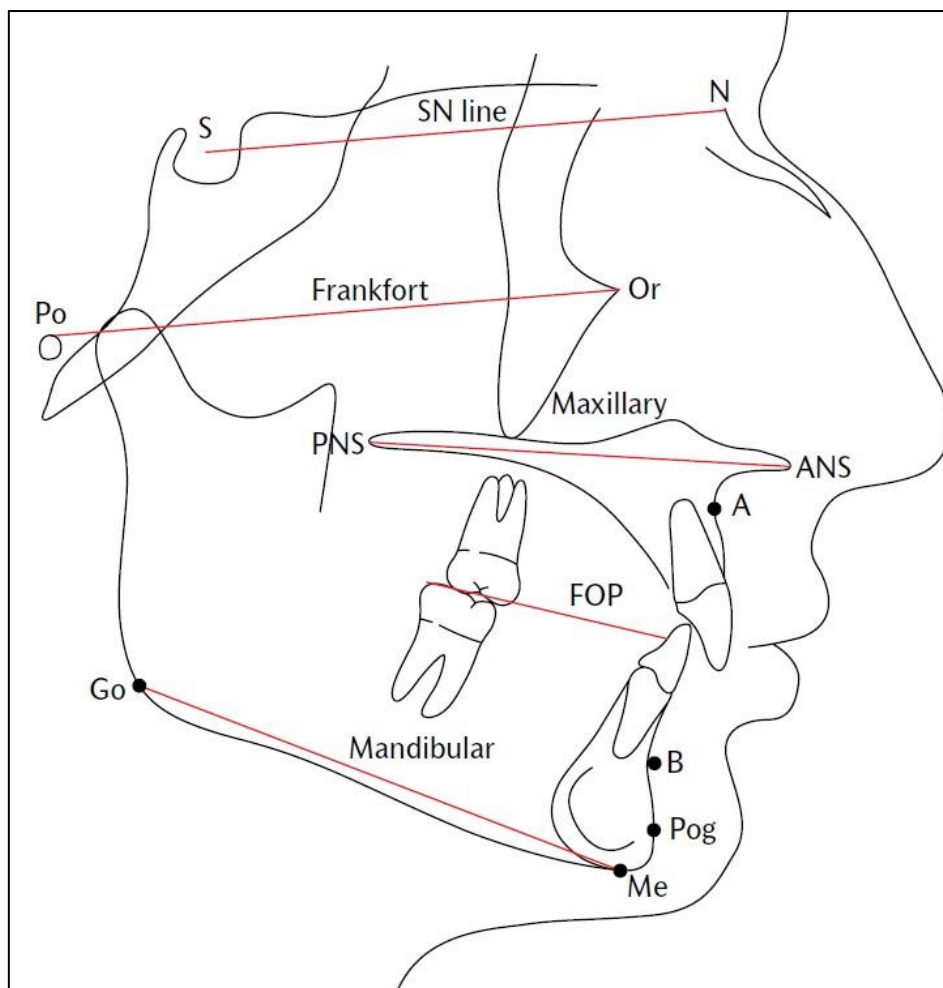


Figure 4: Commonly used cephalometric points and lines.

Note: The horizontal reference lines used for growth pattern assessment.

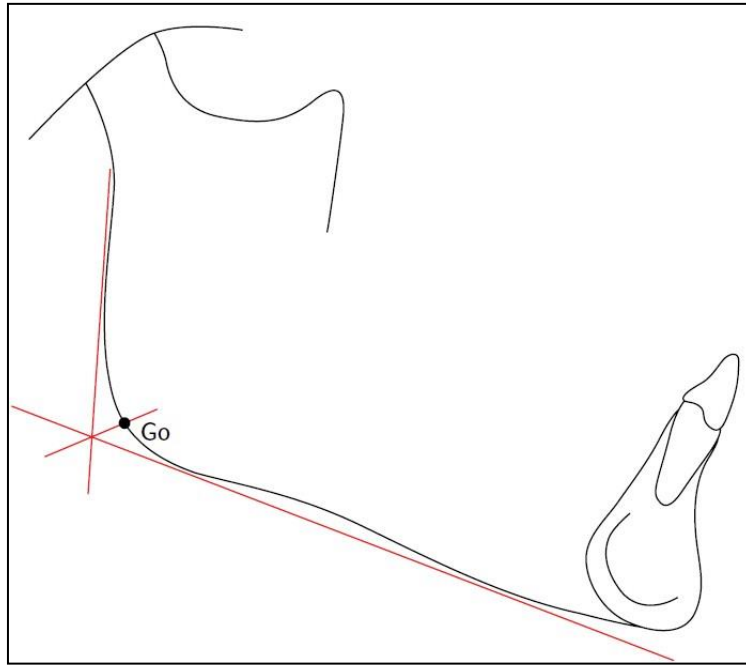


Figure 5: Construction of Goniometer.

### ***Vertical Reference Lines***

A-Pog Line: it is a line from point A to the Pogonion.

Facial Plane: it is a line from the Nasion to the Pogonion.

Note: The vertical reference lines used mainly for incisors position assessment.

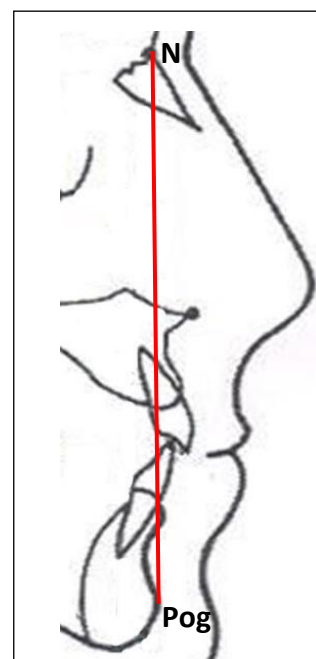
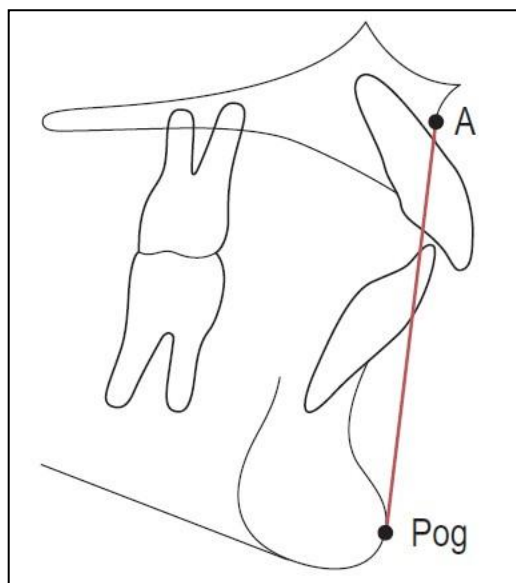


Figure 6: Left: A-Pog line. Right: Facial plane (N-Pog).

## Antero-Posterior Skeletal Pattern

### Angle ANB

To enable comparison of the position of the maxilla and mandible, it is necessary to have a fixed point or plane. The skeletal pattern is often determined cephalometrically by comparing the relationship of the maxilla and mandible with the cranial base by means of angles SNA and SNB. The difference between these two measurements angle ANB is classified broadly as follows:

$ANB < 2^\circ$  Class III

$2^\circ \leq ANB \leq 4^\circ$  Class I

$ANB > 4^\circ$  Class II

However, this approach assumes (incorrectly in some cases) that the cranial base as indicated by the line SN, is a reliable basis for comparison and that points A and B are indicative of maxillary and mandibular basal bone. Variations in the positions of Nasion can also affect angles SNA and SNB and hence the difference ANB. If SNA is increased or reduced from the average value this could be due to either a discrepancy in the position of the maxilla (as indicated by point A) or Nasion, and correction of ANB angle may be required.

### Wits' Analysis

This analysis compares the relationship of the maxilla and mandible with the occlusal plane. There are several definitions of the occlusal plane, but for the purposes of the Wits analysis it is taken to be a line drawn between the cusp tips of the molars and premolars (or deciduous molars), known as the FOP. Perpendicular lines from both point A and point B are drawn to the FOP to give points AO and BO. The distance between AO and BO is then measured. The average values are  $-1$  mm for males and  $0$  mm for females. The main drawback to the Wits analysis is that the FOP is not easy to locate, which affects the accuracy and reproducibility of the Wits analysis. A slight difference in the angulation of the FOP can have a marked effect on the relative positions of AO and BO.

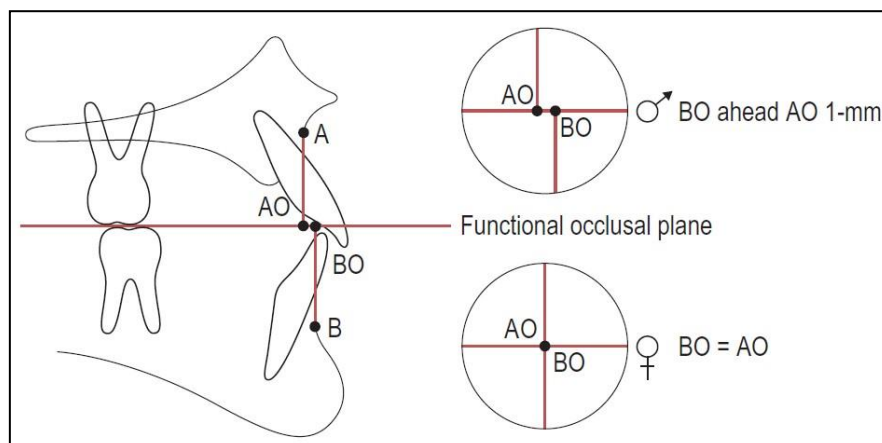


Figure 7: Wits' analysis.

## Vertical Skeletal Pattern

There are many different ways of assessing vertical skeletal proportions. The more commonly used include the following:

### 1. Maxillary Mandibular Plane Angle (MMPA)

The average angle between the maxillary plane and the mandibular plane is  $27^\circ \pm 4^\circ$ .

### 2. Frankfort Mandibular Plane Angle (FMA)

The average of this angle is  $28^\circ \pm 4^\circ$ . However, the maxillary plane is easier to locate accurately and therefore the MMPA is preferred.

### 3. SN-Mandibular Plane Angle (SN-MP)

The average of this angle is  $32^\circ$ .

### 4. Anterior Facial Proportion

This is the ratio of the lower anterior facial height (maxillary plane to Menton) to the total anterior facial height (Nasion to Menton) measured perpendicularly from the maxillary plane (average value is 55%).

$$\text{Anterior Facial Proportion} = \frac{\text{Lower anterior facial height}}{\text{Total anterior facial height}} \times 100$$

Normal value = 55%

### 5. Facial Heights

Posterior facial height (S-Go)  $\times$  100/ anterior facial height (N-Me) = 62-65% (Jarabak ratio). A smaller value means shorter posterior face height (or longer anterior facial height) and vertical growth. Higher value means greater posterior face height (or shorter anterior facial height) and horizontal growth.

$$\text{Jarabak Ratio} = \frac{\text{PFH}}{\text{AFH}} \times 100$$

Normal value = 62-65%

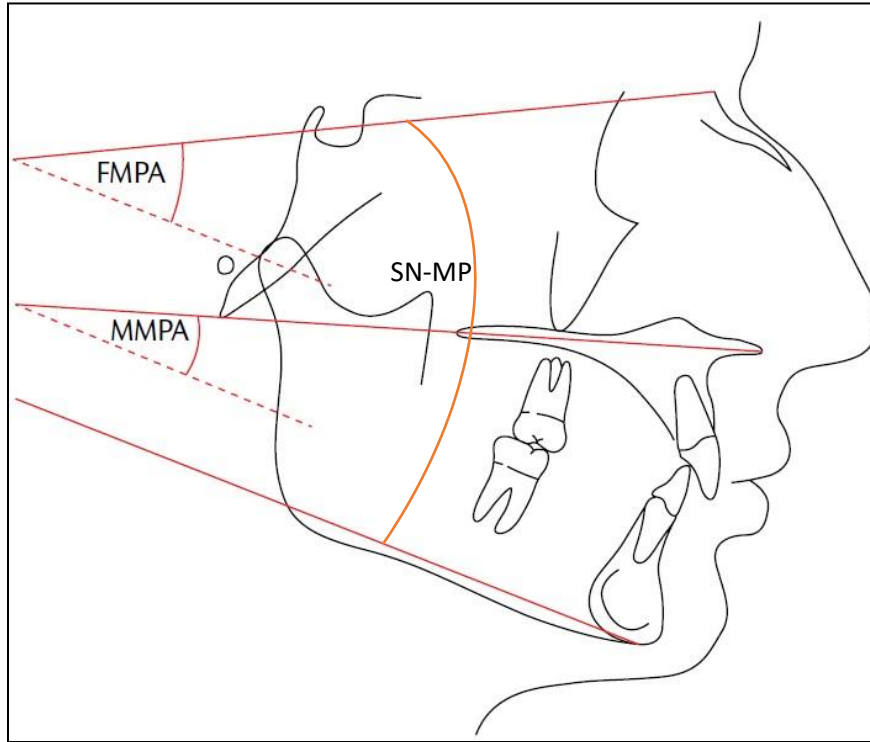


Figure 8: Vertical skeletal angles.

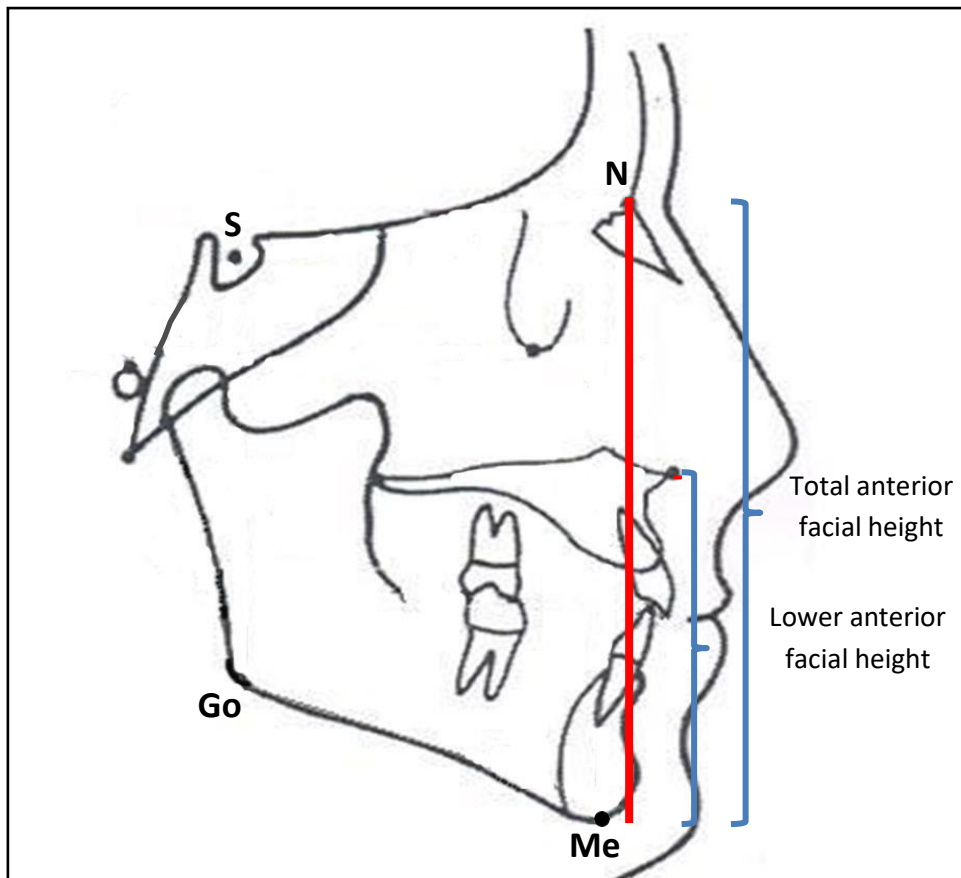


Figure 9: Anterior facial proportion.

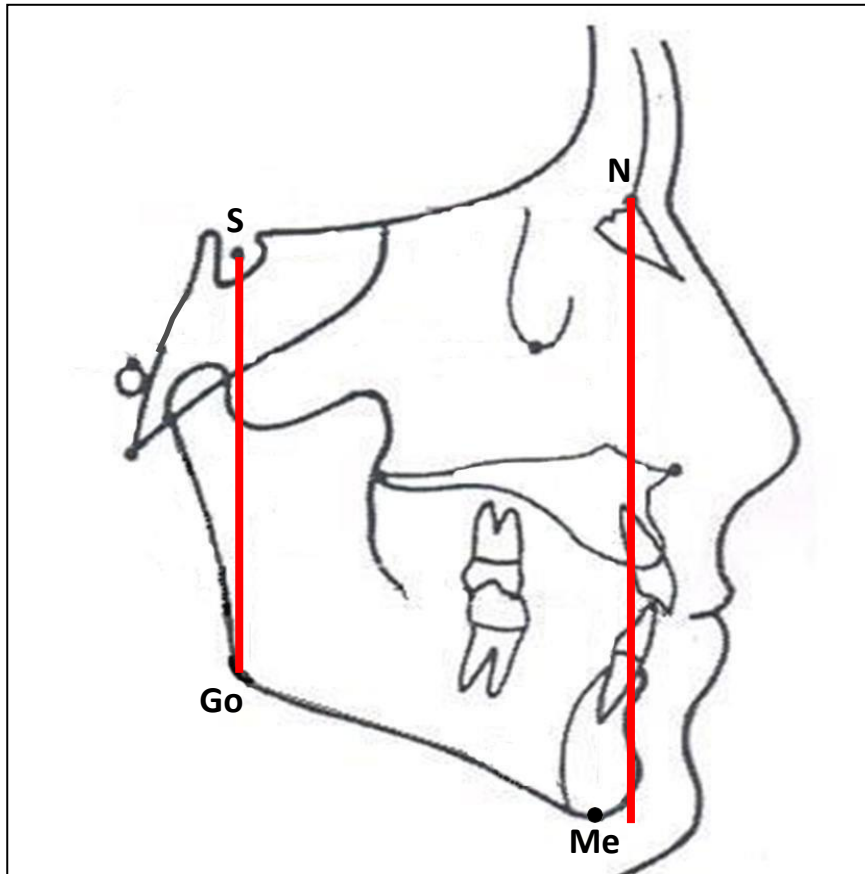


Figure 10: Jarabak ratio.

### ***Incisor Position***

The average value for the angle formed between the upper incisor and the maxillary plane is  $109^\circ \pm 6^\circ$ . The average value for lower incisor to mandibular plane angle is  $93^\circ \pm 6^\circ$  for an individual with an average MMPA  $27^\circ$ .

However, there is a relationship between the MMPA and the lower incisor angle: as the MMPA increase, the lower incisors become more retroclined. As the sum of the average MMPA ( $27^\circ$ ) and the average lower incisor angle ( $93^\circ$ ) equals  $120^\circ$ , an alternative way of deriving the 'average' lower incisor angulation for an individual is to subtract the MMPA from  $120^\circ$ : Lower incisor angle =  $120^\circ - \text{MMPA}$ .

### ***Soft Tissue Analysis***

This is particularly important in diagnosis and planning prior to orthognathic surgery. As with other elements of cephalometric analysis, there are large numbers of different analyses of varying complexity. The more commonly used measurements are:

### Nasolabial Angle

It is formed by two lines, a columella tangent and an upper lip tangent. Normal range for this angle is  $102^{\circ} \pm 8^{\circ}$ . This angle should be studied prior to orthodontic extraction and retraction – if it alters to unesthetic value, extraction and retraction should be avoided.

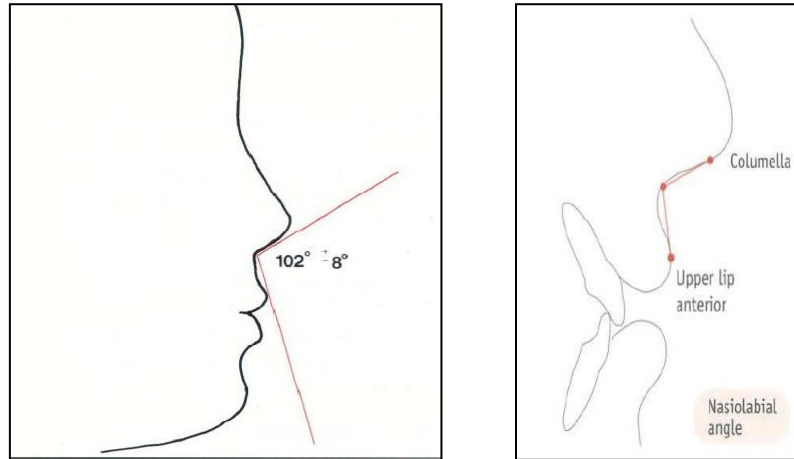


Figure 11: Nasolabial angle.

### Rickett's E-Line

The E-line is drawn from the soft tissue pogonion to the tip of the nose. Normally the upper lip is about 4 mm behind this reference line while the lower lip lies about 2 mm behind it.

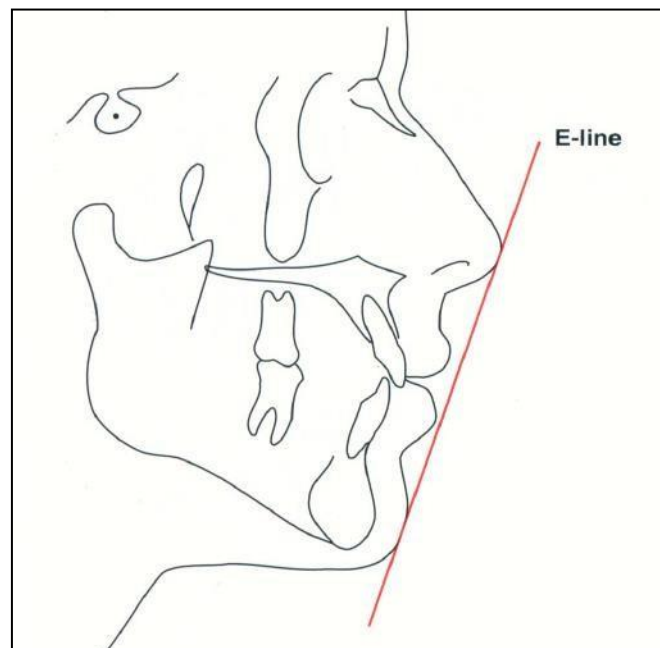


Figure 12: Rickett's E-plane.

## Steiner's S-Line

The S-line is drawn from soft tissue pogonion to the midpoint of S-shaped curve between Subnasale and nasal tip. The lips should touch the reference line. Lips lying behind this reference line are too flat, while those lying anterior to it are too prominent.

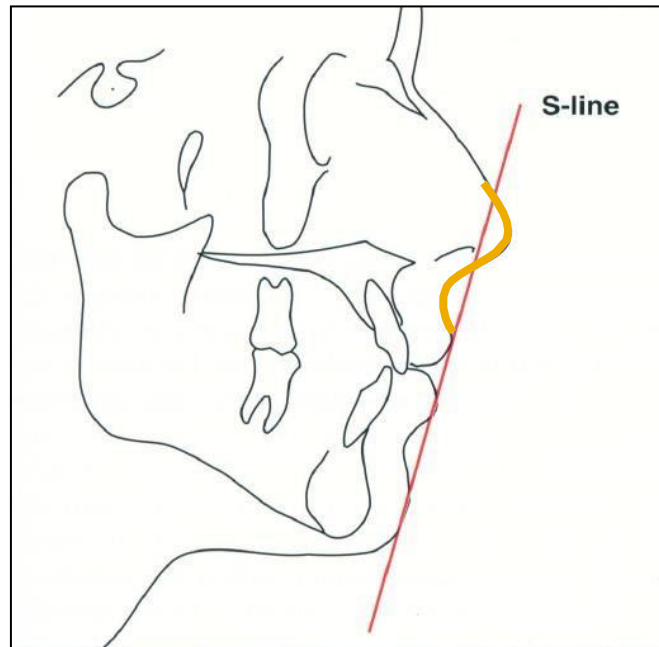


Figure 13: Steiner's S-plane.

Note: The lip position (upper or lower) could be varied according to the age, sex and ethnic group

### *Assessing Growth and Treatment Changes*

The advantage of standardizing lateral cephalometric radiograph is that it is then possible to compare radiographs either of groups of patients for research purposes or of the same patient over time to evaluate growth and treatment changes. In some cases, it may be helpful to monitor growth of a patient over time before deciding upon a treatment plan, particularly if unfavorable growth would result in a malocclusion that could not be treated by orthodontics alone. To enable accurate comparison of radiographs, it is necessary to have a fixed point or reference line, which does not change with time or growth. This poses a dilemma, as there are no natural fixed points or planes within the face and skull. This should be borne in mind when interpreting the differences seen on superimposed cephalometric radiographs.

## **Cranial Base**

The SN line is taken in cephalometrics as approximating to the cranial base. However, growth does occur at Nasion, and therefore superimpositions on this line for the purpose of evaluating changes over time should be based at Sella. Unfortunately, growth at Nasion does not always conveniently occur along the SN line; if Nasion moves upwards or downwards with growth, this will introduce a rotational error in comparisons of tracings superimposed on SN. It is more accurate to use the outline of the cranial base as little changes occur in the anterior cranial base after 7 years of age. However, a clear radiograph and a good knowledge of anatomy are required to do this reliably.

## **The Maxilla**

Growth of the maxilla occurs on all surfaces by periosteal remodeling. For the purpose of interpretation of growth and/or treatment changes the least affected surface is the anterior contour of the zygomatic process. This is the preferred structure for superimposition, however, the maxillary plane registered at the PNS is commonly used as it is easier to identify.

## **The Mandible**

The mandibular plane is sometimes used for superimposition of the mandible; however, this can be highly erroneous due to significant remodeling in the lower border and angle of mandible. The landmarks that change least with growth and are therefore preferred for superimposition are as follows (in order of usefulness):

- The innermost surface of the cortical bone of inferior border of the symphysis.
- The anterior contour of the chin.
- The outline of the inferior dental canal.
- The crypt of the developing third permanent molars from the time of mineralization of the crown until root formation begins.
- The tip of the chin.