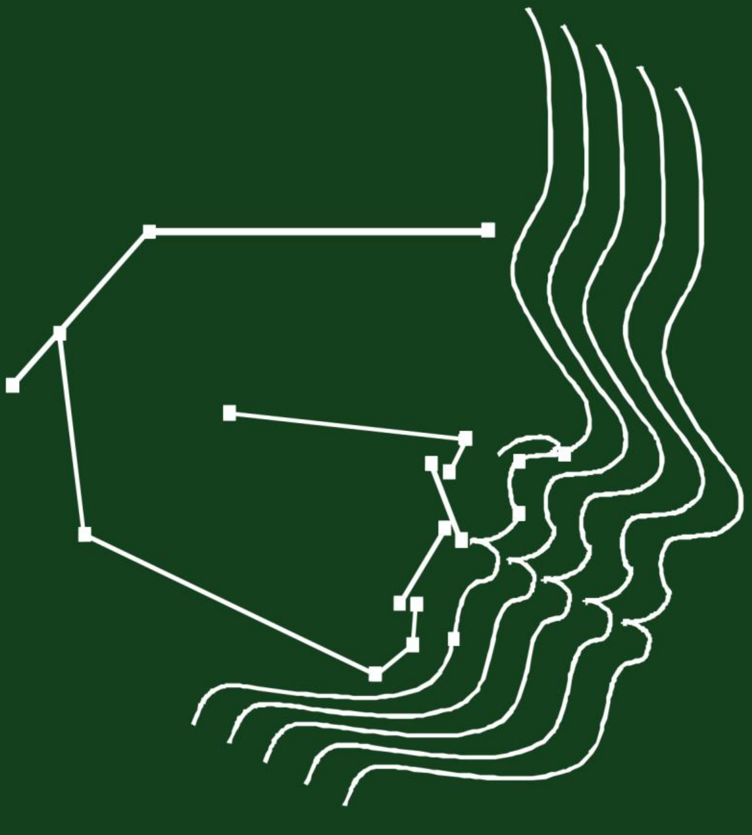
Dietmar Segner
Asbjørn Hasund

Individualized Cephalometrics

5th edition

Translated by
Paula Toll



DIETMAR SEGNER

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Hamburg

2024

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5th updated edition; translated into English

 Dietmar Segner, Verlag und Vertrieb,
Herwigredder 110c, D-22559 Hamburg, Germany
info@segner-online.de

Translation: Paula Toll

Printed: available only in digital format

ISBN 3-9802709-5-5

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Preface

The concept of individualized cephalometrics in its current refined form was introduced in the first edition of this book in 1991 in Germany. Thousands of students and practicing clinicians have experienced its benefits and have employed it for the benefit of their patients and themselves. While it is more common in these times to evaluate diagnostic measurements with special regards to the individuality of a person, it was a rather new and uncommon concept in the last quarter of the 20th century.

It was my colleague Prof. Asbjørn Hasund who introduced individualization into orthodontic cephalometric diagnosis as part of the Bergen-Technique, the predecessor of the Individualized Cephalometrics. Sadly, Prof. Asbjørn Hasund passed away on August 20, 2022. His contribution to orthodontic diagnosis and treatment technique cannot be overestimated. I would therefore like to dedicate this updated and translated edition of the book to him.

People are not all the same; there are variations in size and form as well as in the individuals' physiology and biochemistry. While common sense readily accepts that body height and weight measures for males and females need separate standards for evaluation, and that the medication dosage needs to be related to the body weight, the understanding that individual cephalometric measurements cannot be related to one universal population mean is much more recent. It is precisely this that requires an individualized approach. Each patient needs a reference to set his or her measurements in relation to for a meaningful and valuable diagnosis and this reference needs to be individually determined. It is not important if a certain angle is large or small, it is important if it is too large in relation to other measurements, too large for a harmonious whole.

Individualized Cephalometrics has been translated into the Polish and Czech languages, but for various reasons not yet into English, limiting access of the international community to this important diagnostic tool. Therefore it was a pleasure when Paula Toll approached me and volunteered to implement the translation into English with proofreading support by Richard Foster.

In order to evaluate, what relation would be expected as harmonious and suitable for a good dentition it is also important to use a suitable reference population. In this book a group of European individuals was used to optimally make use of the described analysis in Europe and for patients of European descent. However, the principles described can be and have been applied to other ethnic groups, for example for Filipinos. It would be advantageous if this English translation and the availability in digital form makes it possible for more people in more countries to benefit from *Individualized Cephalometrics*.

Dietmar Segner

Hamburg, February 2024

A. Introduction

There are many methods for analyzing lateral cephalograms; one could almost say they are "as common as fish in the sea." Each method has its own peculiarities. With their large number, it is clear that many of them overlap. The large number of analytical methods is limited only by the number of usefully measurable variables in a cephalometric image.

Therefore, the aim of this book cannot be to present a completely new, completely different method to perform cephalometric analysis. Nor does it claim to be the only correct or even the best one. Such statements would be inappropriate, since the analysis is only a tool for the practitioner. A lot depends on how familiar the practitioner is with the diagnostic approach and how much they know what can be expected from it - and what not.

A practitioner with sufficient clinical experience most likely can provide good treatment plans and results with a minimum of analytical measurements and analysis.

The evaluation method described in the following chapters offers certain advantages over many other approaches due to its emphasis on individuality.

In this context it appears more important that the orthodontic practitioners, especially in the first years of their activity, gain a tool that allows them to use the information provided in the cephalometric image as optimally and efficiently as possible. Even an experienced specialist will not omit this tool; on the contrary, they will use it as the very basis for their detailed treatment planning.

Moreover, it is important that the cephalometric evaluation reveals the possibilities and limitations of orthodontic therapy. These limitations become evident in the borderline cases of orthognathic surgery, as well as in the distinction as to whether a case ought to be treated by a practitioner who is only partially practicing orthodontics or whether it is better to refer the case to the specialist. These limits are primarily determined by craniofacial morphology and can therefore only be detected by an appropriate cephalometric evaluation.

Also, the dentist who is not an expert in orthodontics may employ the described principles of cephalometric analysis not only in their task as the "initial recognizer" of an anomaly, but also in their general dental practice. This is true for major alterations of the occlusal plane including the planning for total dental prosthesis. In addition to the registration of mandibular articulation, prosthodontists are increasingly using radiographs, including cephalograms as a diagnostic tool.

The present cephalometric analysis differs from many others in that it gives special importance to the individuality of each patient. A conscious decision has been made not to use population mean values, because the goal of orthodontic therapy cannot be to treat every patient as an average "norm" person.

A similar line of thought was already expressed by A. M. Schwarz in his book *Lehrgang der Gebißregelung*. He clearly distinguished between the "average (mean) value" and the "norm" value. He also writes: "The top priority here is the imperative to lessen the peculiarities of the disfigurement so as to make it as discreet as possible. This is often achieved –but by no means always– by bringing the malformed jaws closer to their average positions."

Hence, it is clear that he recognized already more than 70 years ago that one must employ specialized standards for each particular case. Unfortunately, it has proved to be not quite as easy to establish these standards for the individual case. Therefore, even in the context of a multitude of mean-value studies, comparisons have usually been made only with population averages.

The present book shows, nevertheless, how by application of simple mathematical-statistical methods both diagnostic conclusions and treatment plans can be made. They can make clear assessments, despite, or precisely because of, taking into account the individual circumstances of each patient.

The importance of the individualization of cephalometric values is so highly regarded by us that we have emphasized this fact in the choice of the title of this book.

Only common and easily measurable variables are used where the significance and meaning can be immediately recognized. Complicated constructions such as hard-to-define cephalometric landmarks and inconsistent reference lines were deliberately avoided. This evaluation method has proven to be a clear, straightforward and practical approach, both with computer-assisted analysis and with purely manual application so that the results provide clinically useful information.

All evidence and individualized treatment guidelines are based on scientific studies on Central and Northern Europeans. Here, the fundamental principle is to observe how nature, without the intervention of an orthodontist, succeeds in creating good or even perfect occlusions irrespective of individual variations in facial morphology. From the elaborated principles diagnostic values and concepts for treatment planning are developed.

After an overview of the technical aspects of cephalometric imaging, a definition and description of the reference points used is given.

This is followed by a specification of the variables, how they are measured, and what clinical significance they carry.

Finally, the assessment of the measured values and the individualization of standards are discussed in detail. The topic of growth is addressed, as far as it is important for the cephalometric analysis. Finally, the principles are discussed based on some examples from the clinic.

B. Technical part

1. Radiographic Technique

The foundation of any cephalometric analysis is a lateral cephalogram. Since the radiographs are evaluated on a metric scale and the measured values are bound to directly influence the modality of treatment, radiographs for cephalometric analysis must have minimal geometric aberrations and good reproducibility. This is in addition to the standard quality requirements such as, among other things, good detectability of the structures. Treatment planning that is based on a cephalometric image is possible only if a second image taken at the same time would lead to the same diagnosis and thus to the same treatment concept.

General Set-up

A cephalostat (or craniostat) consists of the actual X-ray machine, the head holder and a sensor (flat panel detector) or film cassette holder (see Fig. 1). These three components are firmly connected to one another so that defined and reproducible conditions are maintained for each radiograph. The X-ray machine consists of an X-ray tube of sufficient output with a specific aperture adjusted to the size of the sensor/film cassette. The head positioning and stabilizing apparatus consists of two rods, the distance between which can be varied. They each have a conical head (for ear rod covers), facing each other at the lower end. These ear rods are carefully inserted into the patient's external auditory meatuses, slowly reducing the distance between the rods until the patient's head is fixed in place to the extent that it can only make nodding movements along the axis that passes between the auditory meatuses. The sensor/film cassette holder is placed close to the head positioning and stabilizing apparatus in such a way that the film plane is exactly perpendicular to the longitudinal axis of the apparatus.

Fig. 1 Head holder in a cephalometric X-ray machne. The arrow marks one of the ear rod holders.

In theory, it is possible to perform X-rays while the patient is sitting or standing. The advantage of the standing method allows the patient to be X-rayed in the natural head position (flexion of the neck). It is essential to be able to adjust the apparatus to the patient's height, so either the unit itself or the seat or platform on which the patient is placed must be easily adjustable in height. If the setup does not take into account the natural head position, the patient is usually positioned according to the Frankfort horizontal.

The exact alignment of the apparatus, and correspondingly that of the patient, must be controlled on a regular basis. On the one hand, the rods of the head holder may deform due to the application of too much force, and on the other hand, the head holder may have some degree of interplay of movement. It is usually possible to

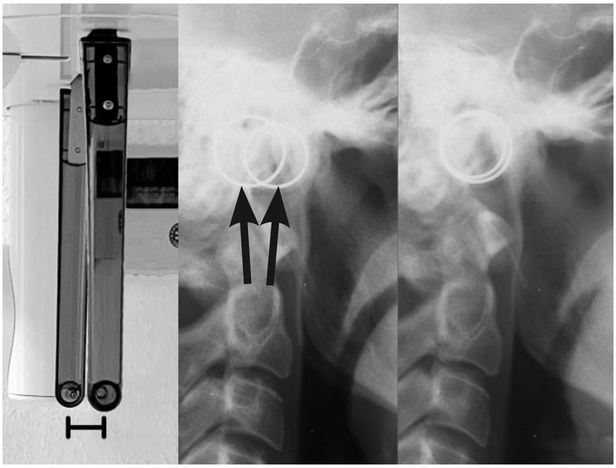


Fig. 2 Wrong position or deformation of the ear rods (left) invitably results in undesirable double contours (center). Right picture shows aligned ear rods and minimal double contours.

rotate the head holder by 90° in order to be able to take antero-posterior radiographs. If the locking screw is not sufficiently tightened, the rods of the head holder may be moved back and forth by the patient in the range of millimeters. Both play of the head holder and deformation of the ear rod holders cause the ear rods to be out of alignment vertically and/or horizontally when viewed from the X-ray tube (Fig. 2). This error is evident on the radiographs from the appearance of the ear rods on the radiograph. If the ear rods do not overlay one another exactly, the system is not aligned precisely and needs to be adjusted.

<u>Geometric imaging errors</u>

Geometric aberrations are inherent in every X-ray image, it is only their magnitude that can be influenced. The most significant imaging errors are:

1. magnification and emergence of double contours due to the divergence of the X-ray beam

2. blurring

The radiation generated at the anode of the X-ray tube leaves the tube radially. The majority of this radiation is blocked out by the aperture, with only the desired area of the head and neck reached by the X-rays. As the radiation extends from the approximately 1 x 1 cm anode onto the 18x24 cm film, the X-rays that reach the peripheral areas of the film are divergent. Only the central beam, which runs from the anode to the film parallel to the axis of the X-ray machine, strikes the patient's head and the film in a perpendicular path. The divergence of the X-rays causes the image on the film to appear enlarged at the marginal areas when compared to the real size. This occurs in all parts of the head where the sensor/film is not hit exactly perpendicularly which is everywhere except for the central beam. The magnification itself is not the main problem here; rather it is the fact that the parts of the head furthest from the film are projected with a larger magnification factor in comparison to those closer to the film.

The divergence of the X-rays reaching the margins of the X-ray sensor or film, which is predetermined in size, is easily proven to be smaller as the distance between the X-ray source and the patient's head increases. The magnification results from:

$$V = \frac{1}{d - d_1}$$

where V is the magnification factor, d is the distance between the sensor/film and the X-ray tube, and d_1 is the distance between the point to be projected and the sensor/film(Fig. 3). To obtain the percentage of the magnification factor, V must be multiplied by 100. For larger distances d, the gap d_1 is practically negligible, so that the magnification factor is then almost inversely proportional to the distance between sensor/film and tube. Here are two practical examples with common focus-film distances to illustrate this:

Focus-to-film distance	4.00 m	1.70 m
Median plane of the head to the film	0.20 m	0.20 m
Magnification factor	5.26 %	13.3 %

For technical and practical reasons, the focus-to-sensor/film distance cannot be increased as desired. In many clinics the distance is about 1.70 m, while other clinics use a distance of about 4.00 m.

As described above, it is not the magnification factor per se that is the problem, but rather the difference between the magnification factor for the left and right sides of the face. A magnification factor in general is only noticeable when measuring distances and it can easily be eliminated by calculation. Differences between the magnification factors for the right and left sides of the face, however, lead to double projections and inaccuracies in points that only arise when different structures are projected on top of each other. These differences also decrease as focus-film distance is increased, as is shown in Table 1.

Table 1 Difference of the enlargement factors for the right and left facial half related to the focus-film-distance. Many X-ray machines used in private offices use a focus-film-distance of 1.70 m or even less.

Enlargement factors

Distance center of head to film: 12 cm

focus-film distance	1.70 m	4.00 m
median plane	7.6%	3.1%
close to film	3.7%	1.5%
away from film	11.8%	4.7%
difference	8.1%	3.2%

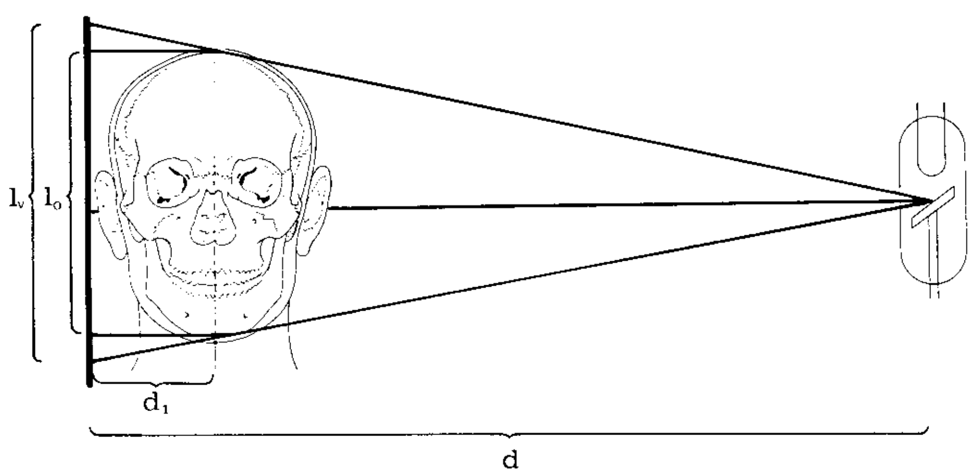


Fig. 3 Enlargement effect during the taking of cephalometric X-rays as a result of the divergence of the rays. V is the enlargement factor, d the focus-film-distance and d_1 the distance of the object from the film.

A certain blurring results from the fact that the anode is not a point source but has an area of 50 mm^2 to 100 mm^2. For this additional reason, a greater focus-sensor/film distance is advantageous. As the focus-film distance increases, so does the required X-ray power. However, there are limitations, one of them being the size of the anode. This sets a limit to the amount of X-ray power generated. A larger distance would require very long exposure times, during which the patient may move, which would produce a blurred image.

Furthermore, high-power X-ray tubes require a great deal of equipment. In practical applications, the focus-to-film distance is usually limited to a range of 1.70 m to 4.00 m.

Fig. 4 Image of the soft tissues on cephalometric X-rays using radiopaque cream (top) and soft tissue filter (bottom).

<u>Sensitivity of radiographic film or digital sensor</u>

Specific requirements are applied to match the film material, filters and radiation dose. The structures which must be viewed and measured to an accuracy of fractions of a millimeter require a very fine cephalometric image. This means that the usual film cassettes with high-speed intensifying screens would produce too coarse a grain. Therefore, in order to keep the grain of the radiograph as fine as possible, slow-speed (detail) intensifying screens are used.

There are structures of highly variable radiopacity in the region of the head and neck that should be easy to identify for the purpose of cephalometric analysis. The area of the Basion and condyles is usually overlaid by the sphenoid bones and is very radiopaque. The same applies for the region of the teeth. In contrast, the area of the Spina nasalis anterior presents itself as being quite radiolucent. It is therefore important that the X-ray film be relatively low in contrast (is "soft") in order for all these structures to be seen clearly.

Moreover, for the purposes of cephalometric analysis, it is not only the bony structures that are of interest, but also the soft tissues in the mid-sagittal plane, namely the soft tissue profile. A radiation intensity that allows clear visualization of the structures in the region of the base of the skull will not permit any effective visualization of the soft tissue profile, even with a low-contrast film.

There are two ways of visualizing the soft tissues. One way of visualizing the soft tissues is to apply a more radiopaque material (zinc ointment) to the soft tissues (Fig. 4, top). The other way of visualizing the soft tissues is to use a filter which covers only the soft tissue profile area (Fig. 4, bottom). It is preferable if this soft tissue filter does not simply cover a vertical strip, but is adapted to the shape of a typical profile. Adapting the position of the filter is important because, in the region of the lips, the soft tissue profile and the incisors are quite close to each other. While the lips as soft tissues require a relatively low radiation intensity for imaging, the clear differentiation of the incisor root from the surrounding bone requires a much higher radiation dose. A similar approach is taken by a method using intensifying screens with varying levels of intensity. Here, the range of maximum gain is extended in the posterior region, while smaller gain sizes are used in the anterior region. The advantage of this method is the continuous transition from maximum to low gain. Thus, no edges of filters, which may cause misinterpretations, are visible in the X-ray image.

With digital radiography similar requirements exist and the manufacturer of the X-ray machine must ensure that through filters, large dynamic range, and/or software based soft tissue highlighting and sharpness enhancement both adjacent hard and soft tissues appear in good quality.

<u>Positioning of the patient</u>

It is possible for the position of the mandible to be influenced by the operator of the X-ray machine as well as by the patient

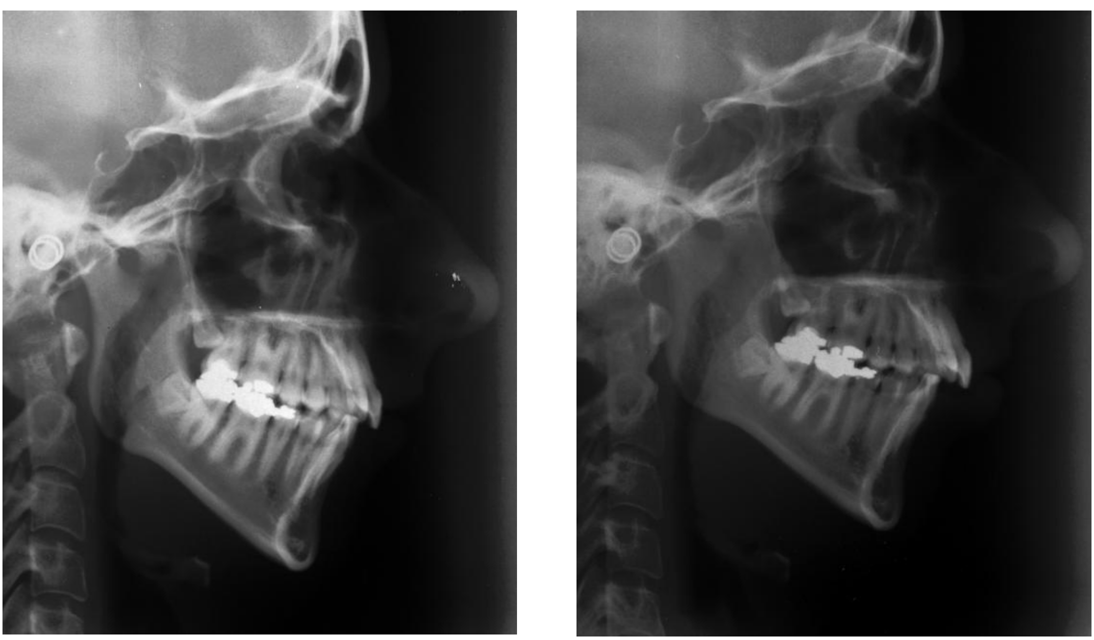


Fig. 5 Lateral cephalogram of a patient, who has unnoticed advanced the mandible during the X-ray exposure. On the right the same patient is shown with a wax bite assuring the retral position during imaging.

themself. This may lead to completely useless results during the cephalometric evaluation. In order to avoid repeated radiographs or incorrect evaluations, the patient's bite position must be thoroughly verified before the radiograph is taken. As a rule, the patient should be X-rayed in the most retral mandibular position that can be achieved without force. Patients with a pronounced mandibular retrognathia or with a forced bite (especially with anterior crossbites and significant asymmetries) tend to slide the mandible unintentionally and unnoticed into a position other than the desired mandibular position (Fig. 5). In such cases, misleading analysis results can easily occur and, consequently, incorrect treatment plans will be made. Given such cases, it is generally advisable to create a wax bite in the correct position before the radiograph is taken and then insert it shortly prior to the imaging.

It goes without saying that the requirements for radiation protection must be complied with. It is often the case, especially during initial consultations, that up-to-date radiographs of the patient have already been made by another party.

A high-quality orthodontic treatment requires both an accurate diagnosis and a continuous monitoring of the treatment process that includes the taking of several radiographs. This sequential production of radiographic records must take place before, during and after treatment, i.e. in the retention and follow-up phases as well. Attention should also be paid to the increasingly stringent documentation requirements with regard to forensic developments.

2. Landmarks used

In order to be able to analyze lateral cephalograms using metric methods and thus be able to make conclusions about the shape and size of the craniofacial region, it is necessary to define clear and reproducible reference points. The reference points should meet the following criteria:

- It should be possible to find them in an identical way by different operators based on their definition.
- Once the relevant reference lines and angle or distance measurements are made, the information required by means of cephalometric analysis should be attainable.
- In finding the reference points the smallest possible error should be permitted, especially regarding the points used for construction of the reference lines.

It is also advantageous, if the points:

- can be found easily and without the need for any auxiliary construction
- are commonly known by their descriptions and definitions (for ease of communication).

20 points are required for the cephalometric analysis described here (Fig. 6). Most of these are points that can be found on the contour of the craniofacial bones; only the points tgo and Sp' have to be constructed. UL, sPg, Sn and ctg represent soft tissue points.

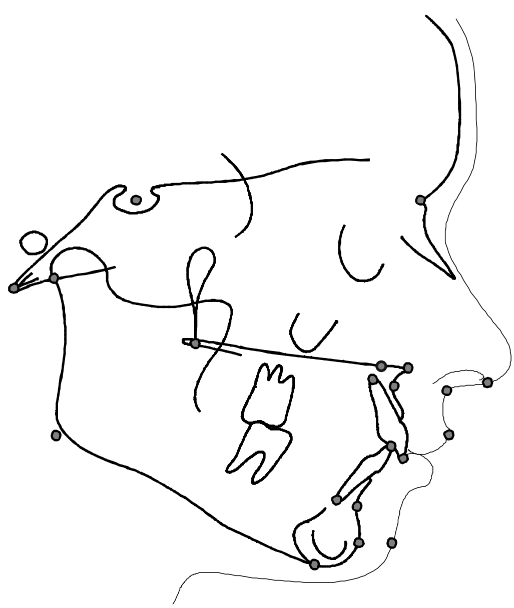


Fig. 6 Landmarks used

Detailed definition of the reference points is as follows:

1. Sella (S)

The S point is defined as the center of the osseous crypt of the Sella turcica (Fig. 7). It is a constructed point located in the median sagittal plane. This point is found by dividing the longest cross section of the Sella in half.

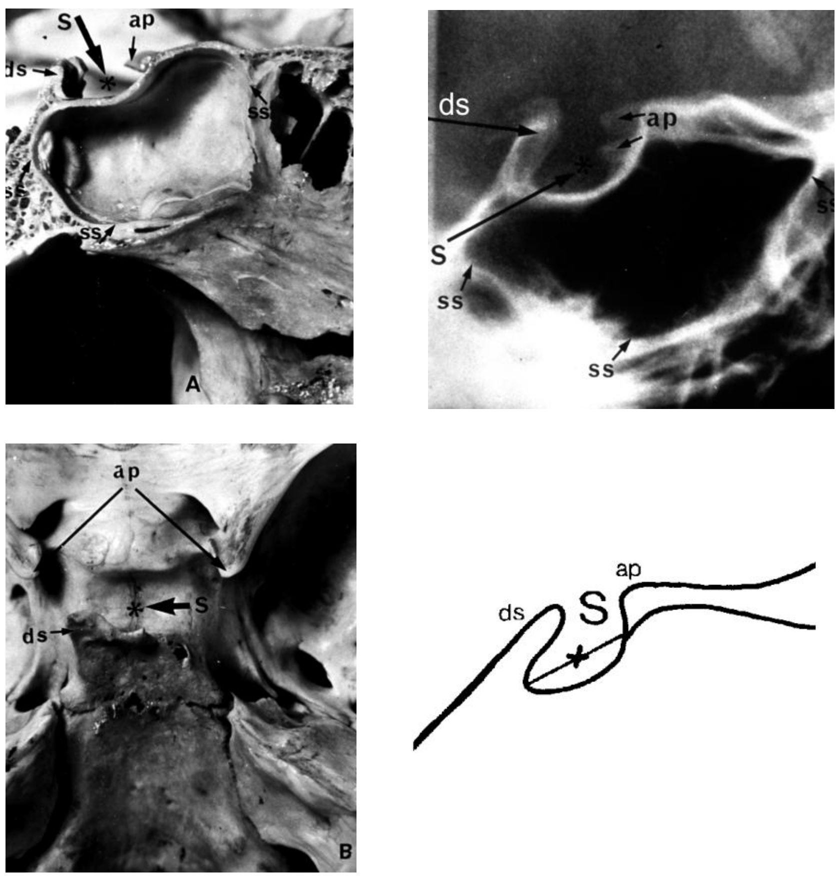


Fig. 7 Vicinity of the Sella point on the macerated skull from the side and front. Sella point shown in lateral cephalogram. Construction of the Sella point as a bisection of the largest diameter of the Sella turcica.

2. Nasion (N)

Nasion is the most anterior point of the naso-frontal suture (Fig. 8). If the suture diverges anteriorly into an open V-shape, the most posterior point of the "V" is used. This point lies in the median-sagittal plane (Fig. 8).

If two radiographs taken at a time interval are superimposed, be aware that the Nasion may be unstable during puberty due to relatively strong bone apposition on the outer bone surface in the glabellar region.

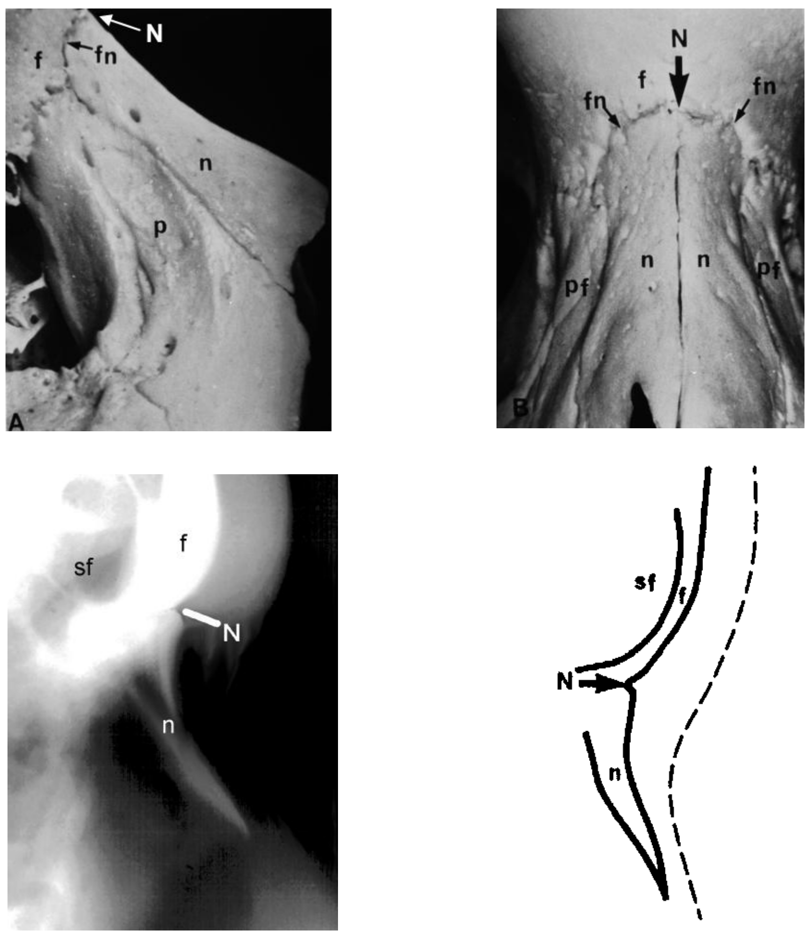


Fig. 8 Nasion and adjacent structures (f frontal bone, n nasal bone, sf frontal sinus) on the skull and on the cephalogram

3. Basion (Ba)

Basion is the most posterior and caudal point of the clivus in the median-sagittal plane (Fig. 9) and thus the most anterior point of the foramen magnum. Often, the dorso-caudal end of the cancellous bone of the clivus is used rather than the outer cortical bone of the clivus for ease of localization. For localization, it is helpful to follow the inferior border of the cranial base and the clivus from the dorsum sellae. The Basion reference point is located in the area of intersection. Finding the Basion is often not straightforward because other structures are frequently superimposed on it. For verification, it should be noted that the reference point is located about 1 cm cranial to the dens axis (Fig. 9) and about 1 cm dorsal to the articulare reference point. A frequently observed structure (marked by X in Fig. 9) is not the Basion; in fact this is located laterally to the left and right of the Basion in the area of the foramen magnum. This structure, which can be seen on the cephalometric image as well, should not be confused with the Basion.

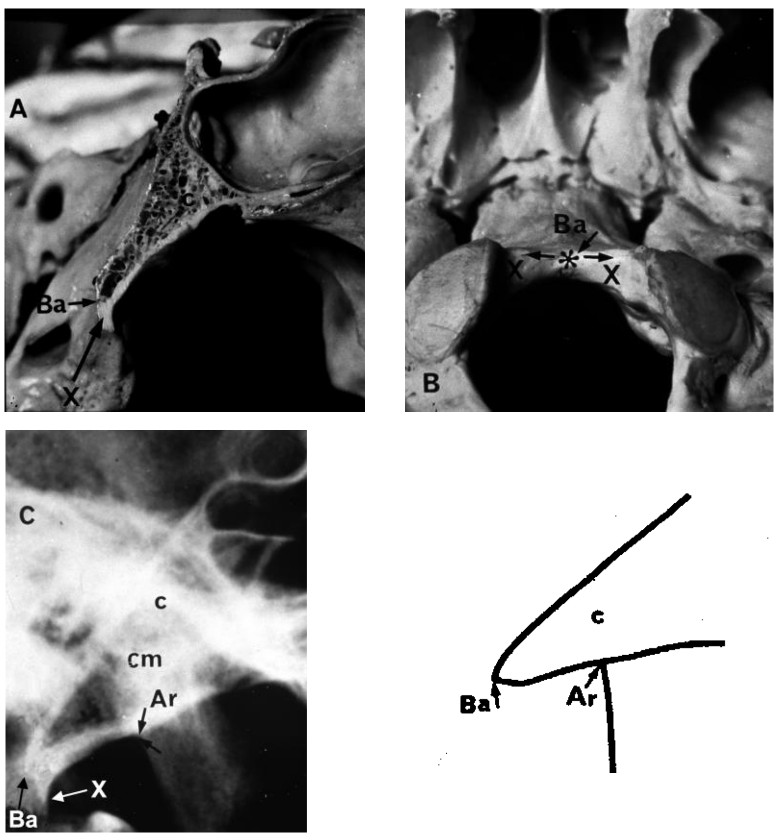


Fig. 9 Basion (Ba) and Articulare (Ar) and adjacent structures (c - Clivus, de - Dens axis, cond - condyle, cm - Collum mandibulae) on the skull from laterally and caudally as well as on the cephalogram. Caution: The structure X does not represent the Basion!

4. Spina nasalis anterior (Sp)

The Sp reference point is the most anteriorly located point of the osseous Spina nasalis anterior (Fig. 10). The reference point lies in the median-sagittal plane. A similar-looking structure is the cartilaginous continuation of the osseous Spina and should not be confused with the actual Sp reference point.

5. A point (A)

The A reference point is the deepest point of the anterior contour of the maxillary alveolar process in the mid-sagittal plane (Fig. 10). It is found by drawing a line from reference point Sp to the alveolar crest and then moving it in a parallel manner dorsally until it becomes a tangent with the concave anterior contour of the alveolar process. This tangent point is the A point. It may serve as a reference that the labial bone lamella above the root of the superior incisors is usually only 1 to 2 mm thick.

The A point corresponds to the anthropological subspinale (SS) point. Sometimes this term is also used in the American and Scandinavian literature.

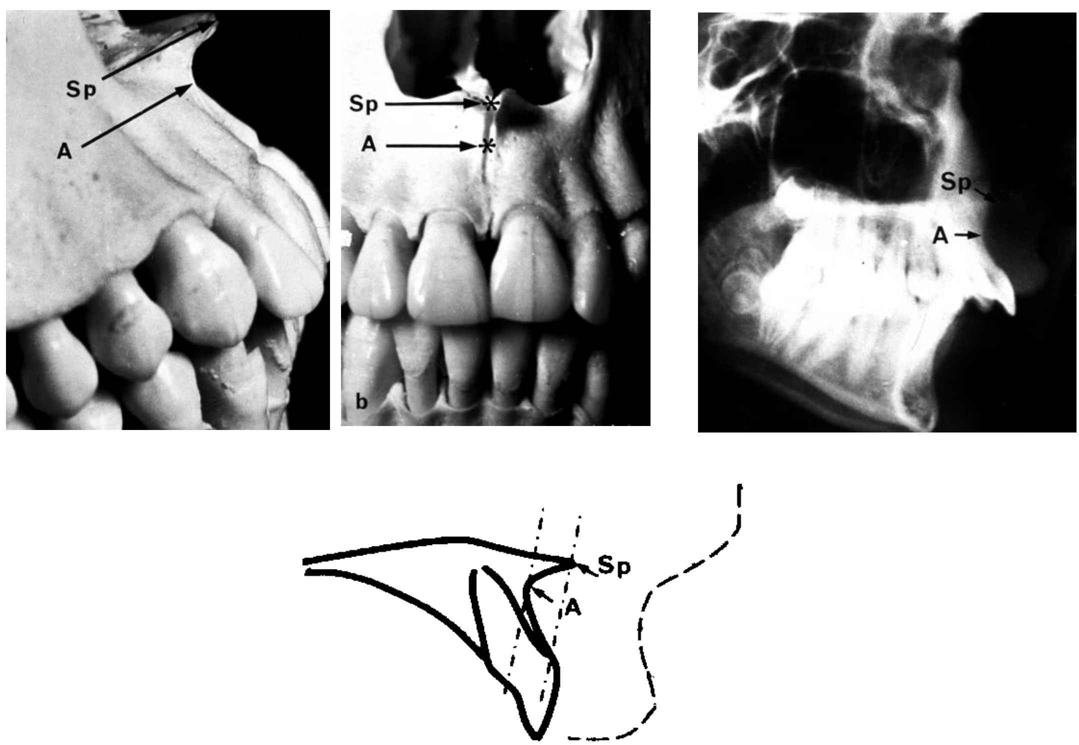


Fig. 10 Anterior part of the maxilla with anterior nasal spine and A point

6. Pterygomaxillary point (Pm)

The Pm point is defined as the intersection of the dorsal contour of the corpus maxillae with the contour of the hard or soft palate appearing in the lateral cephalogram (Fig. 11).

The dorsal contour of the maxilla is the anterior border of the pterygopalatine fossa, which appears as an ampoule-shaped structure in the lateral cephalogram (f in Fig. 11). Often, the Pm point is obscured by erupting molars, so that the contours have to be appropriately interpreted. In patients with cleft lip and palate, this point is very difficult to identify.

Although the Spina nasalis posterior point is located at approximately the same level as Pm point in the vertical direction, it is independent of Pm in the antero-posterior direction.

<u>Beware:</u> The contour of the hard palate may be covered by an erupting molar.

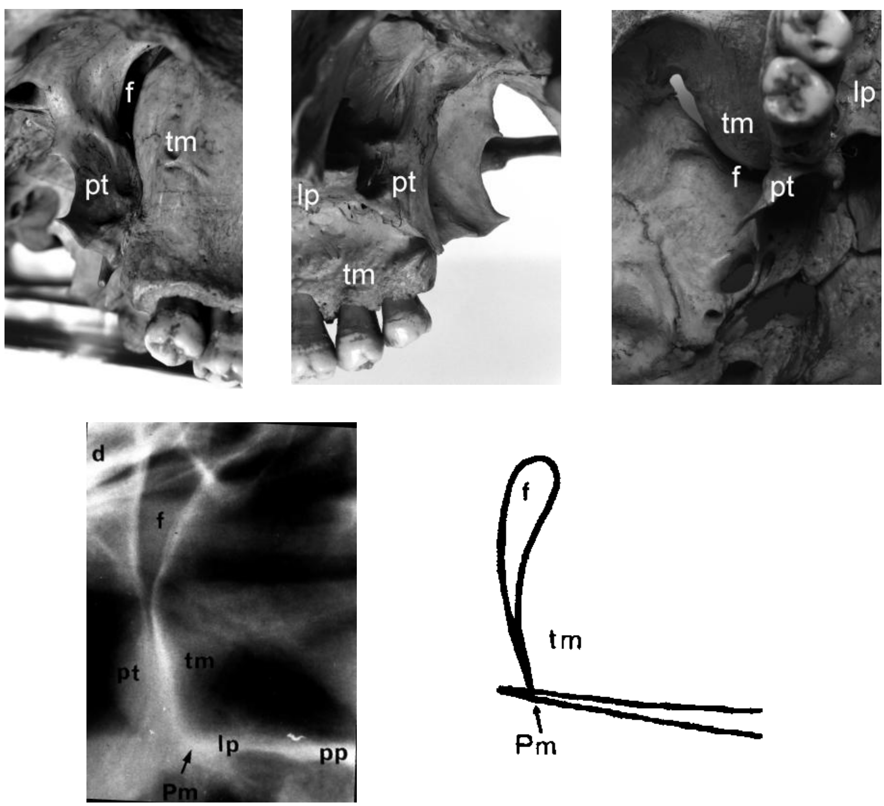


Fig. 11 Pterygomaxillary point and surrounding structures: tm - Tuber maxillae, f - pterygopalatine fossa, pt - pterygoid process, lp - Lamina palatina ossis palatina, pp - palatine process

7. U1i

This is the most incisal point of the most anteriorly positioned maxillary central incisor (Fig. 12).

8. U1a.

The most apical point of the root of the most anteriorly positioned maxillary central incisor (Fig. 12).

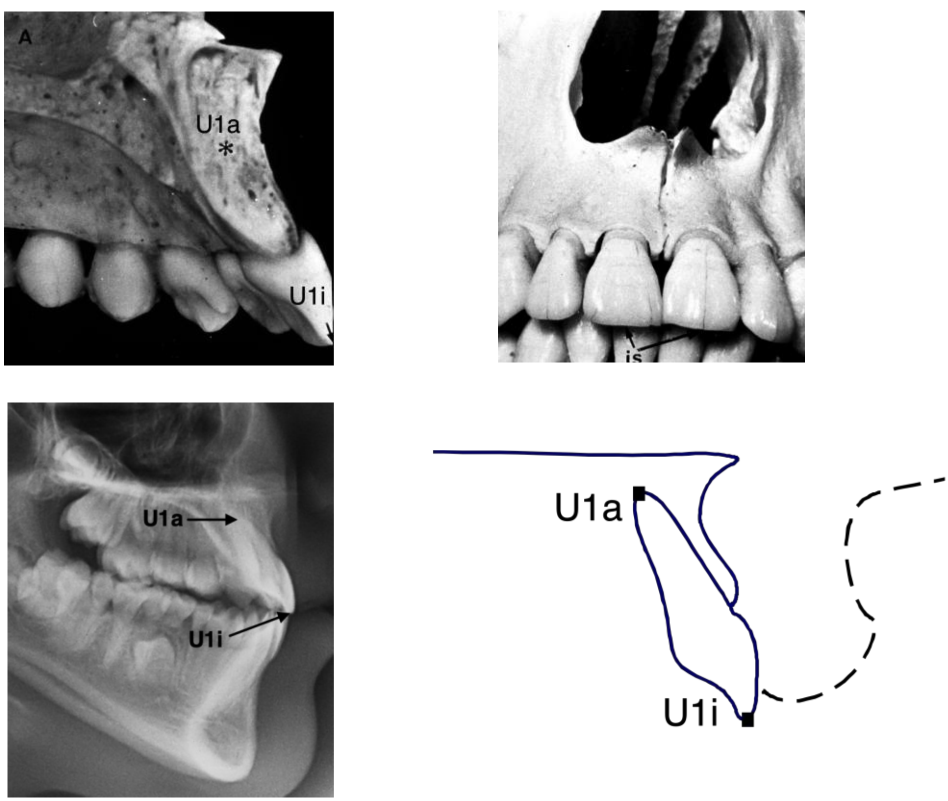


Fig. 12 Upper incisor incisal (U1i) and apical points (U1a) of the central upper incisor on the skull (top), on the cephalogram and on the tracing

9. Pogonion (Pg)

The Pogonion is the most anterior point of the cortical outline of the mandibular symphysis in the mid-sagittal plane (Fig. 13). This reference point is found by sliding a line perpendicular to the mandibular plane from the anterior aspect of the chin until it strikes the chin contour at a tangent point. The tangential point is the Pogonion. In rare cases, the chin is so receding that there is no tangential contact at all. In such cases, a point on the anterior contour of the chin that is 1 cm cranial to the mandibular plane should be used.

10. B point

The B point is the deepest point in the curvature of the mandibular alveolar process in the mid-sagittal plane (Fig. 13). The B point is found by drawing a line from the Pg point to the alveolar crest and then sliding it in a parallel manner dorsally until a tangent with the concave anterior contour of the alveolar process is formed. This point of tangency is then the B point.

The anthropological name for the B point is “supramental” point (SM).

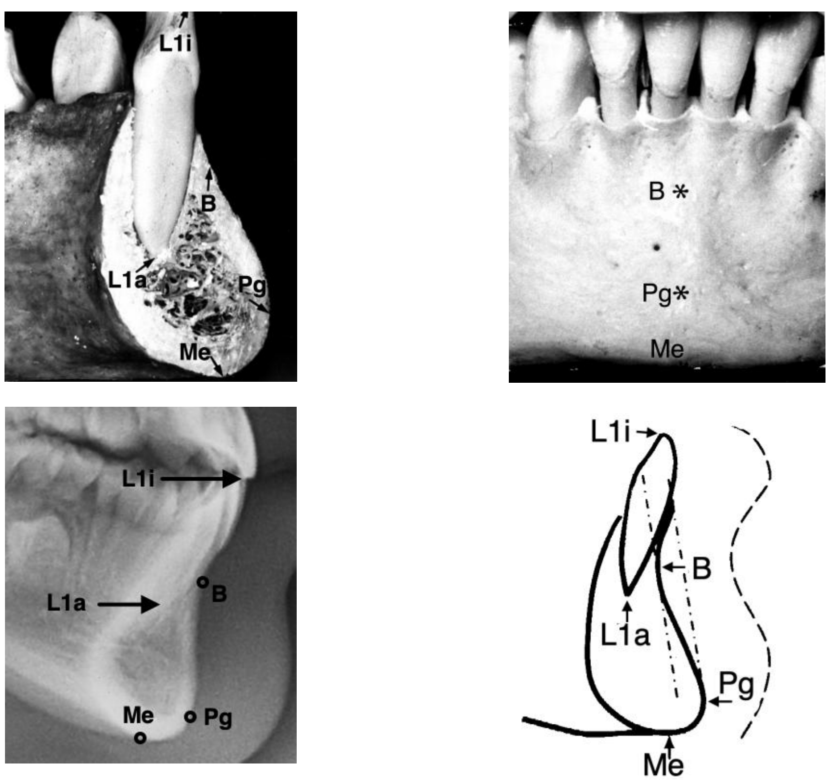


Fig. 13 Landmarks in the anterior area of the mandibular symphysis: Lower incisor incisal (L1i), apex point of lower incisor (L1a), B point (B), Pogonion (Pg) and Menton (Me)

11. Menton (Me)

The menton is the most caudal point of the mandibular symphysis in the mid-sagittal plane (Fig. 13). It is the point that has the greatest distance from the Nasion-sella line. In anthropological terminology, this reference point is often referred to as Gnathion.

12. L1i

This is the most incisal point of the most anteriorly positioned lower central incisor (Fig. 13).

13. L1a

The most apical point of the root of the most anteriorly positioned central mandibular incisor (Fig. 13). Since the four mandibular incisors and also the lower canines are usually situated on the same line, they often overlap, so that an exact identification is difficult. One must bear in mind that the longest root is that of the canine and point L1a is not to be found on it.

14. Articulare (Ar)

The reference point Ar is found on the intersection between the posterior border of the ramus (collum mandibulae) and lower border of the cranial base (Fig. 14). This is a constructed point and can only be found on the lateral cephalogram. Due to errors in the imaging, double contours of the ramus often occur. In these cases, the two points of intersection must be identified. The midpoint between these two points is then defined as the Ar point.

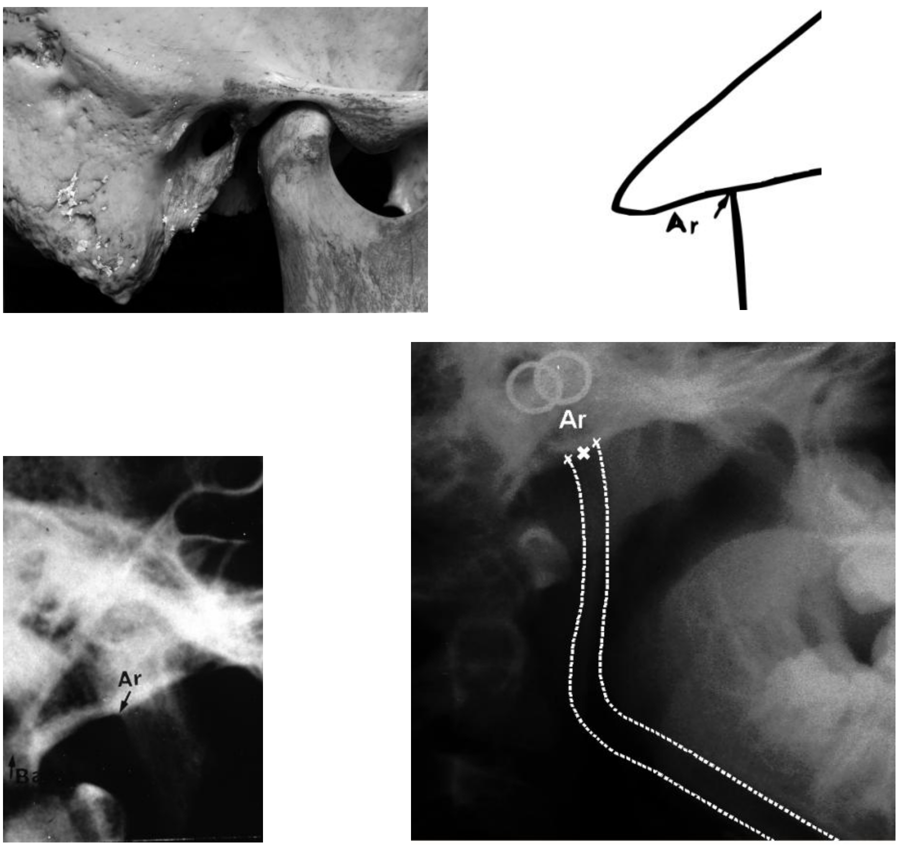


Fig. 14 Landmark Articulare (Ar): On the skull (top) the reference point does not exist; it becomes apparent only in the superimposition of the structures on the cephalometric X-ray. At the bottom right the common double contours can be seen.

15. Constructed Spina point (Sp')

This is a constructed point. It is defined as the intersection of the Nasion-menton line and the Spina-Pterygomaxillary line (nasal line) (Fig. 15).

16. Gonion tangent point (tgo)

The tgo point is defined as the intersection of the mandibular line and the ramus line (Fig. 15). The ramus line begins at landmark Ar and runs along the tangent posteriorly to the mandibular ramus where a convexity of the posterior region of the mandible may be seen. If a double contour in this region occurs, before the tangent is drawn a dissecting point between the two outlines must be chosen. For determination of the mandibular line the same principle applies. Here the Me point is aligned with the tangent of the lower convexity of the mandibular base.

In the computer-assisted evaluation of cephalometric radiographs, the point tgo is usually constructed by the program, so that instead of the point tgo itself, only the tangent points of the jaw angle need to be identified.

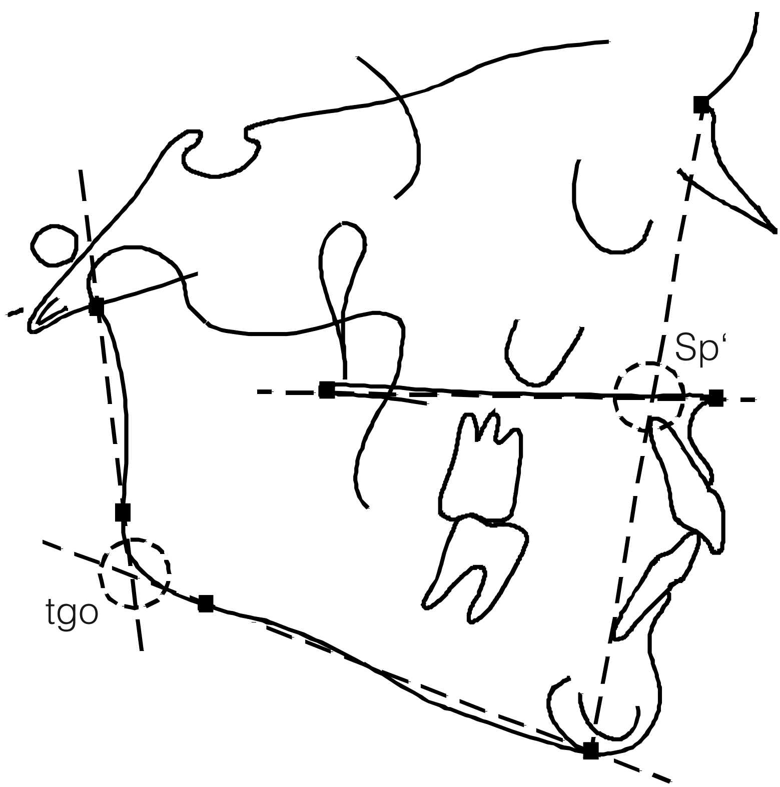


Fig. 15 Constructions to determine the cephalometric landmarks Sp’ and tgo

17. Soft tissue Pogonion (sPg).

The soft tissue Pogonion is the most anterior point of the chin in the mid-sagittal plane of the soft tissue profile (Fig. 16). It is found by placing a tangent from the soft tissue Nasion to the chin.

18. Upper lip point (Ul)

The Ul point is the most anterior point of the upper lip in the mid-sagittal plane (Fig. 16). It is also found by applying a tangent from the soft tissue Nasion.

19. Subnasal point (Sn)

Point of the smallest radius of curvature at the transition from the Columella to the upper lip.

20. Columella tangent point (ctg).

The ctg point is located where the straight portion of the columella transitions into the convexity of the nasal tip.

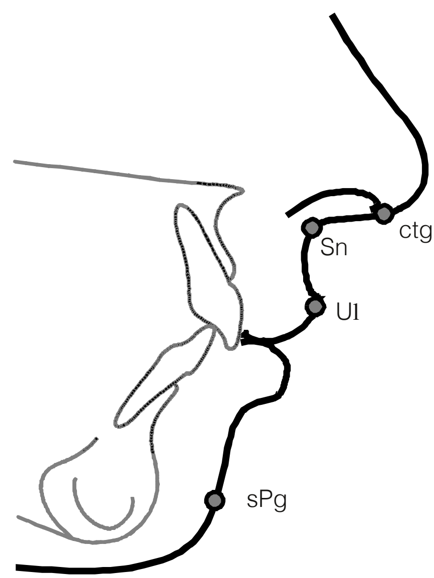


Fig. 16 Soft tissue profile with the four soft tissue landmarks Columella tangent point (ctg), Subnasal point (Sn), Upper lip point (Ul), and soft tissue Pogonion (sPg)

3. Reference lines

Following the definition of the reference points, the description of reference lines is necessary, for they are fundamental to the metric analysis of the lateral cephalogram. To describe the facial skull in the vertical direction, horizontal reference lines are used, and to describe the antero-posterior relation, vertical reference lines are needed.

Horizontal reference lines:

1. Nasion-sella line (NSL).

   The entire facial skull is measured in relation to the anterior cranial base (Fossa). Therefore, the Nasion-sella reference line is used as the main plane of reference (Fig. 17). This line is also used for the comparison of two X-ray images; superimposition is applied to the Sella point and the Nasion-sella line.

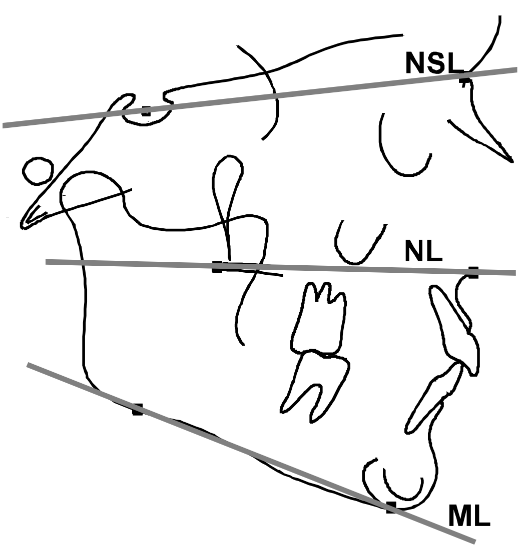


Fig. 17 Main reference line NSL and the other two horizontal reference lines NL and ML.

2. Nasal line (NL)

   The line connecting the Spina nasalis anterior (Sp) and Pterygomaxillary point is used as the reference plane for the floor of the nose and the base of the maxilla (Fig. 17). It is called the nasal line and abbreviated as NL.

3. Mandibular line (ML)

   The line through the Menton and Gonion tangent point is called the mandibular line and is used as the reference line for the corpus mandibulae/mandibular base (Fig. 17).

   When using this line, it should be noted that there are other definitions for this line in the literature, so it is important to verify that it is the same mandibular line before comparing measurements.

   Furthermore, it should be noted that this line is not very stable in relation to the corpus mandibulae, since apposition and resorption processes take place at the lower margin of the mandible during growth. As a result, growth-related rotational processes of the mandibular body can be masked or become more pronounced.

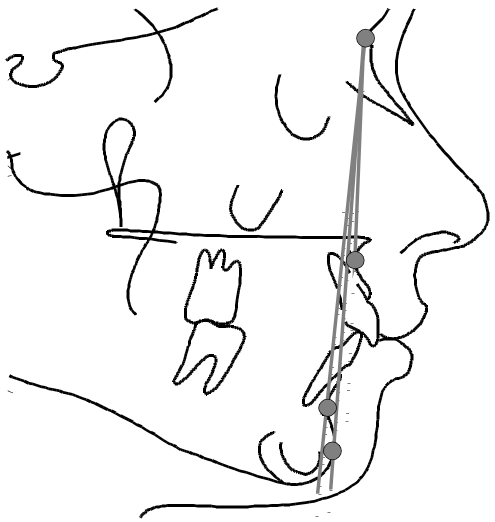


Fig. 18 The vertical reference lines NA, NB and NPg line

Vertical reference lines:

4. NA line

   The line connecting the Nasion and the A point is used to describe the sagittal position of the maxilla (Fig. 18). Furthermore, it is used as a reference line for describing the axial inclination of the maxillary anterior teeth.

5. NB line

   This is the line from the Nasion to the B point and is used to describe the sagittal position of the mandible and as a reference line for measuring the axial inclination of the mandibular anterior teeth (Fig. 18).

6. NPg line

   The interconnection between the Nasion and Pogonion point is used to describe the sagittal position of the chin. It can also be used as a reference line for the position of the mandibular anterior teeth (Fig. 18).

Other reference lines:

7. Ramus line

   Connection of the Articulare (Ar) point with the Gonion tangent point (Fig. 19).

8. Clivus line

   Connection of the Sella and Basion points.

9. Long axis of the maxillary central incisor

   The line connecting the incisal point (U1i) and the apical point (U1a) of the maxillary central incisor is called the long axis of the maxillary central incisor (Fig. 19).

10. Long axis of the mandibular central incisor

    The line connecting the incisal point (L1i) and the apical point (L1a) of the mandibular central incisor is called the long axis of the mandibular central incisor (Fig. 19).

11. Nasion-Menton connecting line

    This reference line is needed to calculate the Index of anterior facial heights.

Soft tissue reference lines:

12. Holdaway line (H-line)

The line connecting the soft tissue Pogonion and the upper lip point is called the Holdaway line (Fig. 20). Since the sPg point is found using a tangent from the soft tissue Nasion to the chin, it may well be that the H-line intersects the chin a little bit. This line is used primarily to describe the lip profile and the convexity of the face.

13. Columella-tangent

This line, which connects the Subnasal and Columella points (Fig. 20), is used in conjunction with the upper lip tangent to describe the upper lip-nose relationship, which is of a great significance.

14. Upper lip tangent

The connection of the Subnasal and upper lip points is called the upper lip tangent (Fig. 20). It is used to describe the inclination of the upper lip.

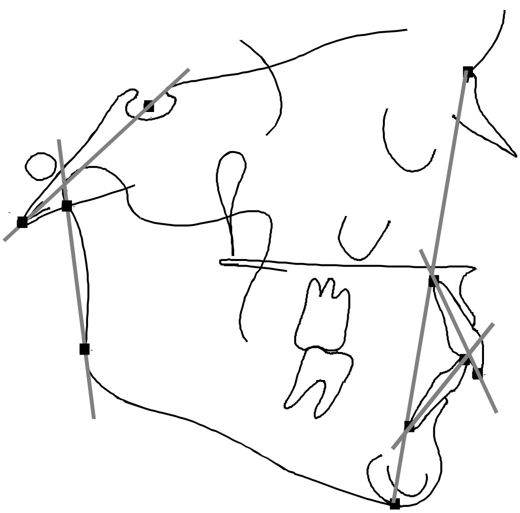


Fig. 19 Further reference lines: Ramus line, Clivus line, incisor long axes as well as the line from Nasion to Menton

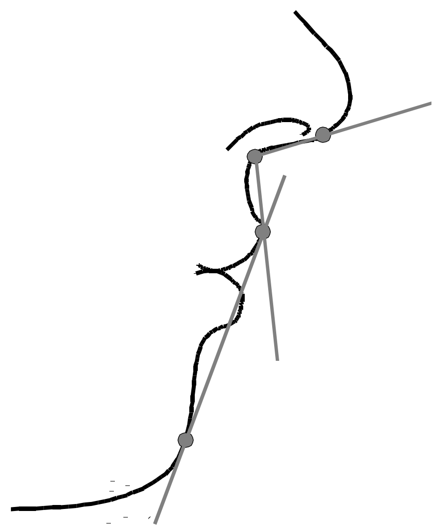


Fig. 20 Soft tissue line according to Holdaway (H-line), upper lip tangent and Columella tangent

4. Manual Tracing Technique

The necessary tools are:

- light box, idealy with brightness control
- tracing paper (acetate sheet; translucent milky paper that can be drawn on)
- adhesive tape for fixing the tracing paper to the X-ray film
- template with millimeter scale as well as incisor and molar outlines
- protractor with half-degree scale
- geometric set square (a special triangular ruler)
- fine mechanical pencils (0.5 mm), additionally with colored leads if needed (these are particularly useful for longitudinal series)
- masking screens (in the simplest case opaque cardboard)

Routine procedure for tracing:

1. The cephalometric image is placed on the light box with the profile to the right. It is oriented so that the Nasion-Sella reference line is parallel to the upper edge of the light box. The X-ray film is secured in this position with adhesive tape (Fig. 22).

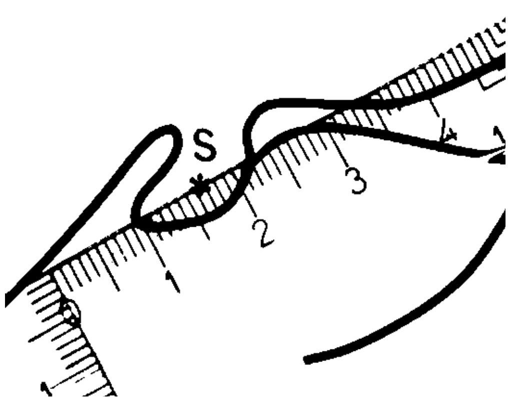


Fig. 21 Detail: Locating the Sella point using a ruler with millimeter graduation

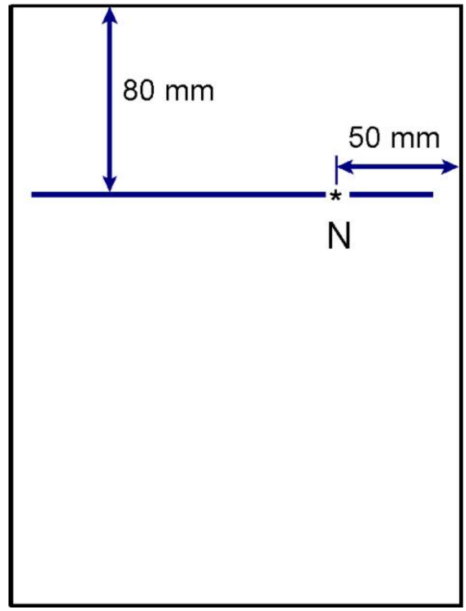


Fig. 22 Standardized plotting of the main reference line NSL on the tracing paper.

2. Using a pencil, mark the Sella (S) and Nasion (N) points directly on the X-ray film according to the definitions in the previous section. To mark the Sella point, it is best to use a ruler with millimeter graduation. The point is then placed in the center of the largest diameter (Fig. 21).
3. The tracing paper has a glossy side and a matte side. Since pencil marks can be made only on the matte side, it is placed with the glossy side facing the X-ray film. Before securing the sheet, draw a line approximately 8 cm below and parallel to the upper edge of the paper. On this line about 5 cm from the right edge, mark the Nasion point (Fig. 22).
4. Now the acetate sheet has to be moved over the X-ray film until the

Nasion point marked on the sheet corresponds to the mark on the X-ray film so that the line passes through the marked Sella point as well. This line will now represent the Nasion-Sella line. Now, the tracing paper is fixed in this position with two adhesive tape strips on the left or upper edge (Fig. 23). By placing the two adhesive strips at the greatest possible distance from each other, it is possible to prevent the film from being displaced even by rotational movements.

On the other hand, fixing only one edge of the acetate sheet allows it to be lifted off the film in order to be able to assess a specific structure directly on the film without losing the relationship from the previous tracing.

The anchor line on the acetate film (NSL) is the main reference line used for all measurements made on the X-ray tracing. The standardization of the orientation has the advantage of enabling the estimation of certain parameters, for example the degree of prognathism or the degree of inclination, which can be estimated after some experience even without performing measurements. Among other things, this results in a higher degree of certainty in the analysis by eliminating unconscious or conscious bias.

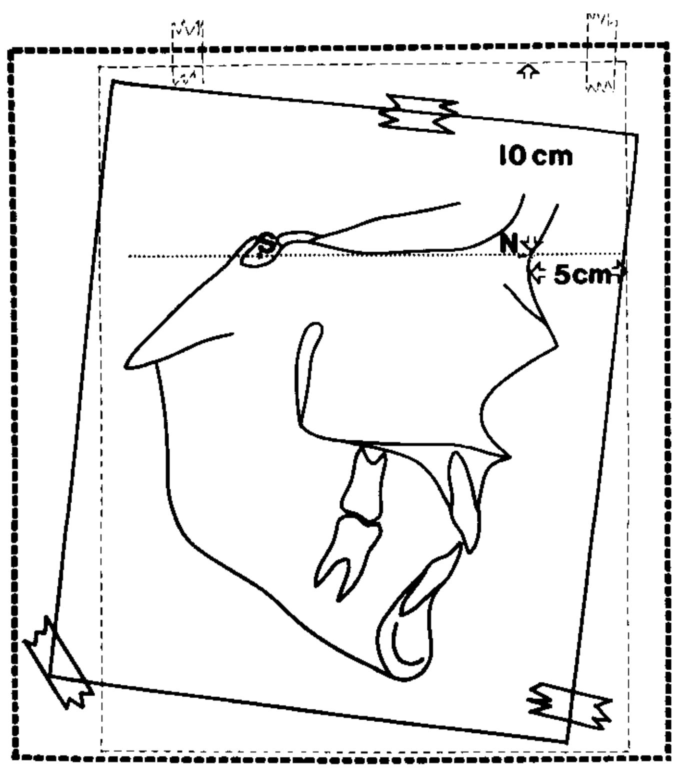


Fig. 23 X-ray film and tracing paper in standardized orientation on the light box. The figure also shows the routinely traced bony contours

5. From now on, according to the definitions from the previous section, all further reference points are located and marked. When locating points in the dark areas of the X-ray image, it is often advantageous to cover the nearby light structures with masking screens. It may also be helpful to dim the room in which the analysis is being performed.

6. The most important bony structures are traced as shown in Figure 23. During the tracing process, care must be taken that the reference points that have already been marked are not covered by the lines of the contours. As a general rule, it is beneficial to interrupt the contour line shortly before and shortly after any reference point.

   For structures that present a double contours on the X-ray image, it is necessary to draw an average of the two contour lines. This applies in particular to the lower and posterior margins of the mandible. Because the mandibular angle region does not lie in the median plane, double contours appear very often on the radiograph due to both incorrect patient alignment and the difference of the magnification factors of the left and right sides of the head (see page 9). If such a double contours occur, only one contour line, which lies in the middle between the two contours on the X-ray image, is marked (Fig. 24). The averaged contour line is then used as the basis for further analysis. Only for cases with known asymmetry, and for the appropriate therapy planning, the two contour lines need to be marked and analyzed separately.

7. The incisors and molars should be traced using the template. For this purpose, the longitudinal axes of the upper and lower incisors are drawn first as connecting lines of reference

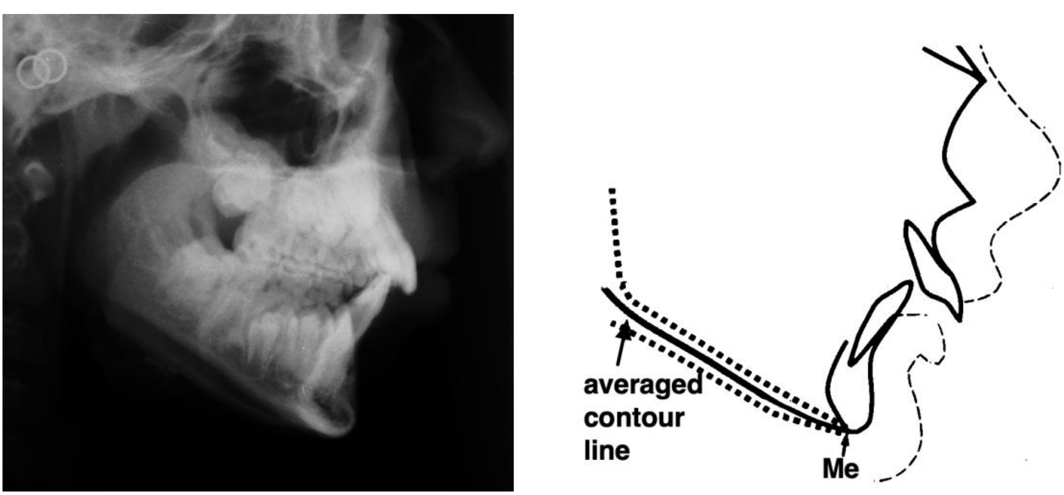


Fig. 24 Tracing technique with double contours of the mandible. Left: cephalogram with double contour; on the right: tracing with averaged contour line. The same technique is also used to establish ML.

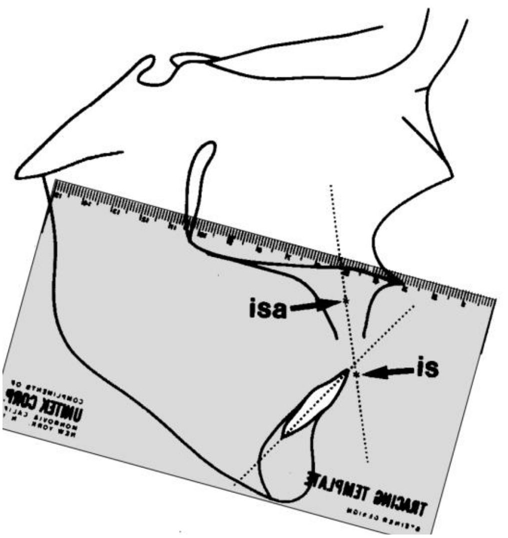


Fig. 25 For drawing the outline of incisors and molars a transparent plastic template with cut-outs is used.

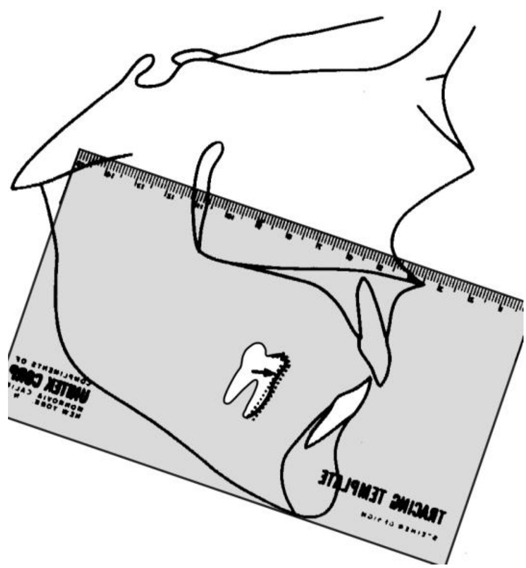


Fig. 26 Orientation of the template according to the averaged contour of the mesial surfaces of the left and right molars.

points L1i and L1a and U1i and U1a, respectively (Fig. 25). Then the template is used to draw the contours of the maxillary and mandibular incisors so that they coincide with the long axes. Even if the tooth size on the radiograph and the template do not match, the template is positioned at the incisal point. Although the apex of the template does not correspond to the actual apical point, the apex of the template is nevertheless located on the long axis of the tooth.

The problem of the double contour also often occurs when dealing with molars. In addition to the errors due to imaging, unilateral mesial drifting may occur. Similar to the jaw angle region, an average of the contours of the mesial surfaces of the molars is used to guide the template (Fig. 26).

8. Now the soft tissue profile is traced.
9. Finally, the reference lines are marked. The result is the complete tracing (Fig. 27).

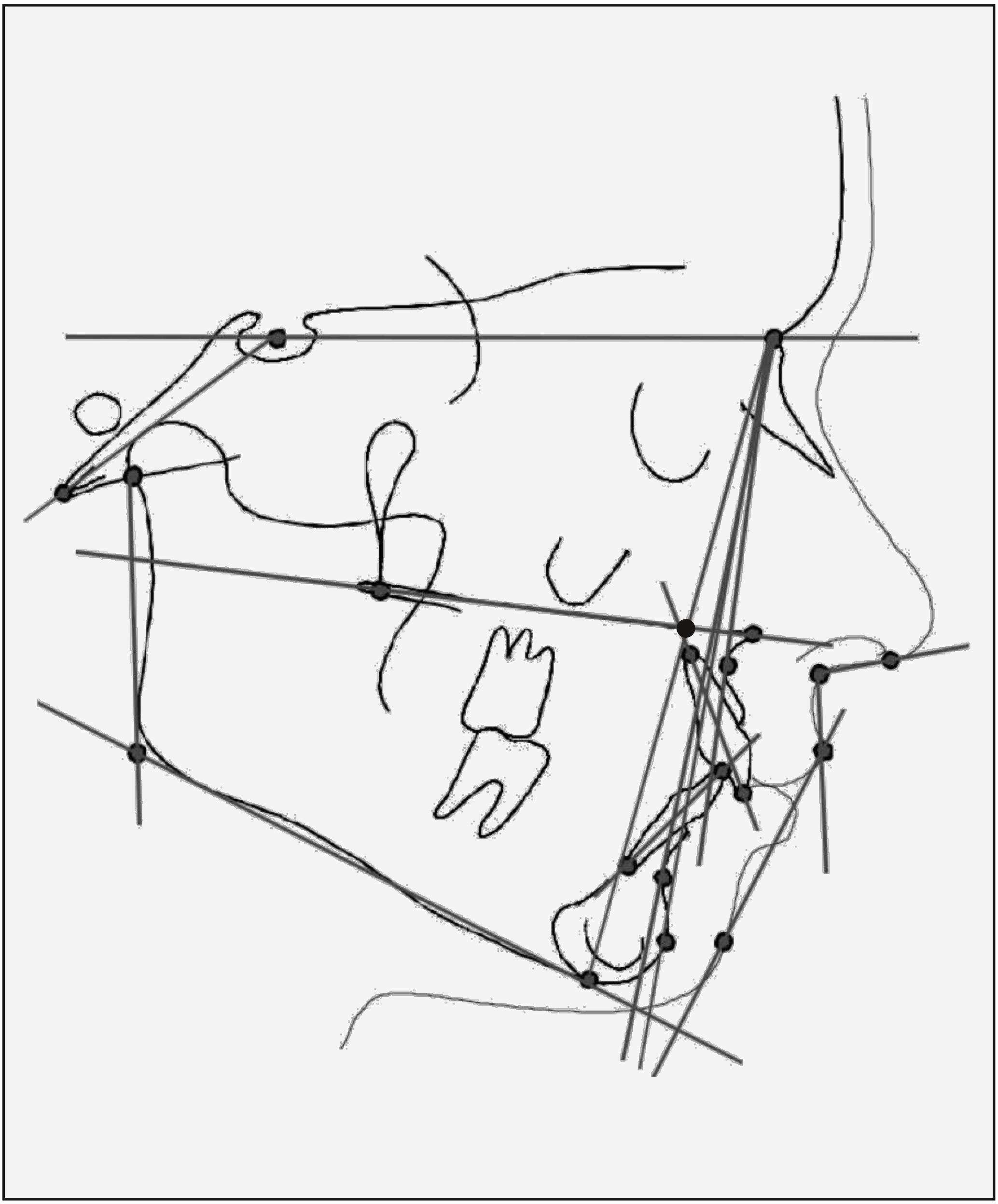


Fig. 27 Complete tracing with landmarks, bony structures, soft tissue profile and reference lines.

5. Manuaul Measuring of Distances and Angles

The angles are measured with a protractor with 0.5° graduation, the distances with a ruler with 0.5 mm graduation. To make the procedure more reliable, several angles and distances are measured in each measuring series.

1. Measuring series

The first series includes the angles SNA, SNB, ANB and SNPg. For this purpose, the protractor is aligned to the Nasion with its midpoint while its baseline is oriented to NSL (Fig. 28). It is then possible to read three of these four angles directly without changing the position of the protractor.

The ANB angle is the difference between SNA and SNB (SNA - SNB). Since the ANB angle may have both positive and negative values, it is important to specify the sign correctly. If the A point lies in front of the NB line, the value is positive; in the opposite case, it is negative. If the A point is on the NB line, then the ANB angle is 0°.

2. Measuring series

The second series of measurements includes the angles NSBa and the mandibular angle Me-tgo-Ar. For the determination of the angle NSBa, the center of the protractor is aligned with the Sella point (S) and the baseline along the Nasion-Sella line (Fig. 29).

To determine the Me-tgo-Ar jaw angle, the center of the protractor is aligned with the tgo point and the baseline is aligned with the mandibular line (ML) (Fig. 30).

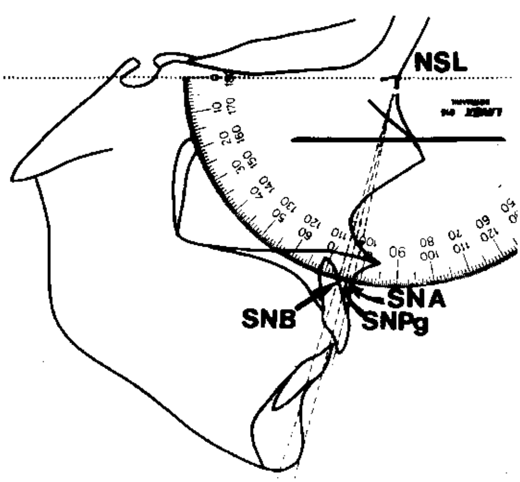


Fig. 28 Angular measurements of the sagittal variables

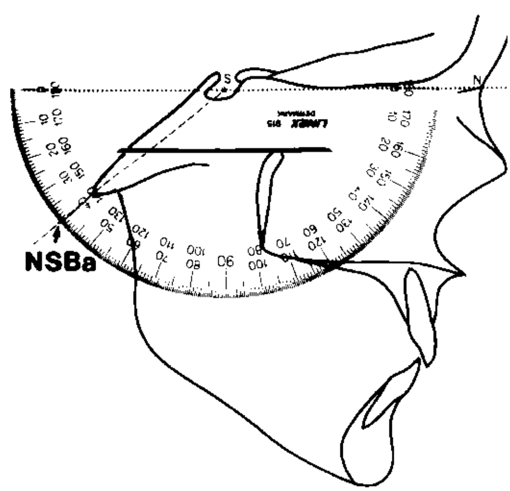


Fig. 29 Measuring the angle NSBa

3. Measuring series

This series includes the angles NL-NSL and ML-NSL. For angle NL-NSL in particular, whose value may be very small, it can often be difficult to read the value without shifting NL in a parallel manner to a point of intersection with NSL.

Also, for determining the ML-NSL angle, it is often advantageous to shift ML in a parallel fashion. It is therefore recommended to routinely use a lined acetate sheet to read both angles between the guiding lines and NSL (Fig. 31).

The NL-NSL angle can sometimes have a negative value in cases where the NL and NSL lines converge anteriorly (to the right).

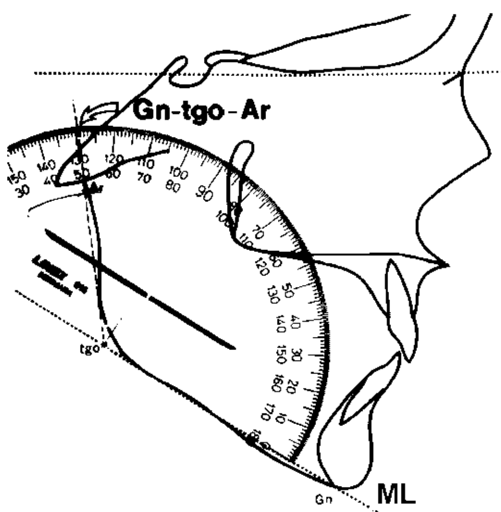


Fig. 30 Determination of the mandibular angle Me-tgo-Ar

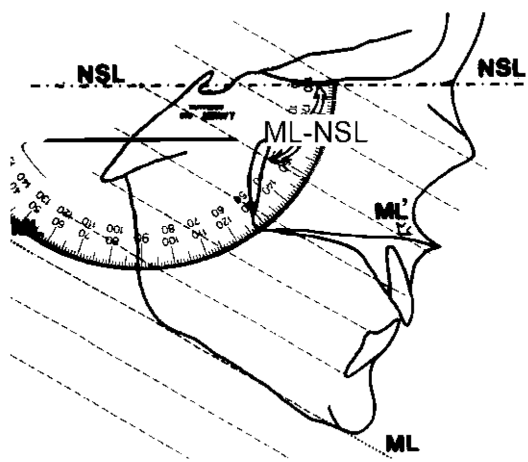


Fig. 31 The use of lined acetate sheet for parallel shifting. ML' is the parallelly shifted mandibular line ML. The angle ML'-NSL is measured instead of ML-NSL directly. Proceed accordingly for NL-NSL.

4. Measuring series

This series covers the axial incliations of the incisors ⊥-NA° and ⊤-NB° as well as the interincisal angle ⊥-⊤.

To measure the ⊥-NA° angle, align the center of the protractor with the intersection of the NA line with the long axis of the maxillary incisors or its extension and place the baseline along the NA line (Fig. 32).

To measure the ⊤-NB° angle, place the protractor so that its center coincides with the intersection between the long axis of the mandibular incisors and the NB line. The protractor's base line should be placed along the NB line (Fig. 33).

To determine the interincisal angle ⊥-⊤ the center of the protractor is placed at the intersection of the long axis of the maxillary incisors and the long axis of the mandibular incisors. The baseline is placed along the long axis of the mandibular incisor (Fig. 34).

To verify the validity of the attained values, the following formula can be applied:

⊥-⊤ = 180 - (ANB + ⊥-NA° + ⊤-NB°)

5. Measuring series

This measurement series provides measurements for the soft tissue profile, namely the Holdaway angle and the Nasolabial angle. The H-angle is measured between the bony reference line NB and the Holdaway line (sPg to Ul) (Fig. 35).

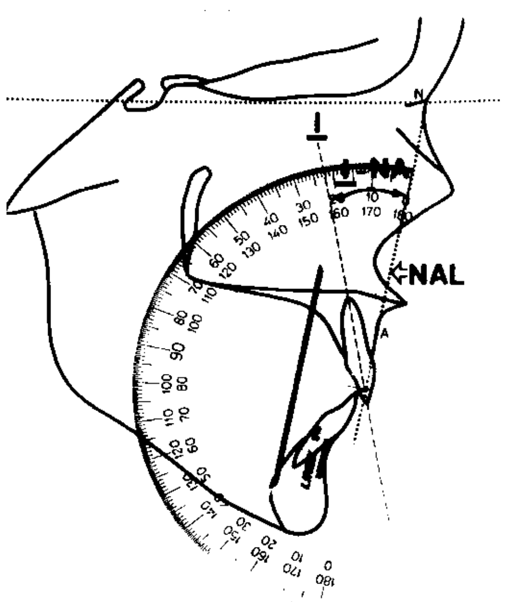


Fig. 32 Determination of the angle ⊥-NA°

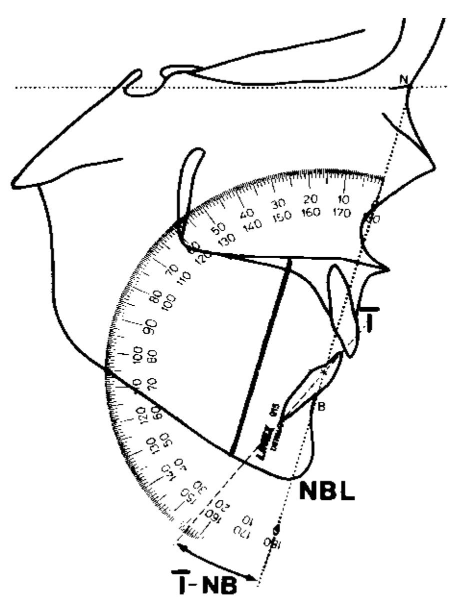


Fig. 33 Determination of the angle ⊤-NB°

In order to establish an intersection point between these two lines of interest, the lined acetate sheet is handy to establish a parallel line to the NB line. The center of the protractor is then aligned with the intersection of the translocated NB line (NBL') and the H-line, and the baseline of the protractor is aligned along the NBL' (Fig. 35).

Usually, the two arms of the H-angle converge caudally, which results in the H-angle having a positive value. However, in rare cases, the arms may converge cranially; then the value is negative.

To measure the Nasolabial angle, the protractor is centered at the Subnasal point and its basis along the Columella tangent line. The Nasolabial angle can be measured along the upper lip tangent line.

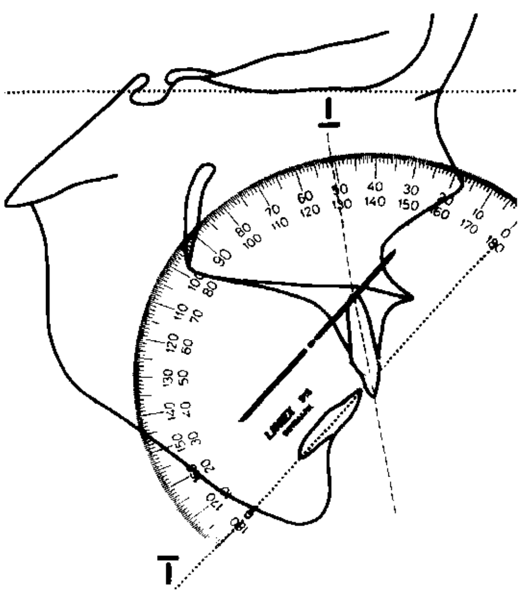


Fig. 34 Determination of the interincisal angle ⊥-⊤

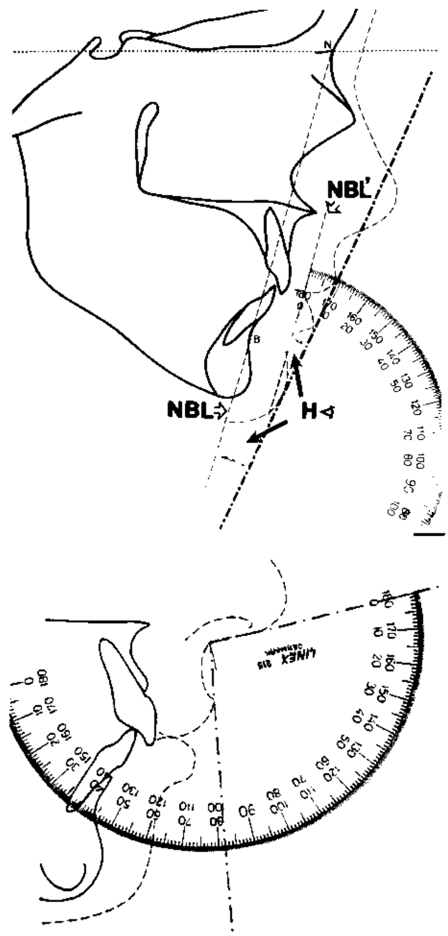


Fig. 35 Measuring of the Holdaway and Nasolabial angles

6. Measuring series (distances)

The sixth series deals with the position of the incisors. Measure both the distance of the incisal edge of the maxillary incisor from the NA line ($\perp$-NA_{mm}) and the distance of the incisal edge of the mandibular incisor from the NB line ($\top$-NB_{mm}) Also measured is the distance of the Pogonion point from the NB line (Pg-NB_{mm}).

To determine the distance ($\perp$-NA_{mm}), the ruler is placed perpendicular to the NA line and the distance from this line directly to the incisal edge is measured (Fig. 36).

For all linear tooth measurements, the values have a positive sign if the incisal edge is located anterior to the respective reference line. If not (which is rare), the sign is negative.

Similarly, for the other two measurements, the ruler is placed perpendicular to the NB-line and the distances $\top$-NB_{mm} and $PgNB_{mm}$ are measured. While it may sometimes be problematic to determine which contour is the most representative of incisor position regarding $\top$-NB_{mm} , such difficulties do not occur with Pogonion (Fig. 37). If the Pogonion is located anterior to the NB line, the $PgNB_{mm}$ value has a positive value.

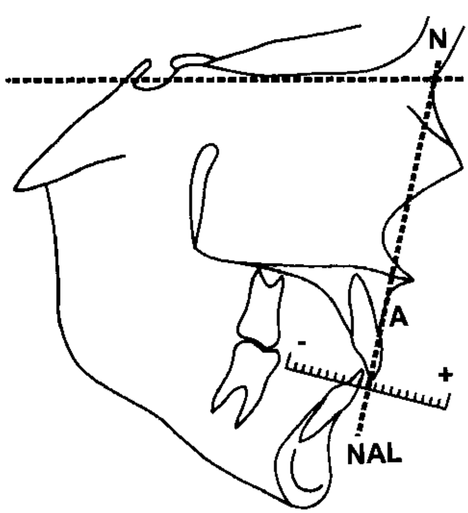


Fig. 36 Determining the distance of the upper incisor incisal edge from the NA-line ($\perp$-NA_{mm}). $\top$-NB_{mm} is meassured correspondingly.

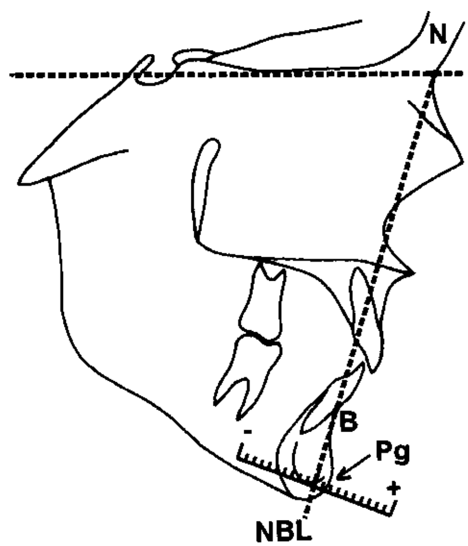


Fig. 37 Determining the distance of $PgNB_{mm}$ from the NB line. If Pogonion is anterior to the NB-line, the value is positive.

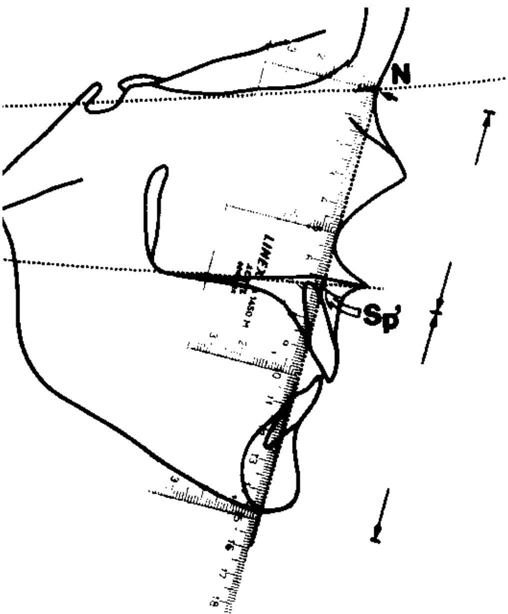


Fig. 38 Determining the midfacial and lower facial heights on the connecting line Nasion-Menton. The ratio between the two measurements as a percentage gives the Index.

7. Measuring series (distances)

In this series, the measurements describing the vertical dimension of the face are carried out, i.e., the measurement of the midface height N-Sp' and the lower face height Sp'-Me. This is done by placing the ruler along the Nasion-Menton connecting line with the zero point at the Nasion. Sp' represents the intersection of the lines N-Me and NL. The two lengths can now be successively identified on the ruler. When using a geometric set square (a special triangular ruler), it is useful to align the zero point in the middle with the point Sp', so that both distances can be read without shifting. To determine the Index measurement the distance N-Sp' is divided by Sp'-Me and multiplied by 100.

As a result, the following measurements are made for clinical cephalometric evaluation (see also the analysis sheet in Fig. 42):

SNA
SNB
ANB
SNPg
NSBa
Me-tgo-Ar
ML-NSL
NL-NSL
ML-NL
H-angle
Nasolabial angle
⊥-⊤
⊥-NA°
⊤-NB°
$\perp$-NA_{mm}
$\top$-NB_{mm}
$PgNB_{mm}$
N-Sp'
Sp'-Me
Index

Angle measurements are given in degrees (°), distance measurements are given in millimeters (mm), and the Index is given as a percentage (%).

6. Computer-aided Evaluation

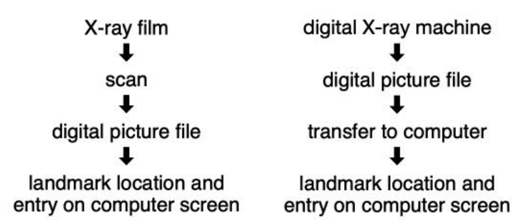
In principle, computer-assisted evaluation is performed in exactly the same way as manual evaluation. The difference is that the measurement of the angles and distances is carried out by the computer. Due to the fact that the same principles apply as in manual evaluation, no additional information can be extracted from the lateral cephalogram by the computer than is possible with manual evaluation. In other words, any computer analysis, no matter how complex it may seem, can be performed by hand, even though it may take considerably more time. Furthermore, errors arise for the same reason, namely the identification of the reference points. Here errors are often only noticed after the evaluation has been completed, whereas with manual evaluation, errors are usually noticed during the actual measuring process. Even though the appearance of the results of a computer-aided analysis is usually very clean and neat, one should be cautious not to have more confidence in these results than in those from analysis performed by hand. This is especially true if one has not performed the computer-aided evaluation oneself.

Fig. 39 A software for computer aided cephalometric analysis running on a notebook

On the other hand, in favor of the computer-aided evaluation, it must be said that errors that can occur when working with ruler and protractor are eliminated so that the measuring accuracy is slightly higher (Wingberg 1984). Furthermore, the correct localization of the reference points can be quickly verified by viewing the graphic illustration. Finally, carrying out the given analysis twice considerably reduces the risk of "outlier" values. With computer aided analysis the picture can be enhanced by optimizing the grey-scale and by increasing sharpness which means emphasizing borders on the X-ray. Last not least, the predominant use of digital X-ray makes computer-aided analysis rather beneficial as otherwise the digital X-ray would have to be printed out in high quality.

<u>Evaluation system</u>

Computer-aided analysis can be carried out using one of two possible workflows depending on whether the source is a digital radiograph or an X-ray film:



In X-ray film-based systems the film needs to be converted to an X-ray picture file using a flatbed scanner with a transparency unit. A photo of the X-ray film on a light box would not suffice regarding geometric distortions and reliable scale. It is important that the scan file includes the original dimensions of the X-ray film and the scanning resolution/scale so that the analysis software can accurately carry out metric measurements.

With a digital X-ray apparatus the X-ray will be present as a file already and the analysis software can load it directly. But also in this procedure it is of importance that the resolution and/or scale of the image is known to the analysis software. The software (Fig. 39) will —after entering personal data and the date the X-ray was taken— display the X-ray and allow the user to position a mouse marker or a crosshairs over each of the landmarks to be entered. Depending on the software a magnification function is available to increase localization accuracy (Fig. 40).

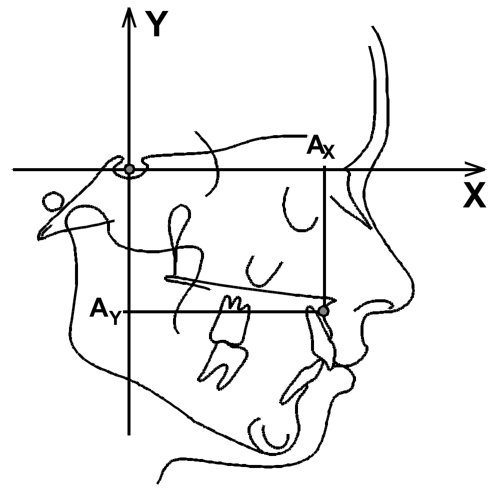


Fig. 41 Principle of conversion of the position of the reference points to X- and Y-coordinates

The positions of the reference points in relation to each other are recorded as X and Y coordinates in numerical form. After the landmark entry is finished the evaluation in the form of the calculation of the angles and distances is carried out by

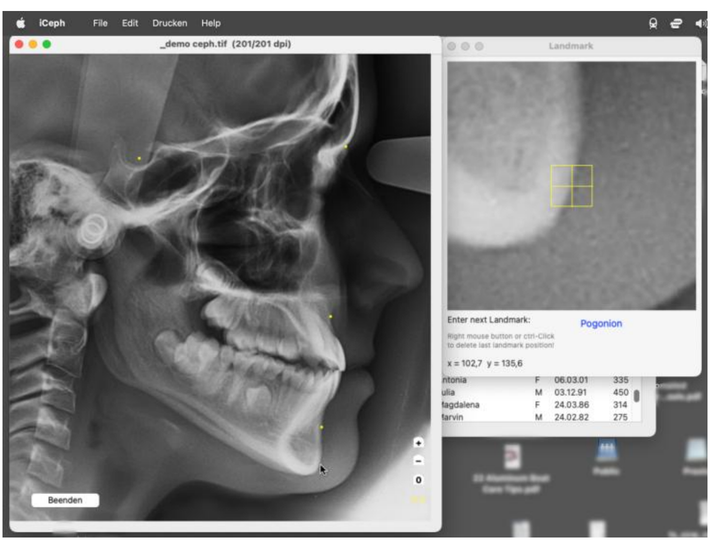
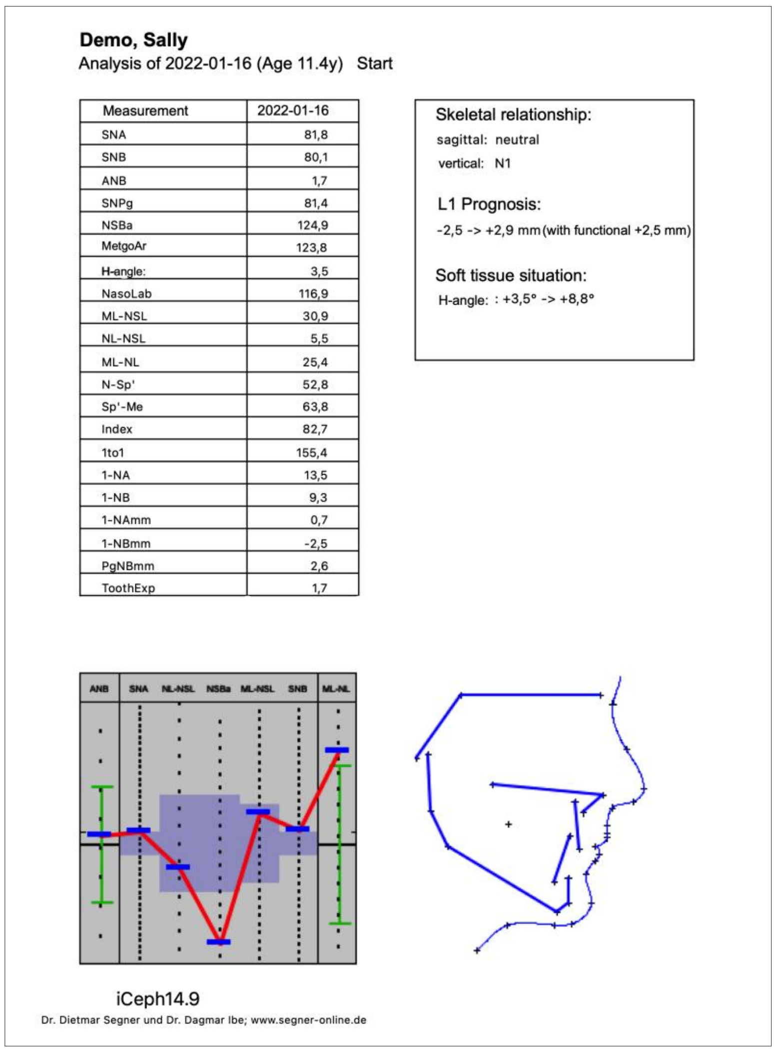


Fig. 40 Landmark location on the screen. Note the magnified image in the second window on the top right

the software program. The list of variables to be calculated is given by the program. However, there are programs that allow the list of variables to be changed. Depending on the program, further calculations such as tooth position analysis or drawing of the Harmony Box (see chapter "*norm*") can be carried out automatically. The numerical results are then displayed on the screen and/or printed out (Fig. 42). Furthermore, the measured values of the analysis can be stored permanently in the computer so that the analysis can be referred to at a later point in time.



Measurement	2022-01-16
SNA	81,8
SNB	80,1
ANB	1,7
SNPg	81,4
NSBa	124,9
MetgoAr	123,8
H-angle:	3,5
NasoLab	116,9
ML-NSL	30,9
NL-NSL	5,5
ML-NL	25,4
N-Sp'	52,8
Sp'-Me	63,8
Index	82,7
1to1	155,4
1-NA	13,5
1-NB	9,3
1-NAmm	0,7
1-NBmm	-2,5
PgNBmm	2,6
ToothExp	1,7

Fig. 42 Example of a printout of a computer-aided cephalometric analysis

7. Control of Measurement Errors

Every evaluation of a lateral cephalogram contains a certain amount of measurement error, regardless of whether the evaluation is performed manually or by computer. This can be easily confirmed by evaluating an X-ray image twice in order to compare the results. Whether the evaluation is performed manually or with the aid of a computer, it will generally be impossible to reproduce the measured values of the first evaluation to an accuracy of 0.1° or 0.5 mm. However, this fact, which is startling at first glance, is by no means unusual in the measuring of biological quantities. Similarly, the measurements of other quantities, such as blood pressure, glucose concentration, or the size of an organ, cannot be carried out with absolute precision. The fact that cephalometric measurements are subject to error should not lead to the conclusion that the cephalometric measurements are inadequate as the basis for an orthodontic intervention. No one would claim that blood pressure measurement should be rejected as a diagnostic tool because it always contains a measurement error. Rather, it is important to be able to assess the nature and magnitude of such errors, as well as their effect on the result of the analysis.

The corresponding considerations are referred to as control of errors. Since it is not possible to eliminate measurement errors completely, a degree of residual error is accepted; however, its magnitude and impact are closely monitored.

Types of measurement errors

To check the measurement errors, several measurements of the same variable are made in order to compare the individual values with each other or with the true, objectively correct value. The correct true value is usually not known, but for the following considerations its existence shall be assumed. By comparing the numerous individually measured values with the true value of the investigated variable, it shows that there is a certain distribution of the measured values around the true value

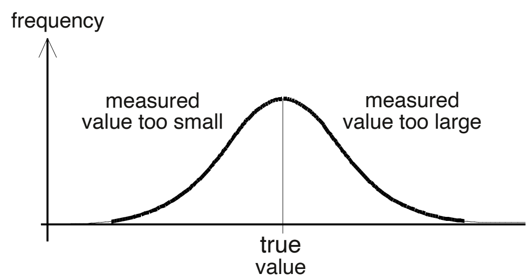


Fig. 43 Spread of the actual measured values around the correct value

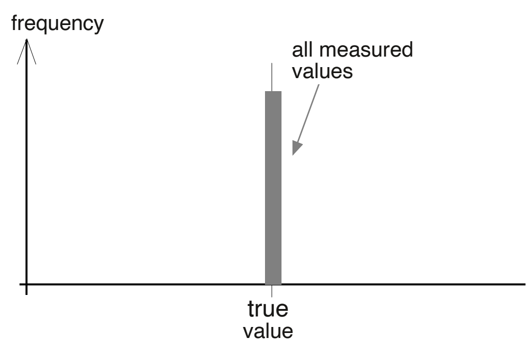


Fig. 44 Missing variance of the measured values: all measured values coincide with the true value

(Fig. 43). Most of the measured values are close to the true value. The further from the true value such measured values are, the more rarely they appear. If there was no measurement error, all measured values would be equal and would coincide with the true value (Fig. 44).

In practice, however, the distribution of the measurements looks like Fig. 43. The fact that there is a certain scattering of the measured values, i.e., that not all measured values are equal, is called random error (Fig. 45). If all measured values are equal but not identical to the true value (Fig. 46), this is called a systematic error.

In Fig. 46, for example, all measured values are too large. A combination of random and systematic error is shown in Fig. 47. Although the average of the measured values is too large, some values are smaller than the true value.

For example, a systematic error may arise from the magnification factor that is produced in each X-ray exposure. All distances would be measured with values that are too large as a result of the magnification factor. A misaligned head position would also lead to a systematic error. It is usually possible to eliminate systematic errors — once they have been detected — by modifying the method or at least eliminating them mathematically. As an example, the systematic error in the distance measurements can be eliminated by dividing by the known magnification factor of the cephalometric system.

Also, a different approach to localizing certain reference points can lead to systematic errors. For example, if the Nasion reference point were always marked on the os frontale at the junction with the notch between the nasal bone and the os frontale, the angles SNA, SNB, and SNPg would be systematically measured as slightly too small. A systematic error of this kind would not have a major impact on the individual practitioner, since it would occur in every case evaluated, thus allowing the comparison to be made with other cases from the same practitioner. However, such a systematic error is probematic if a case in

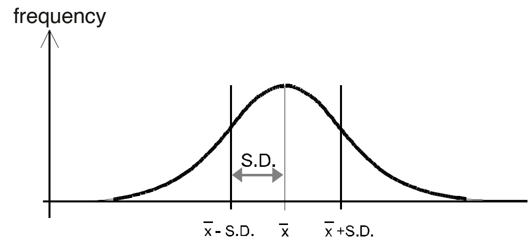


Fig. 45 Random error (variance)

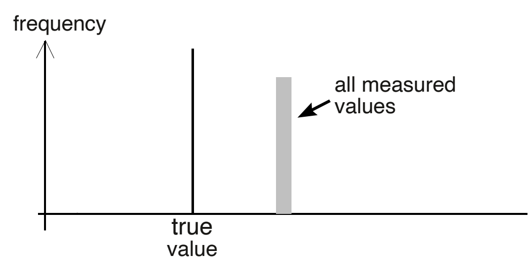


Fig. 46 Systematic error (bias): All measured values are too large

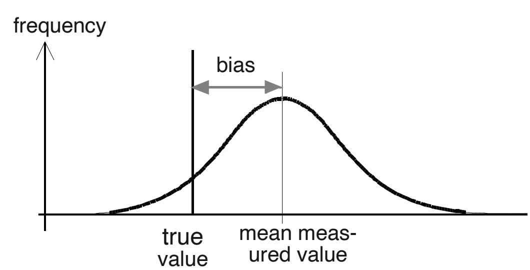


Fig. 47 Combination of random and systematic errors (variance and bias): Most measured values are too large, but some are too small

which this error is present is compared with a group in which it is not present. This is even more so when different groups are compared in a scientific study.

In contrast to a systematic error, random error cannot be eliminated, but only reduced. In order to be able to control the success of such measurements, a measurement of the magnitude of the measurement error is required. As shown in Fig. 43, there is a distribution curve for a large number of measurements of the same variable on the same X-ray image. This distribution curve corresponds approximately to a Gaussian normal distribution curve. As measurements which are far from the true value may occur — so-called outliers — it is not possible to give a specific figure for this measurement error in advance. Also, a "maximum error" cannot be given.

It is necessary to use statistical methodology. As shown in Fig. 45, a normal distribution and thus a distribution of repeated measurements can be described by the mean value and the standard deviation. Provided there is no systematic error, the mean of all measurements is equal to the actual true value. For this reason, the actual true value is not mandatory or strictly defined in the subsequent chapters. The standard deviation is a measure of the range of distribution, i.e., the smaller this value is, the closer the number of measurements lie to the mean value and thus to the actual value. In Fig. 45 it is shown that the value for the standard deviation (S.D.) indicates the interval around the mean value within which 67% of all measurements are to be expected. In this example, the S.D. is 1.5°, i.e., between 84° ± 1.5°, or between 82.5° and 85.5° 67% of all measurements are to be found. It is also possible to say that 95% of all measurements lie in the interval between 81° and 87°, which is twice as large as the interval between 82.5° and 85.5° or within two standard deviations. In other words, only 5% of the measurements lie outside this interval of ± 2 S.D. A distribution of the measured values with a small S.D. (Fig. 48; dashed curve) indicates a small random error and thus a relatively high measureent accuracy. A series of measurements with a large S.D. (Fig. 48; continuous line) has a large random error, hence the measurement accuracy is low.

S.D. is a suitable reliable parameter to evaluate the accuracy of the measurement. Unfortunately, the S.D. of a measurement series can only be calculated if a large number of measurements are performed of the same X-ray image for each variable. In practice, this is difficult to do because it is very time-consuming and tedious.

In fact, the individual measurements of the same image would have to be independent of each other. In two consecutive evaluations of the same image, remembering the structures influences the second evaluation. To be independent, the individual evaluations would have to be performed at a time interval of at least one to two weeks. Furthermore, due to the different quality of the X-ray images, different values

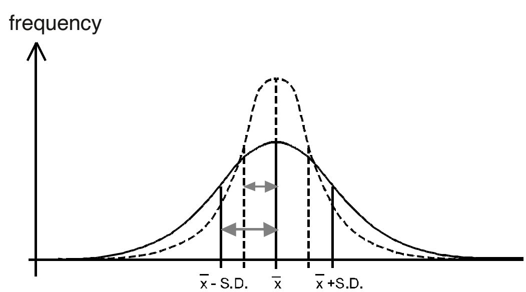


Fig. 48 Two distributions of measured values with identical mean but different variances. See text for explanation

are obtained for each patient. Nevertheless, rather than obtaining a value for the measurement accuracy for each patient, it would be desirable to obtain a value for the measurement accuracy for each variable.

Such a value was described by Dahlberg (1943). To calculate the measurement error, he used a formula

$$s_e = \sqrt{\frac{\Sigma\, d^2}{2n}}$$

in which d is the difference between the single measured value and the mean value from the single measurements of the same X-ray image and n is the total number of measurements. All the X-ray images in the group were thus measured two or three times, and this was the sum of the squared individual differences. The resulting value is approximately equal to the standard deviation, i.e., the smaller it is, the more accurate the measurement. Since the differences are squared, a single outlier influences the value significantly.

In order to be able to make a statement about the reliability of a measured variable, its error of method must be put in relation to that of its biological variability. If the variability is large, a given method error will have less effect than if it is small. To assess this relationship, Houston (1983) has invented the reliability coefficient:

$$reliability = 1 - \frac{\delta^2}{s_v^2}$$

Here the method error is represented by δ and s_v is the standard deviation of the variable. The closer this value is to 1, the more reliable the variable being examined and the less likely that measurement errors will lead to incorrect results in the cephalometric analysis.

To ensure that the variables used have high reliability, attention should be paid to the likely errors in locating the reference points when selecting variables. Repeatedly locating the same reference point results in scattergrams as shown in Figs. 49 and 50 for the B point and Menton reference points, respectively.

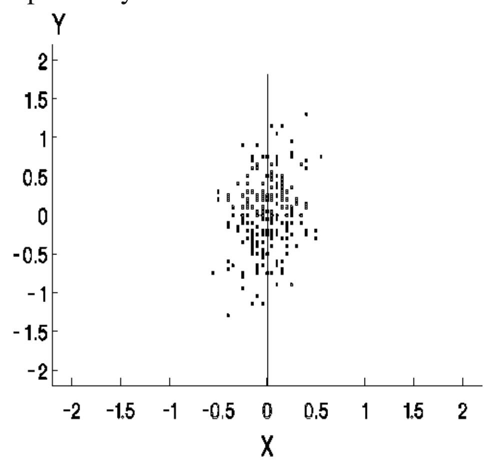


Fig. 49 Scattergram for the landmark B point

Both scattergrams have elongated shapes. As a result, measurements in one direction of space have a lower scatter and thus higher accuracy than in the other direction. The B point, for example, has a much smaller scatter in the sagittal direction; it is therefore well suited for all sagittal measurements. For vertical measurements, however, it is completely unsuitable.

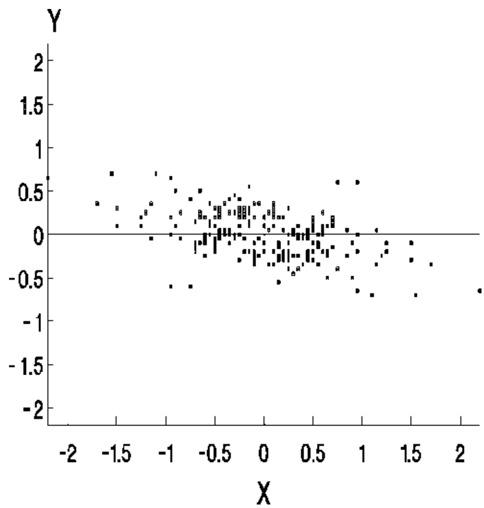


Fig. 50 Scattergram for the landmark Menton

For the Menton point the opposite is true. It is suitable only for vertical measurements, but not for sagittal ones.

Of course, there are also reference points that have spherical scattergrams and are therefore equally suitable for sagittal and vertical measurements. Sella, Nasion and the incisal edges are examples.

Furthermore, the errors of the angular measurements between the reference lines also depend on the distances of the reference points from each other.

$$\varepsilon \approx \frac{1}{\sqrt{d}} \times \sqrt{s_{e_1}{}^2 + s_{e_2}{}^2}$$

The angular error depends on the scattering of the reference points perpendicular to the reference line and from the square root of the distances between the reference points (Segner 1993). The greater the distance, the greater the accuracy and reliability of the given reference line.

The above principles were taken into account in the selection of variables in the previous section.

C. Clinical significance of the variables

The previous chapter described the angles and distances that are measured on the cephalometric image. The importance of measurability and reproducibility was pointed out when selecting the variables to be measured. However, another aspect of no less importance is that the variables used can provide differentiated, comprehensible, and clinically relevant information on the craniofacial structure. A description of the conclusions that can be drawn from the variables used is described in the subsequent sections.

SNA angle

The SNA angle expresses the anterior-posterior position of the A reference point in relation to the anterior cranial base exressed by NSL.

The A point is located in the border zone between the alveolar process and the base of the maxilla, so clinically, the SNA angle describes the sagittal position of the maxilla.

Individuals within different ethnic groups show wide variations with respect to this angle. To demonstrate these variations, a group of 242 young adults from Hamburg with Angle Class I occlusion was selected and, among other things, the SNA angle was measured. The distribution of the measured values is shown in Fig. 51. It can be seen that the values ranged from 72.2° to 91.1° with a mean value of 81.9°. Merely a fraction of the individuals in this group is found to be at or close to the mean value.

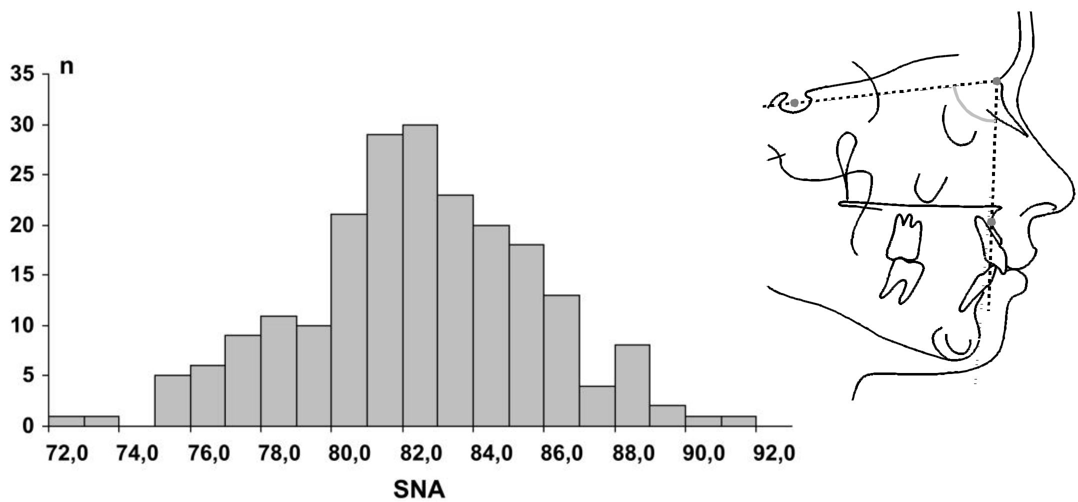


Fig. 51 Distribution of the values for SNA angle in the investigated group

The term *degree of prognathism* is used in conjunction with the sagittal position of the maxilla. If the values of the SNA angle

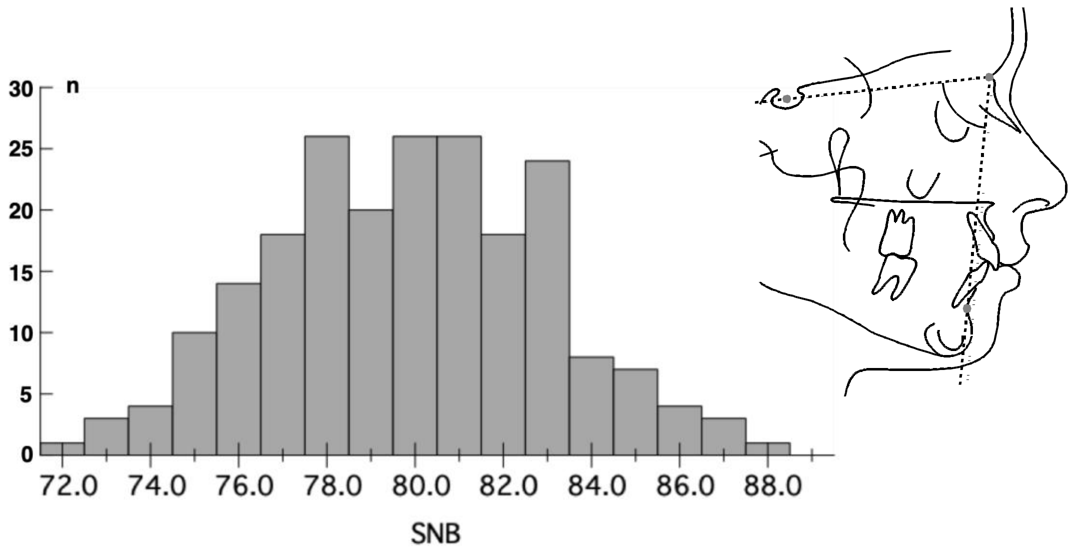


Fig. 52 Distribution of values for SNB angle in the reference group

are large (SNA > 85°), the anterior-posterior position of the maxilla is called prognathic. If the values for the SNA angle are within the range of 79° < SNA < 85°, the position of the maxilla is orthognathic; for values below 79°, it is called retrognathic.

SNB angle

The SNB angle describes the anterior-posterior position of the mandible in relation to the anterior cranial base in the same way the SNA angle does for the maxilla. The B point is located at the junction of the mandibular base and the alveolar process similar to the A point.

The distribution of the SNB angle is also similar to that of the SNA angle (Fig. 52). The bar chart of the study group shows values between 72.2° and 88.0° with a mean value of 79.8°. Even in this limited group with proper occlusion, a wide range of values was found, some of which were quite extreme.

The sagittal position of the mandible is again classified according to the degrees of prognathism, for values greater than 83° as prognathic, for values less than 77° as retrognathic and between 77° and 83° as orthognathic.

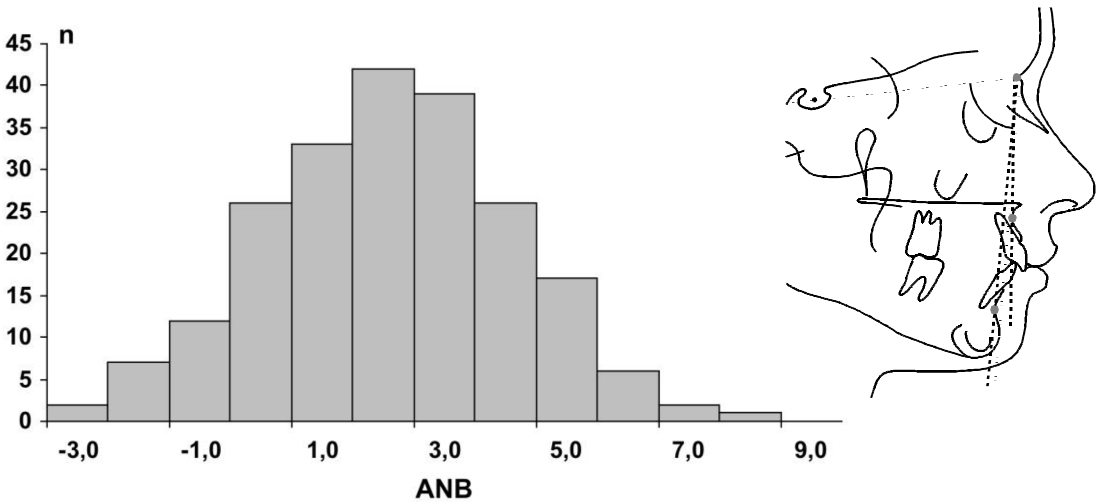


Fig. 53 Distribution of ANB angle in the investigated group

ANB angle

Clinically, the sagittal position of the maxilla in relation to the mandible is of particular interest. This relationship is expressed by the ANB angle.

The distribution diagram in Fig. 53 shows that in the sample group there is a spread of -3.1° to 7.8° with a mean of 2.1°. Despite this wide range, all individuals in the group showed proper Angle Class I occlusion. The ANB angle assumes positive values when the A point is anterior to the NB line (Fig. 54, left). If the NA and NB lines coincide, the ANB angle equals 0° (Fig. 54, center). If the A point lies behind the NB line, the ANB angle assumes negative values (Fig. 54, right).

To simplify communication, the sagittal relation of the jaw bases described by the ANB angle is divided into the three categories: distal, neutral and mesial. For the *orthognathic* face the following applies:

1. mesial ANB < 0°
2. neutral 0° < ANB < 4°
3. distal ANB > 4°

Due to geometric correlations, the ANB angle must be considered in relation to the degree of prognathism of the jaws. Jacobson mentioned this relationship in his article in 1975. In his famous drawing (Fig. 55) it becomes clear that anterior and posterior displacement of the jaws, as well as a sagittal displacement of the Nasion, with otherwise the same relation of the jaw bases to each other, lead to different ANB angles. One reason for this is the fact that the SNA and SNB angles normally deviate from 90° and that the inclination of the jaws —as described in detail below— depends on the degree of prognathism. Both, however, influence the ANB angle: with the same relation of the jaws to each other, a retrognathic face will lead to a smaller ANB angle, while a simultaneous posterior rotation of maxilla and mandible will lead to an increase of the ANB angle.

There have been many attempts to avoid these problems with the ANB angle by using other measurements. So far, however, no other measurement has been shown to have better reproducibility and clinical significance.

The ANB angle usually assumes smaller values in the retrognathic facial type and larger values in the prognathic facial type. For the classification of the sagittal basal relation, the intervals must be shifted up or down by 2° accordingly, so that, for example, the following applies to the *prognathic* facial type:

1. mesial ANB < 2°
2. neutral 2° < ANB < 6°
3. distal ANB > 6°

This classification can be more precise if the individually optimal ANB angle is determined. In Chapter D, it is described how this can be done for each patient.

The ANB angle is of particular clinical importance. Not only does it provide information about the possibility of treating a malocclusion in the sagittal plane, but it also influences the position of the incisors. Several studies have shown that even in untreated cases there is a good correlation between the position of the incisors and the value of the ANB angle. Nature makes use of the incisors to compensate for the deviations of the jaw bases in the sagittal plane.

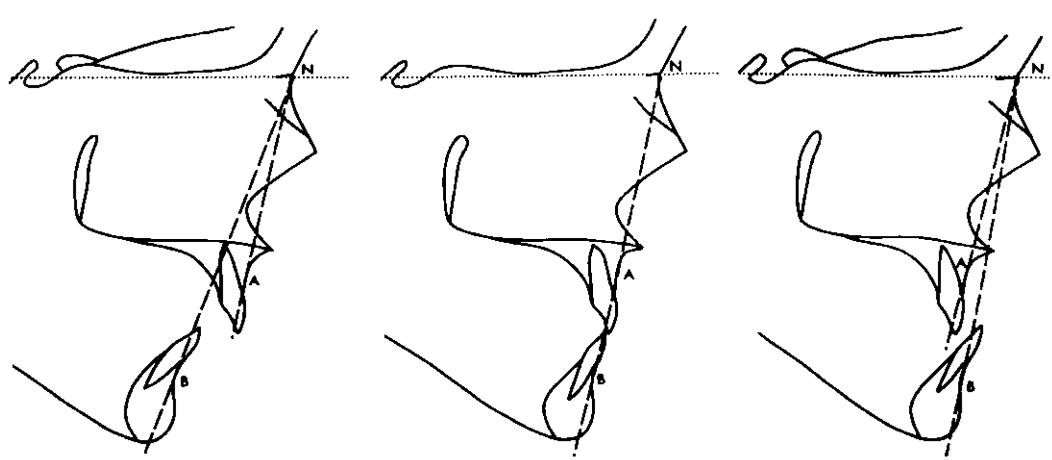


Fig. 54 The ANB angle can have positive or negative values

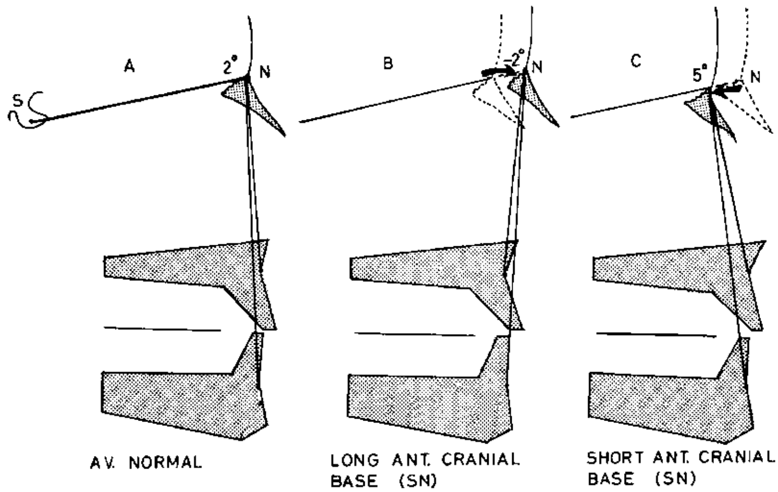


Fig. 55 Influence of the degree of prognathism on the ANB angle. Shown here are varying lengths of the anterior cranial base: left orthognathic, center retrognathic, right prognathic (from Jacobsen: *Application of the „Wits" appraisal (1976))*

In cases with a skeletally mesial configuration of the maxillary base due to maxillary hypoplasia and/or mandibular prognathism, this correlation is particularly evident. In these cases, the maxillary incisors are often strongly protrusive, while the mandibular incisors are more lingually inclined (Fig. 57).

A corresponding compensatory mechanism, but in the opposite direction, can be observed in cases with a large ANB angle (Fig. 56). The lower incisors are clearly protruded, while the upper incisors are inclined more palatally. This combination results in a reduction of the large sagittal overbite which would be expected otherwise.

In the case shown in Figure 56, the compensating mechanism of the incisor position alone is not sufficient to result in a good anterior relationship. However, this compensating effect of incisor position is also found even in cases with near-ideal occlusion (Fig. 57).

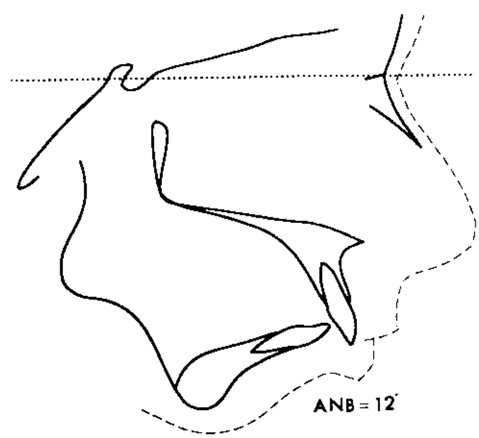


Fig. 56 Compensatory mechanism of incisor position in the case of a large ANB angle

This interrelationship between incisor position and ANB angle should be considered clinically. It is possible to orthodontically change the positions of the incisors in both jaws. The question then is where they should be positioned. Since the ANB angle can be determined, it is possible to use it as a guide for addressing this question. If the ANB angle is reduced during treatment, it is often necessary to upright the mandibular incisors to the linual just as nature would do it. While it is possible to obtain an acceptable incisor position within a wide range of ANB angles, doing so requires a different inclination of the incisors from case to case. This depends, among other things, on the size of the ANB angle.

It must be emphasized that this is a simplification of the issue, since other compensatory mechanisms in the facial skull may vary from patient to patient, so the influence of other cephalometric variables must also be discussed. Furthermore, there are correlations between the soft tissue profile and the ANB angle. For example, the H-angle can only be discussed in relation to the ANB angle.

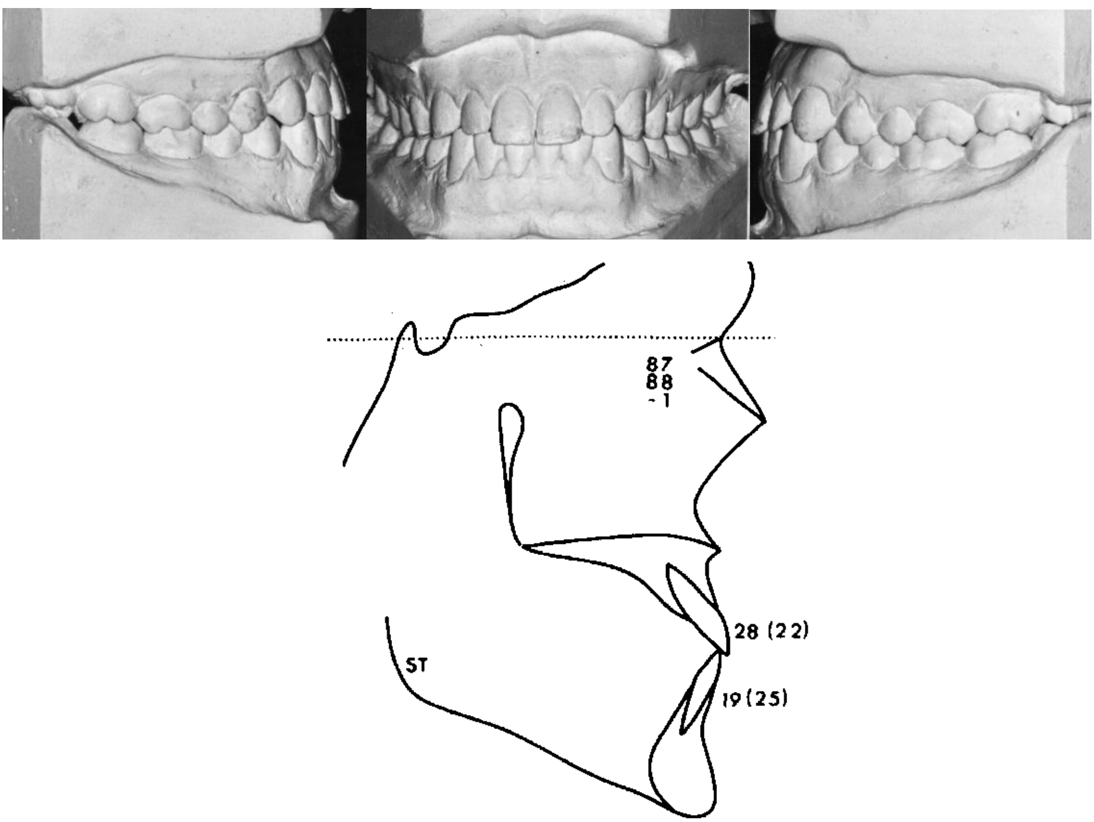


Fig. 57 The compensating mechanism of the incisor inclination shown in a case with almost ideal occlusion but a slightly mesial jaw relation

SNPg angle

The SNPg angle, like the SNB angle, provides an indication of the sagittal position of the mandible. The Pogonion is the most anterior point of the symphysis, while the B point, which serves as the basis for the SNB angle, is located at the transition between the alveolar process and the base of the mandible. Both the SNPg and SNB angles express essentially the same relationship, although in individual cases there may well be noteworthy differences between these two measurements. This difference gives us the opportunity to estimate the bony chin protrusion and the sagittal position of the teeth on the corpus mandibulae. This is important in the differential diagnosis for cases with distal occlusion (see also $PgNB_{mm}$).

The scatter of the SNPg angle is similar to that of the SNB angle, but with a somewhat flatter distribution. With a mean value of 81.0°, the study group shows a range from 73.6° to 90.4°.

The mean difference between SNB and SNPg is 1.2° for the orthognathic facial type in the adult study group. In cases with alveolar retrusion, as often found in Angle Class II division 2 cases, the difference is significantly higher than the mean value. In cases without alveolar retrusion, especially in conjunction with a large ML-NSL angle, the Pogonion point may be located posteriorly to the NB line, leading to a SNPg angle that is smaller than the SNB angle.

ML-NSL angle

The ML-NSL angle expresses the inclination of the mandible in relation to the anterior cranial base. The control group presents values between 13.3° and 41.6° with a mean value of 28.0° (Fig. 60).

Based on this mean value, the terms posterior inclination and anterior inclination were introduced. If the ML-NSL values

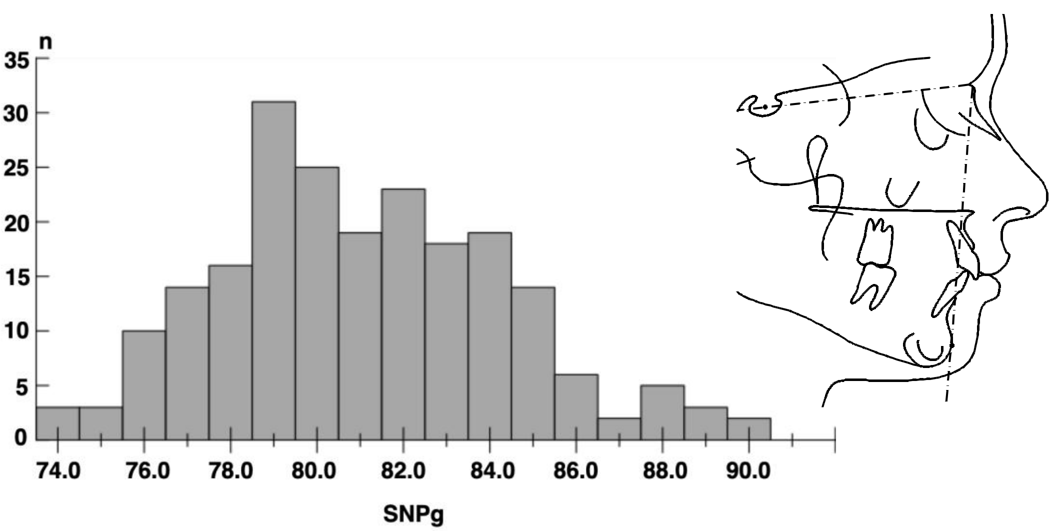


Fig. 58 Distribution of the SNPg angle

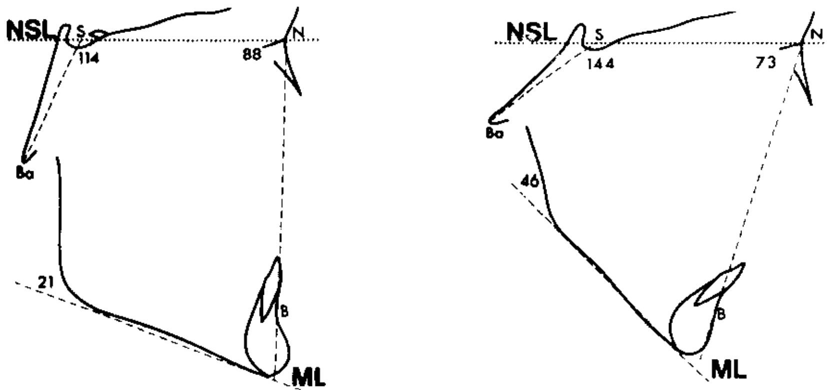


Fig. 59 Visualisation of the mandibular inclination. Left: anterior, right: posterior

are above the mean, they point to a posterior inclination (Fig. 59, right); if they are below, they imply an anterior inclination (Fig. 59, left).

Compared to the other cephalometric variables, the ML-NSL mean angle is more influenced by regional differences in the populations. For example, in the past, a mean value of 32° was frequently used, which was based on study results performed by Björk in central Sweden. However, several subsequent investigations have shown that, at least for the Norwegian, Danish and German populations, the mean value is significantly lower. Another reason is the fact that Björk used a different definition of the ML-Line.

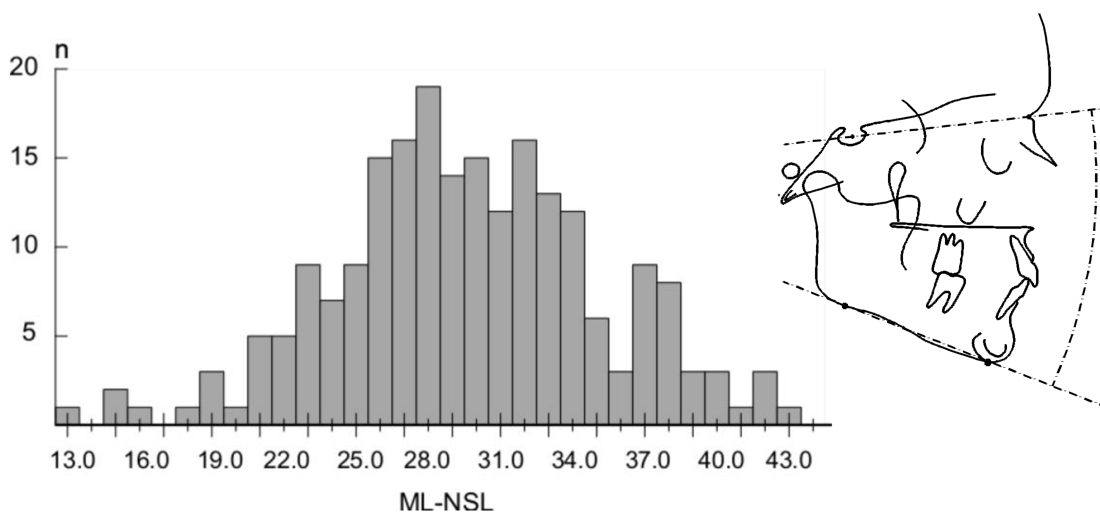


Fig. 60 Distribution of the angle ML-NSL angle

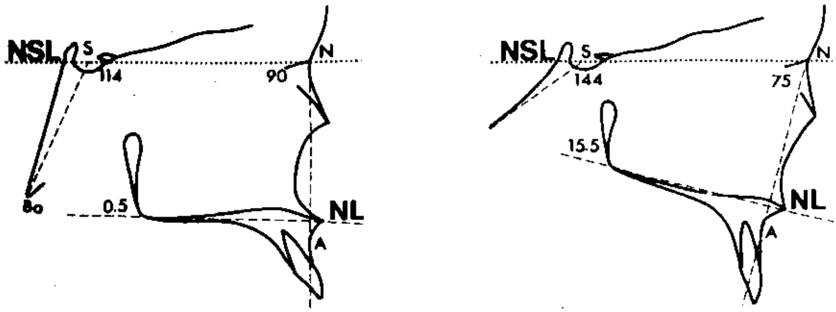


Fig. 61 Visualization of the maxillary inclination: left anterior, right posterior

NL-NSL angle

The NL-NSL angle expresses the degree of inclination of the maxilla in relation to the anterior cranial base. Once again, the sample group shows a significant variation, although the range is not as broad as that of the ML-NSL angle. The values found range from 1.3° to 16.5°, with a mean value of 8.1°.

Based on the mean value of 8.1°, the terms *posterior inclination* (for large values) and *anterior inclination* (for small or negative angular values) are also used here.

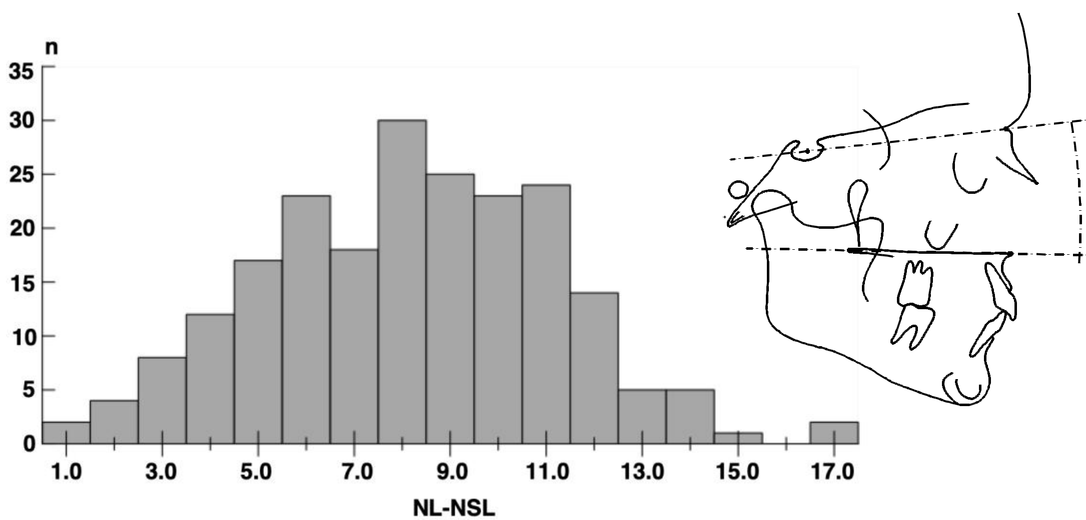


Fig. 62 Distribution of the angle NL-NSL angle

ML-NL angle

The ML-NL angle describes the angle of inclination of the mandible (ML) in relation to the maxillary base (nasal line NL). The angle is also called the interbasal angle. It describes the divergence of the maxillary and mandibular bases.

The study group shows values between 7.1° and 34.3°. The mean value is 19.8°. What was said about regional differences in ML-NSL also applies to this angle. The often-mentioned average value of 23.5° or 25° is too large for the local population of this study group. Furthermore, the evaluation of this angle must be made in connection with the facial type. This correlation is discussed in detail in the chapter "Norm".

Clinically, this angle is used as a basis for evaluation of dental anomalies with basal deviations in the vertical plane: open and deep bite. In addition, this angle is of particular importance in borderline cases when, due to a lack of space, a decision must be made as to whether distalization of molars in the maxilla and/or mandible can be performed. Thus, if the angle is large, caution should be exercised in distalizing molars, as this may result in posterior rotation of the mandible and consequent opening of the bite. In contrast, this side effect would be desirable for small values of the ML-NL angle.

In this context, the direction of pull when applying a headgear to the upper molars is also very important, regardless of whether an active distalization is intended or whether the molars are only to be "held in place" for the purpose of anchorage. Apart from a possible rotational effect, a cervical pull (neck pull) can cause an extrusion of the molars and thus an opening of the ML-NL angle along with the bite. By using an occipital pull, this possibly undesirable side effect cannot only be avoided, but even an intrusion of the upper molars can be achieved with the subsequent reduction of the ML-NL angle.

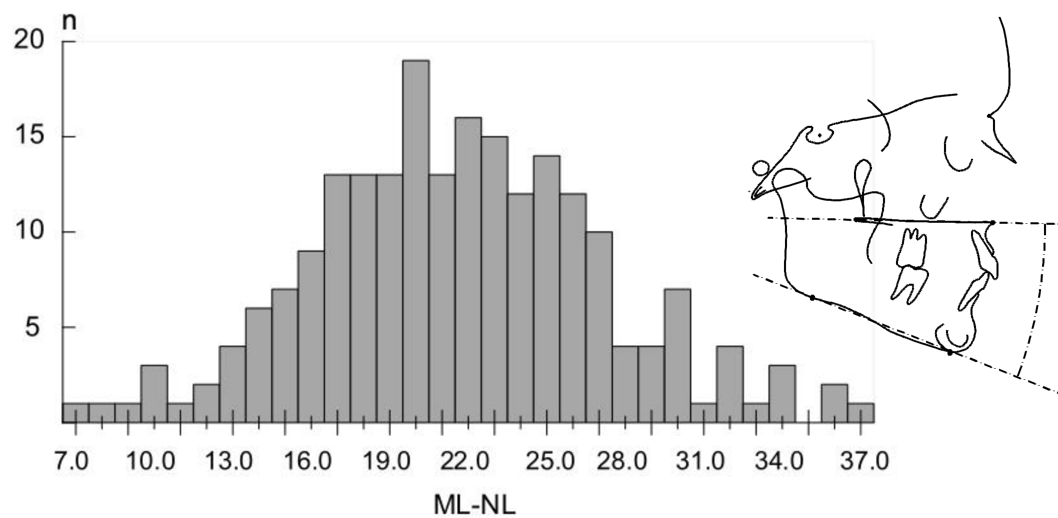


Abb. 63 Distribution of the ML-NL angle

NSBa angle

The NSBa angle describes the angulation of the cranial base in relation to the clivus. The study group shows a distribution from 118.9° to 151.2°, with a mean value of 131.7°.

A morphological association exists between the NSBa angle and the facial skull, as there is a close positional interrelationship of the clivus and the fossa articularis in the sagittal plane. Thus, the sagittal position of the mandible, with respect to the temporomandibular joint, is also directly related to the NSBa angle.

Me-tgo-Ar angle

The mandibular or gonial angle Me-tgo-Ar describes the relationship of the ramus to the corpus mandibulae and is therefore an indicator of the shape of the mandible. There is a very wide variety for this angle starting from 101.4° to 144.5°, with a mean value of 121.8°.

The value of the mandibular angle is influenced, among other things, by the condylar growth direction. If the condyle grows in a posterior direction, this results in a larger value of the mandibular angle. The opposite is true if the condyle is growing in an anterior direction, which results in a smaller value of the mandibular angle. On the other hand, the angle also plays a role in predicting the direction of growth. Large values for this angle indicate that the condyle will continue to grow in a more posterior direction relative to the corpus mandibulae, and consequently, a more vertical growth with a tendency toward posterior rotation is to be expected.

Small gonial angles, on the other hand, indicate more vertical or even anterior

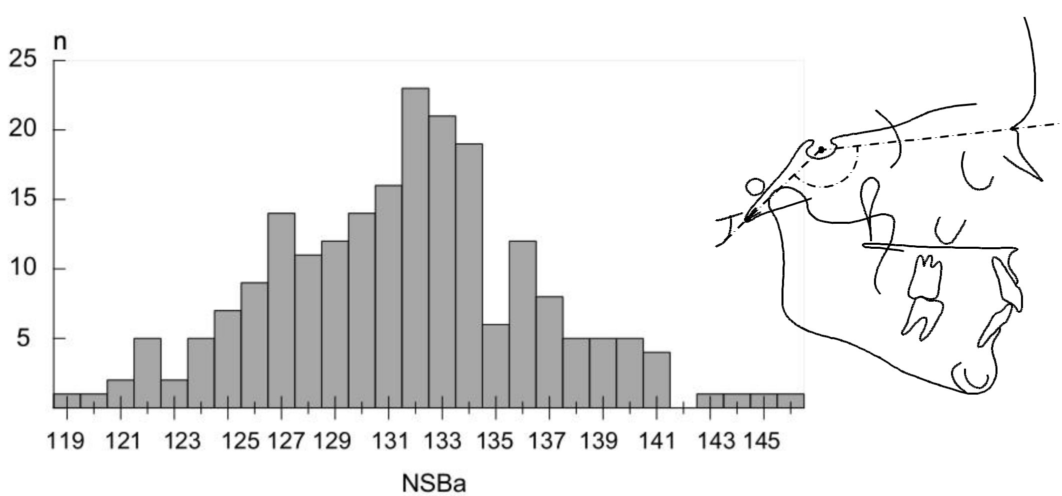


Fig. 64 Distribution of the NSBa angle

Fig. 65 Open and closed mandibular or gonial angle on the skull

growth of the condyles and, consequently, more anterior growth of the mandible. When making prognoses on growth, it should be kept in mind that apposition and/or resorption occur at both the inferior and posterior margins of the mandibular angle during growth. Therefore, all such predictions must be made with a considerable caution.

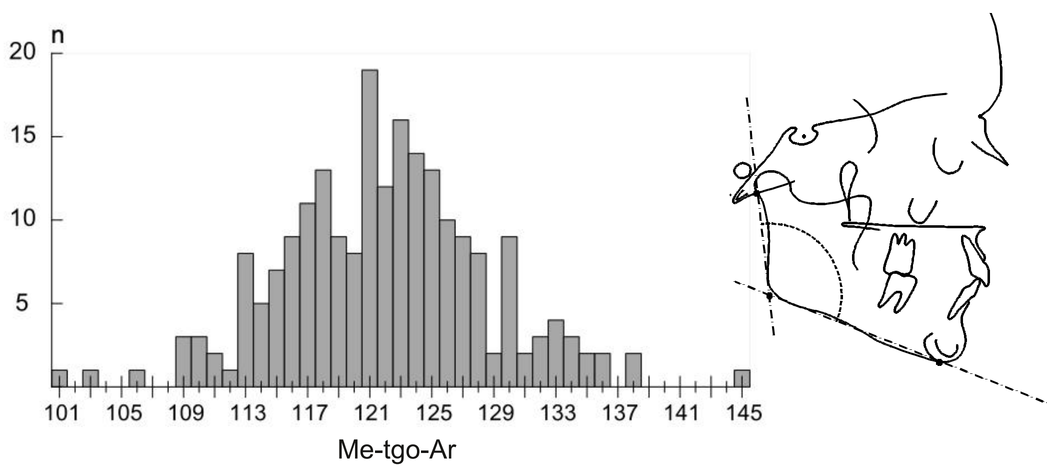


Fig. 66 Distribution of the values for the mandibular angle Me-tgo-Ar

Holdaway angle (H-angle)

The measurement of the H-angle represents an attempt to relate the overlying soft tissues to the hard tissue profile. The angle describes the inclination of the H-line in relation to the NB line. It can be seen in Figure 67 that there is a large distribution around the mean value of 9.2°. It should be kept in mind that the angle is usually significantly larger in young children than in adults; it decreases in value as children grow.

The H-angle should be considered not merely regarding the stability of the occlusal alignment, but above all regarding the esthetic appearance of the patient. Values for this angle that are clearly too large or too small are usually perceived as unpleasant by the patient and his environment when evaluating the profile.

The sagittal plane relation (ANB angle), the chin prominence ($PgNB_{mm}$), the soft tissue thickness of the chin and upper lip and the position of the upper incisors all have an influence on the H-angle. Since the first and last of these variables can usually be influenced by the orthodontist, care should be taken in treatment planning to avoid any unfavorable influence on the H-angle.

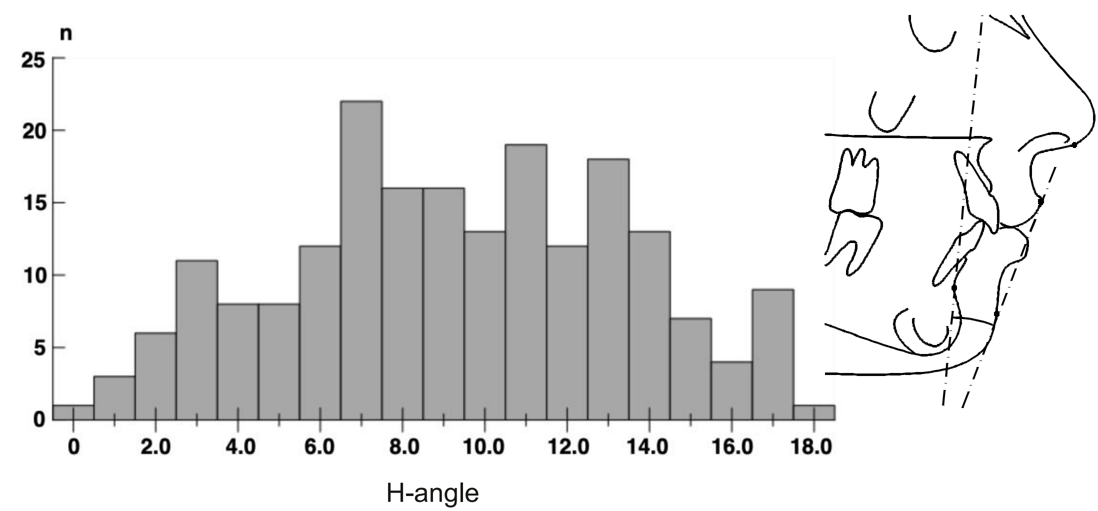


Fig. 67 Distribution of the H-angle

Nasolabial angle

The Nasolabial angle indicates the position of the upper lip in relation to the nose. It is of great importance for the aesthetic assessment of the profile. A large value of this angle indicates either an abnormality of the nose (snub nose) or a retrusive upper lip.

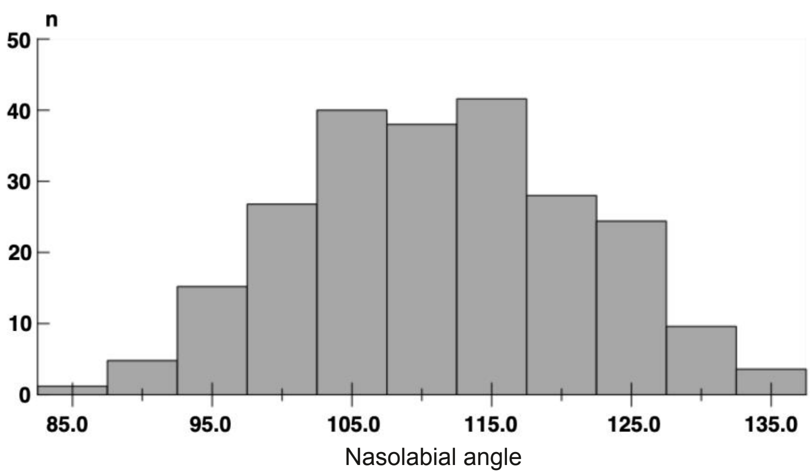
A combination of these two conditions may also occur. Retrusion of the upper lip results in a reduction of visible vermilion. A pronounced vermilion offers a youthful and attractive appearance to most people.

A very small value of the Nasolabial angle occurs primarily in cases of bimaxillary proclination or severe maxillary hypoplasia (cleft lip and palate) and is also considered unattractive.

The mean value of the Nasolabial angle is 109.8°, with an S.D. of 9.8° and a range from 87° to 128°. It should be noted that the individuals of the study group were selected based on the criteria of their occlusions and not on esthetics. Presumably, a group of particularly esthetically pleasing profiles would show fewer extreme values.

The Nasolabial angle is independent of both age and sex; therefore, the mean value given can serve as a reference for all patients.

The assessment of the soft tissue profile cannot be based solely on measurements; a subjective assessment must also be included.



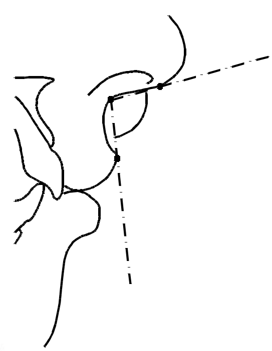


Fig. 68 Distribution of the Nasolabial angle

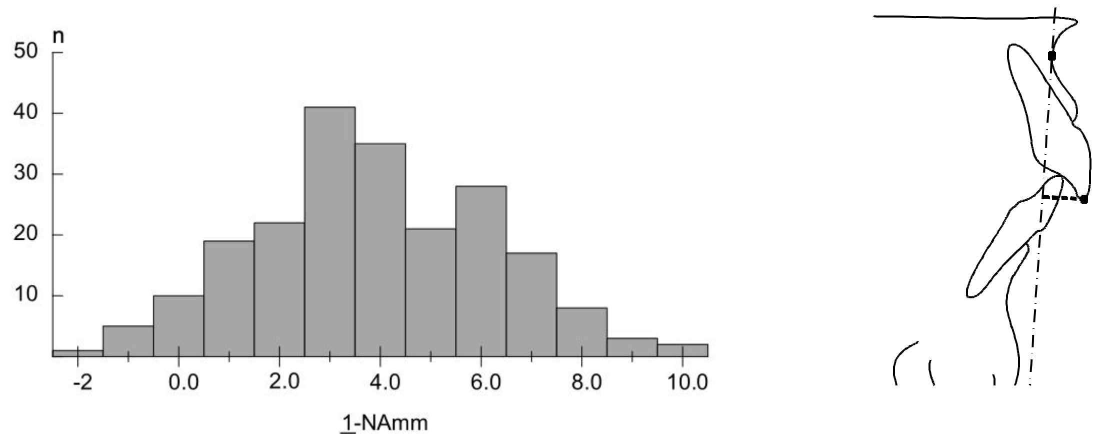


Fig. 69 Distribution of ⊥-NA$_{mm}$

⊥-NA

To describe the position of the upper incisors, a length measurement combined with an angle measurement is used. Both relate to the NA reference line. Based on these measurements, the position of the incisors is assessed in relation to the base of the maxilla in the anterior-posterior direction.

The study group shows a range of measurements from -2.6 mm to 10.5 mm, with a mean value of 3.7 mm (Fig. 69). In addition, the angular value shows the proclination of upper incisors. The proclination in the study group ranged from -0.3° to 34.4°, with a mean value of 20.9°.

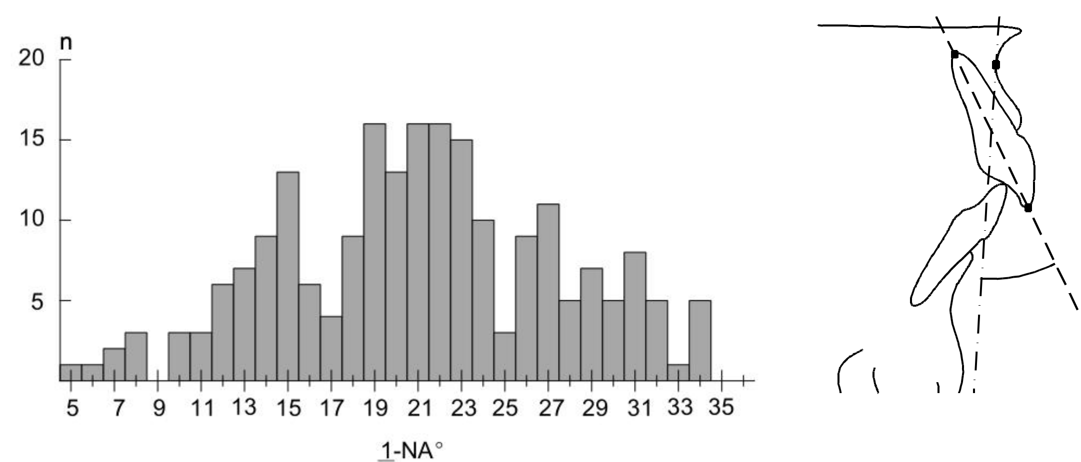


Fig. 70 Distribution of angle ⊥-NA°

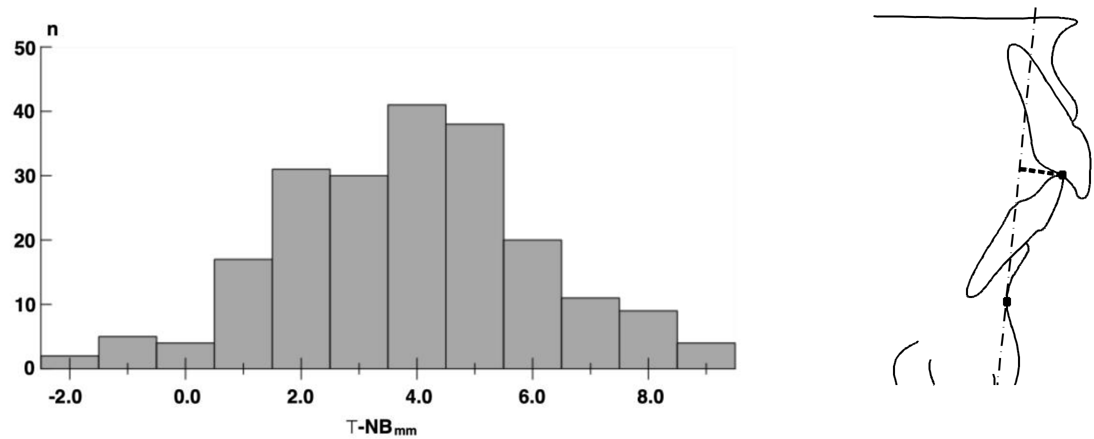


Fig. 71 Distribution of ⊤–NB_{mm}

⊤-NB

A distance measurement along with an angle measurement is also used to describe the position of the lower incisors. The NB line is used as the reference for both of these. In this way, the position of the incisors in relation to the mandible in the anterior-posterior direction is determined.

A range of values from -2.4 mm to 9.6 mm with a mean value of 3.8 mm was observed in this study group (Fig. 71). The angular measurement indicates the degree of proclination of the lower incisors. The values of the incisor proclination ranged from 0.2° to 40.8°, with a mean value of 24.1°. The assessment of the incisor position is discussed in more detail in the chapter "*norm*".

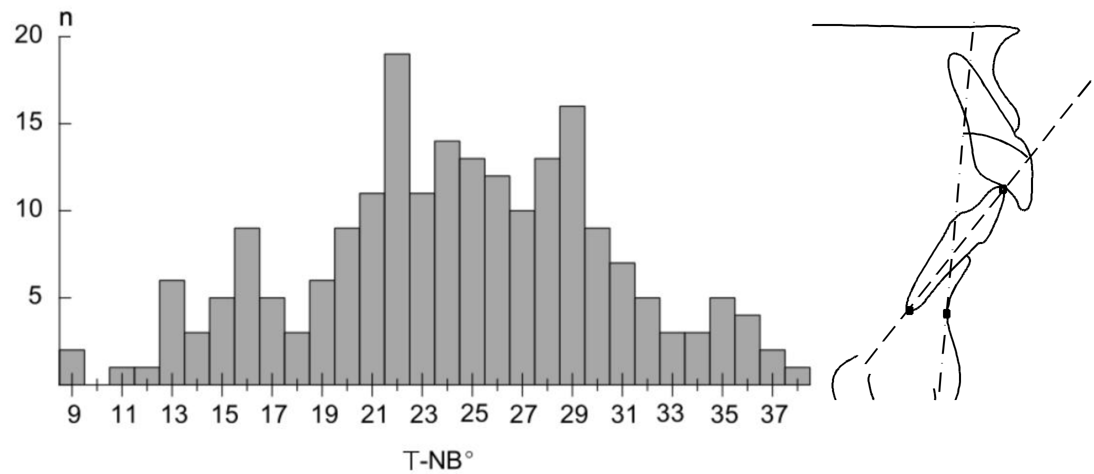


Fig. 72 Distribution of angle ⊤-NB°

Interincisal angle ⊥-⊤

The interincisal angle is used to further describe the incisor position. The study group shows a large distribution of values for this variable. The smallest value is 108.6°, and the largest is 159.4°. The mean value is 132.9°.

The angle is of great significance when it comes to assessing the treatment results, both in terms of stability and the esthetic appearance of the incisor position. Particularly when treating cases with a deep bite and retroclined anterior teeth, an adequate reduction of the interincisal angle is usually important to achieve the desired vertical support. However, the morphology of the palatal surfaces of the upper incisors is also important for the assessment of vertical stability.

After active treatment, an evaluation of the interincisal angle must be made while keeping in mind the direction and amount of growth that can be expected during the retention period. An increase in the interincisal angle is often seen. This may be caused by the sagittal growth of the mandible which exceeds the growth of the maxilla (e.g., residual mandibular growth) and which might result in the mandibular incisors becoming more upright. This should be considered at the end of the active treatment when aligning the incisors. On the other hand, if after the treatment the growth proceeds in a more vertical direction, it is advisable to directly align the incisors in the desired position.

Which position is acceptable or desirable is described in more detail in the chapter "*norm*".

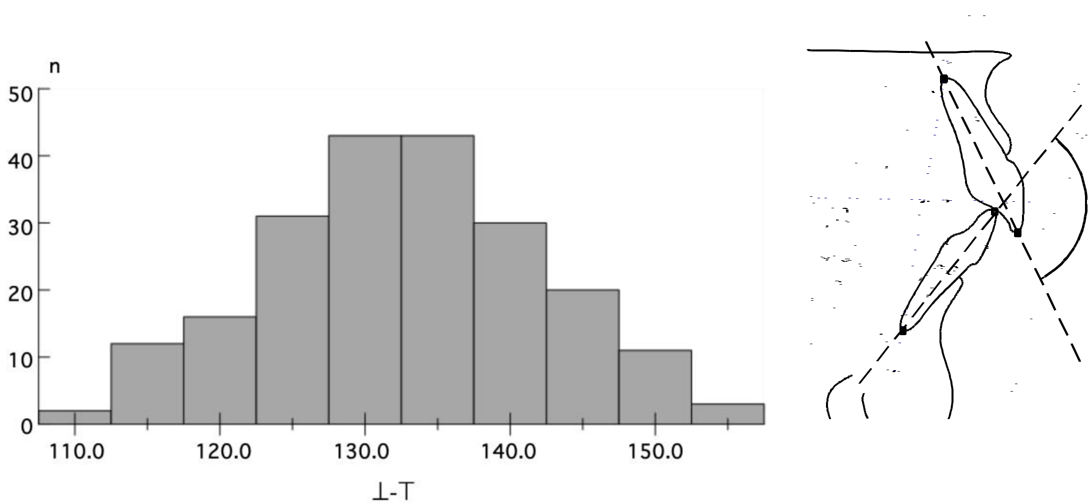


Fig. 73 Distribution of the interincisal angle ⊥-⊤

$PgNB_{mm}$

The distance $PgNB_{mm}$ describes the prominence of the mandibular symphysis (Fig. 74). A range of -3.1 mm to +9.9 mm is oberved in this study group. The average value is 2.3 mm.

A large value of $PgNB_{mm}$ indicates a posterior position of the alveolar process in relation to the mandibular base. Such a retroposition of the B point in some cases can be a reason for an increased ANB angle. It is also an important factor in treatment planning since this variable can influence the tooth position and profile esthetics although it cannot be altered by orthodontic measures.

Age plays a major role in this assessment. At an age of 5 to 6 years, in most cases the mandibular symphysis is not well formed; however, it continues to develop in later growth phases and into adulthood.

The distance $PgNB_{mm}$ is closely related to the position of the incisors. When the alveolar process (B point) is positioned more dorsally in relation to the Pogonion (a large value of $PgNB_{mm}$), the incisors are also more retruded. Both phenomena seem to be caused by a high tonus of the mentalis muscle. This relationship is discussed in more detail in the chapter on dental norms.

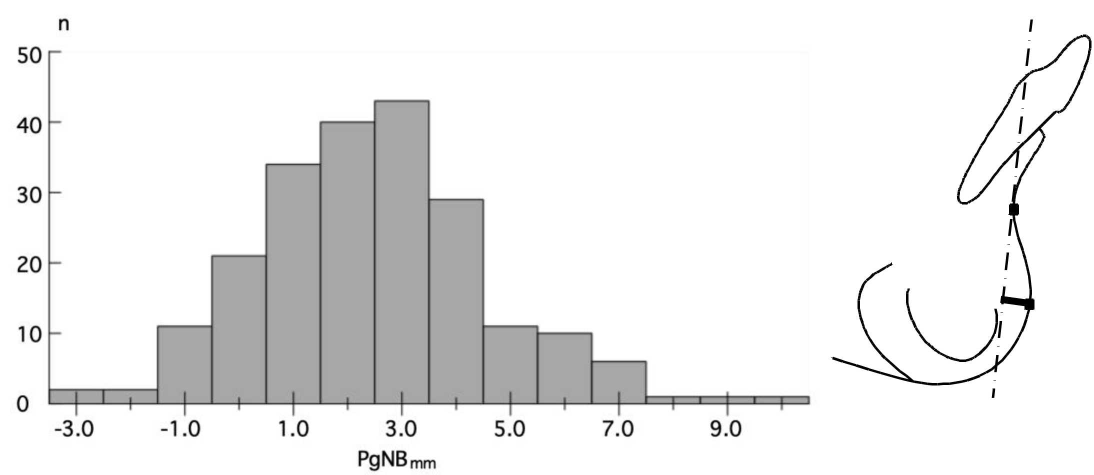


Fig. 74 Distribution of the distance $PgNB_{mm}$

Index of anterior face heights

The Index of anterior face heights expresses the proportional relationship between the anterior mid and lower face heights. It is the ratio of N-Sp' to Sp'-Me expressed as a percentage. As with all indices, it is difficult to determine whether a given deviation from the mean value of the overall Index is due to an aberration in the numerator or the denominator. Since the lower face height shows a significantly larger variability than the midface height, deviations in the value of the Index are mostly due to a variation in the lower face height. Discrepancies in the upper face height occur primarily due to malformations of the facial skull, such as clefts. It is possible to relate the midface height to other linear variables of the facial skull as a control (see chapter "Norm").

The Index in the study group varies from 62.9% to 99.5%, with an average value of 80.1%. Unlike most of the other variables, the Index of anterior facial heights does not depend on face type or sex and shows little correlation with age. In mixed dentition, the Index is up to three percent points higher (relatively smaller lower facial height) than in adults or in children before the onset of mixed dentition.

The Index is particularly significant in the assessment of vertical relationships, e.g., for open or deep bite (Fig. 76). In combination with the interbasal angle ML-NL in relation to the face type, the Index allows a sufficient evaluation of the vertical relationships.

Moreover, it has been shown that the treatment of sagittal problems also improves

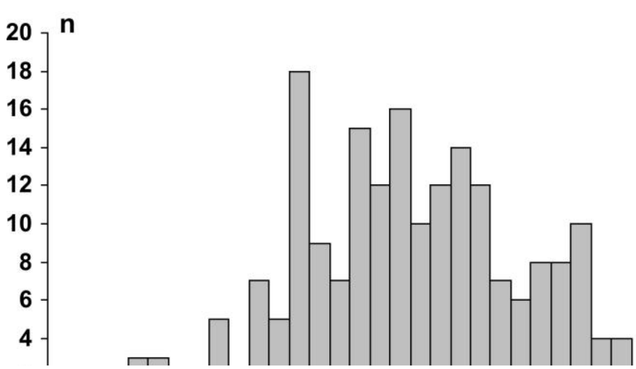
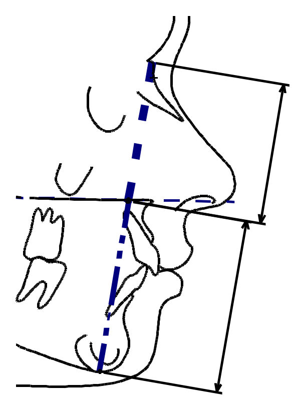


Fig. 75 Distribution of the Index of anterior face heights



considerably —or, in the case of extreme sagittal deviations— is only possible at all if the proportions of the facial heights are in balance (Index ~80%).

According to the sagittal base relation, for simplicity a classification into three groups is used. The three groups are designated O (open), N (neutral), and D (deep) and assigned as follows:

O	Index $< 71\%$
N	$71\% <$ Index $< 89\%$
D	Index $> 89\%$

Approximately $^{2}/_{3}$ of all patients fall into the "N" category, with the remainder split between the "O" and "D" groups.

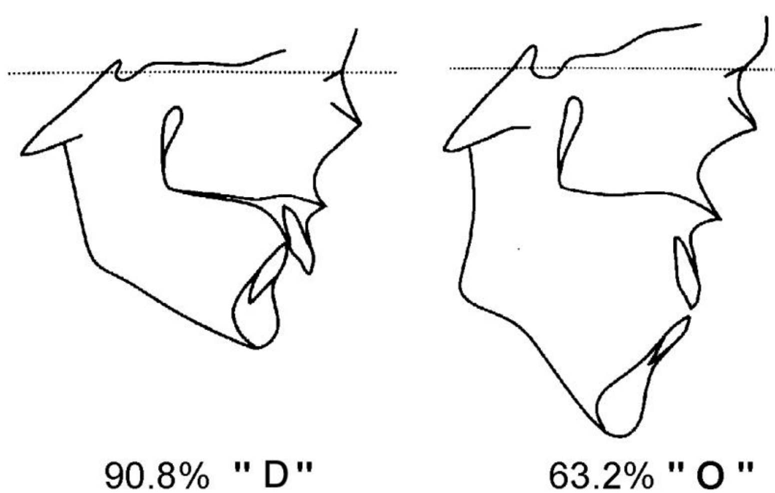


Fig. 76 Tracings of cases with a large Index ("D") and with a small Index ("O")

D. The concept of "*norm*"

Any assessment of a clinical situation is meaningful only if it is compared to a "*norm*". The *norm* does not necessarily represent a situation to be aimed at, but it is essential in order to calibrate the diagnostic measurements. The Angle classification has been established in dental diagnostics; the *norm* here is the "neutral dentition", in which the mesiobuccal cusp of the upper first molar bites into the buccal groove of the lower first molar. This situation is called "Class I". The evaluation of the sagittal condition is then guided by this *norm*. Deviations from this *norm* in the mesial or distal direction can be directly read from the three-dimensionally aligned model. The amount of deviation is indicated in millimeters or in fractions of premolar width.

An interesting fact in this context is that in many regions up to one third of the orthodontically untreated population deviates from the *norm* of "Class I". However, it has been shown that a "Class I" occlusion, as described by Angle, is of such significance to the function of the masticatory system that it is generally accepted as the *norm*.

For the evaluation of the cephalometric variables, a comparable *norm* has not yet been established. Rather, the distribution of the measured variables is continuous and, in general, close to the *norm*. In most cases, small differences do not have such a clear negative or positive effect on the stomatognathic system as the shift in the interlocking of teeth.

1. Assesment of Measurements

The most straightforward assessment of successive measurements is based on the mean ("average") value of a reference population. This reference group can consist of either a typical group of the general population or by a group that meets certain criteria. An "ideal" occlusion is most commonly the main requirement.

The measurements of a patient to be examined will usually not conform to such a mean value or in other words, to a given *norm*. For this reason, a certain range of variation is often tolerated, according to the distribution of the corresponding variable in the reference population. For example, if a variable has a large standard deviation, such as the angle NSBa, deviations of a few degrees are not as significant as for the angle ANB, which has a small standard deviation.

However, for all analyses guided by the mean values of the reference population the impact on treatment of the respective diagnosis must be considered. Most importantly, it must be scrutinized whether achieving the mean value of the population for each variable should be the goal of treatment for each patient. This would, for example, not allow an individual consideration of the patient's facial type. However, if such considerations are not possible, the question arises, if the diagnostic value of the lateral cephalogram justifies its effort and radiation exposure.

The aim should rather be to evaluate the measurements in a way that takes into account the individual characteristics of the patient. In this way, there is no risk of using the same *norm* for all patients. Therefore, the goal is to find the ***individual norm*** for each patient and to assess the measured values based on this *norm*.

Orthognathic and/or dentoalveolar problems can then be identified without omitting the individualized approach. Furthermore, when applying the *individual norms* a more precise threshold for detection of deviations is achieved, than when applying population mean values.

In the following chapter, it will be shown how such *individualized norms* are established and applied.

2. THE CONCEPT OF HARMONY

Examining measured variables from a number of individuals shows that these measured variables do not occur completely independently of one another. In fact, it can be said that a large measured value for one variable usually results in a relatively large value for another variable. This means that there is a correlation between the different variables.

The examples in Figure 80 show human bodies with different heights. The length of the arms of the right figure in Fig. 80 is relatively long; however, the same is true for the length of the legs. In the figure on the left in Fig. 80 they are both short.

All three figures show different measured values for arm and leg lengths. Only the middle figure in Fig. 80 corresponds to the "average human being," while the outer figures deviate significantly from these average values. Now, no one will claim that this deviation is clinically relevant. It is rather an expression of the biological variation of the body height variable. However, in the figure in Fig. 81, it is

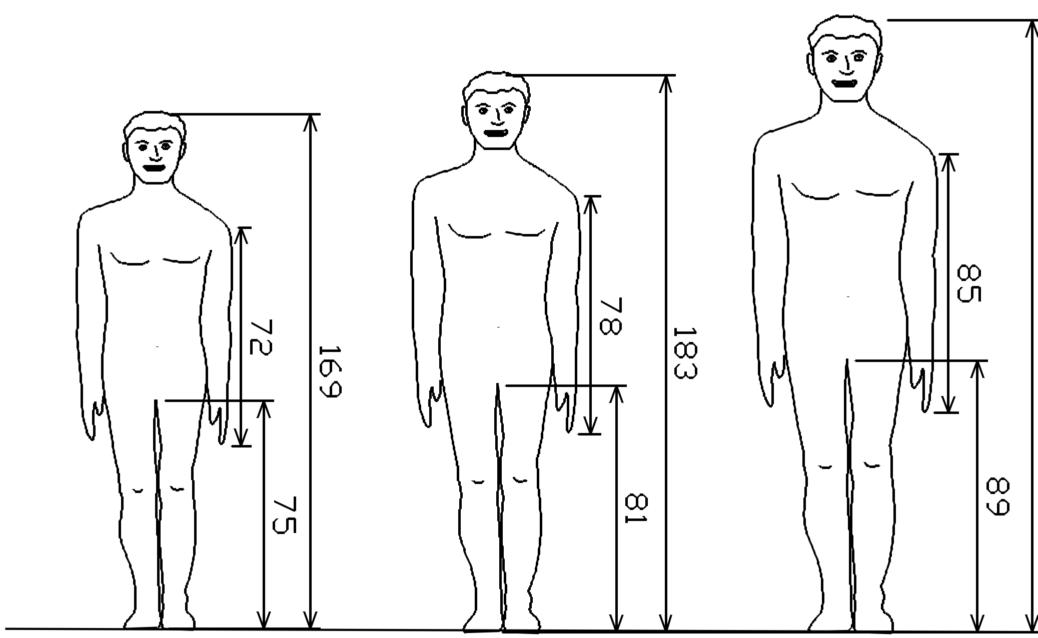


Fig. 80 Figures with a harmonious combination of arm length, leg length and body height. Left a small person, center a person of medium height, right a tall person.

noticeable that, although the arm length corresponds to the mean value for the population (see Fig. 80, center), it does not match the leg length and body size as a whole.

If the figure in Fig. 81 is judged by the mean value of the population, the arm length would be diagnosed as correct. However, if

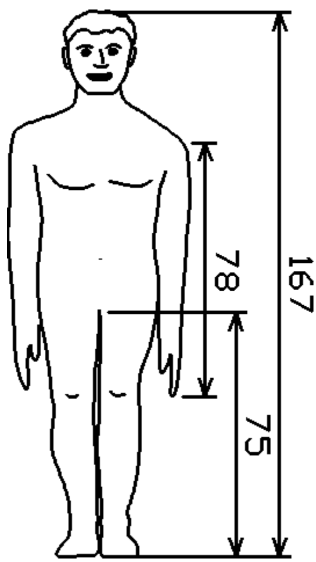


Fig. 81 Figure with a disharmonious combination of arm, leg, and body length. The length of the arm is identical to the one in Fig. 80, center.

the patient's individual proportions are used as a reference, the arms stand out as being too long. There is a discrepancy between the variable of arm length and the other measured variables.

In cases such as Fig. 80 we speak of *harmony*. Here the body parts and consequently the measured variables fit together well, regardless of the mean values. However, this is not the case with the body in Fig. 81. Here at least one of the measured values (in this case the arm length) does not fit to the remaining variables. This is referred to as *disharmony*; the individual parts of the whole do not fit together well.

How can it be objectively determined whether various measured variables fit together and thus whether a harmonious relationship exists?

Correlation studies on a reference population of the respective ethnicity can be used to find out which variables show a correlation. Such investigations were carried out e.g. by Solow in his work "The general pattern of the cranio-facial association". He showed that there are multiple correlations of variables in the region of the facial skull, which together even reveal a facial pattern.

The angles SNB and ML-NSL are presented as an example of the correlation between two angular variables of the facial skull (Fig. 82).

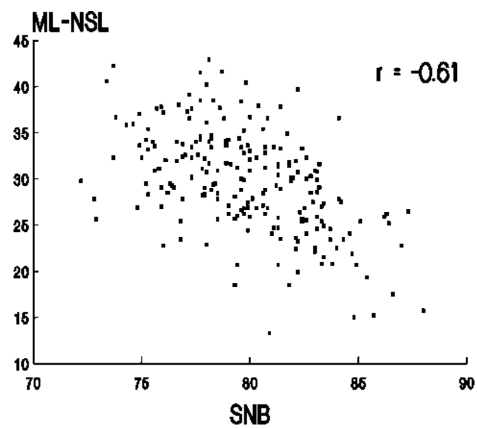


Fig. 82 Scattergram of the correlation between variables SNB and ML-NSL. Note the longish orientation of the point cloud.

The degree of correlation between the two variables is described by the linear correlation coefficient ("r"). The greater the magnitude of this correlation coefficient, the greater the correlation between the variables in question. The maximum value is 1. If, however, the correlation coefficient assumes values around zero, there is no correlation between the two variables.

The sign of the coefficient provides information on the direction of the correlation. With a positive coefficient, the association between the variables is in the same direction, i.e. a larger value for one variable is also associated with a larger value for the other variable. In contrast, if the sign is negative, a large value for one variable is associated with a small value for the other variable, as is the case, for example, with the variables SNB and ML-NSL in Fig. 82.

The strength of the relationship and thus the magnitude of the correlation coefficient can be estimated from the shape of the scattergram. If there is no or hardly any correlation, this cluster of points appears roundish and widely dispersed. On the other hand, an elongated and dense scattergram which appears stretched out, as shown in Fig. 82, for example, suggests a high correlation coefficient. With a coefficient of 1, all points in the scattergram would appear on a straight line. This straight line can be represented by the formula:

$$y = a x + b$$

The value a is shown by the slope of the line, while its sign specifies whether the line rises to the right (positive sign) or the left (negative sign). The value of *b* indicates where the straight line intersects the Y-axis. It is a special case when the straight line is parallel to the X- or Y-axis. In these cases, one variable is constant and does not depend on the other. Thus, the correlation coefficient is zero.

Generally, when not all points lie on a straight line despite a correlation between the two variables, the least squares method can be used to specify a straight line that is suitable for describing the correlation between the two variables. The straight line represents the longitudinal axis of the cluster of points in the scattergram (see also Fig. 82). With the help of this regression line, for a given value of the variable on the X-axis, the optimal matching value for the variable on the Y-axis can be found. This is the value that would be expected for this individual case, based on the correlations found in the reference group. It is therefore an expected value of the Y-axis variable for this individual, which has nothing to do with the population mean.

The linear correlation coefficients between the most important skeletal variables SNA, SNB, NSBa, NL-NSL, and ML-NSL are shown in Table 2. Significant correlations are shown to exist among all of these variables. All correlation coefficients range from 0.31 to 0.82 and are highly significant.

Tab. 2 Correlations between the 5 skeletal variables SNA, NL-NSL, NSBa, ML-NSL and SNB

	NL-NSL	NSBa	ML-NSL	SNB
SNA	-0.37	-0.36	-0.42	0.82
NL-NSL		0.46	0.32	-0.44
NSBa			0.31	-0.45
ML-NSL				-0.61

$n = 275$
$p < 0.001$ for all correlations

Taking SNB and ML-NSL as an example, the meaning of the correlation coefficient of 0.61 can be explained. If, for a given SNB angle, the variance s^2 of the ML-NSL angle is assessed, we find that part of this variance can be explained by the variance of the SNB angle. This fraction can be calculated from the correlation coefficient by squaring it (r^2).

The remaining amount, the so-called residual variance, cannot be explained by the SNB angle and has other causes that are not immediately obvious. The following is therefore valid:

$$s^2_{ML\text{-}NSL} = s^2_{rest} + r^2_{(ML\text{-}NSL/SNB)}$$

In this example, 37% of the variance of the variable ML-NSL can be explained by the variable SNB (37% = 0.37 = 0.61^2). The other 63% of the variance cannot be explained in this way and constitutes the residual variance.

Thus, to evaluate whether a set of cephalometric variables fit together harmoniously, the expected values can be calculated by means of the respective regression equations and then compared with the actual observed values. These expected values are therefore an individual norm for the examined patient.

In order to avoid the time-consuming calculation with the regression equations, these can be calculated once and then displayed in a diagram as shown in Figure 83. The regression values from Table 3 are applied. Matching values for the five variables SNA, NL-NSL, NSBa, ML-NSL, and SNB are shown on a horizontal line. If the individual measured values of a given patient all lie approximately on a horizontal line, it can be said that this patient shows a harmonious constitution of the facial skull (Fig. 84, top). In contrast, when there are greater deviations from this line of *maximum harmony*, the facial skull morphology is rather *disharmonious* (Fig. 84, bottom). Note that, when looking at the vertical position of the values, it is irrelevant whether they lie in the middle of the Harmony Box and thus close to the population mean values or in the upper or lower part of the Harmony Box.

Tab. 3 Regressions between the 5 basal cephalometric variabls used. The material, on which the regressions are based, consists of 275 untreated, young adults with ideal occlusions from Hamburg, Munich and Bergen.

NL-NSL	=	-0.34 SNA + 35.50
NSBa	=	-0.49 SNA + 171.17
ML-NSL	=	-0.70 SNA + 86.05
SNB	=	0.79 SNA + 15.56
ML-NSL	=	-1.07 SNB + 114.37
SNA	=	-0.27 NSBa + 117.06

3. Face Type and Harmony

Variations of the facial skull can be described in relation to a frontal plane as well as to horizontal and sagittal planes. However, the lateral cephalogram can only be applied to discuss the variations in the sagittal and vertical planes.

Most of the clinical-cephalometric analyses address these planes since the vast majority of anomalies in question manifest themselves at least also in the anterior-posterior or vertical direction, which is why they can be described with the help of a lateral cephalogram.

ANB	SNA	NL-NSL	NSBa	ML-NSL	SNB	ML-NL
	61		143		64	
	62			43		28
	63	14	142	42	65	
-2	64			41	66	27
	65				67	
	66	13	141	40	68	
	67			39		26
	68		140		69	
-1	69	12		38	70	25
	70		139	37	71	
	71					
	72	11	138	36	72	24
	73			35	73	
0	74		137		74	
	75	10		34	75	23
	76			33		
	77		136	32	76	22
	78	9			77	
1	79		135	31	78	
	80			30	79	21
	81	8	134			
	82			29	80	
	83		133	28	81	20
2	84	7		27	82	
	85		132		83	19
	86			26		
	87	6	131	25	84	
	88				85	18
3	89			24	86	
	90	5	130	23		
	91				87	17
	92		129	22	88	
	93	4		21	89	16
4	94		128	20	90	
	95					
	96	3	127	19	91	15
	97			18	92	
	98		126		93	
5	99	2		17	94	14
	100		125	16		
	101	1			95	13
	102			15	96	
6	103		124	14	97	

Fig. 83 Combinations of harmonious values for the skeletal variabls SNA, NL-NSL, NSBa, ML-NSL and SNB. Harmonious combinations can be found on lines of equal height in the Harmony Box.

Cephalometric radiographs of other planes may also contain valuable information and are also used in individual cases; however, their practical application is limited because these radiographs present methodological problems and their analysis is complicated and costly (Segner and Scheuer 1990). Therefore, only the lateral cephalogram is discussed in this book. Nevertheless, in clinical practice it should always be remembered that both the dental arches and the skull are three-dimensional entities.

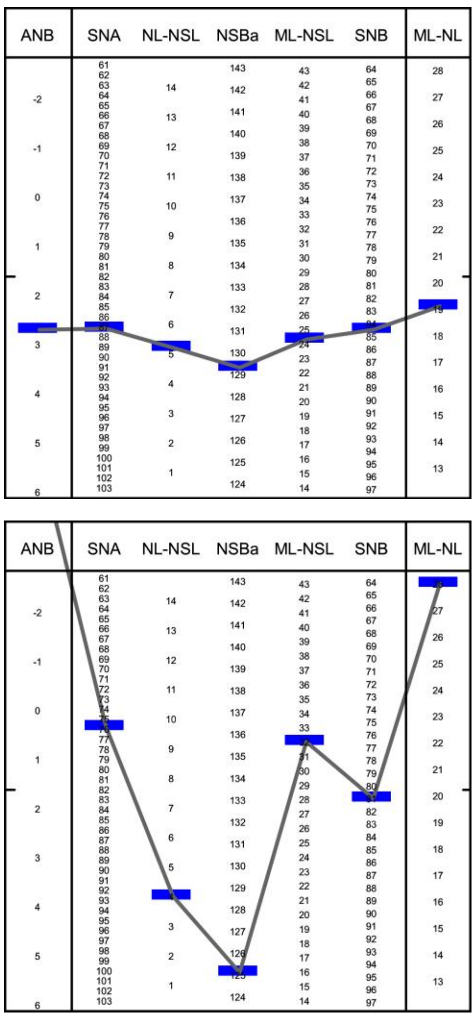


Fig. 84 Harmony Box with harmonious (top) and disharmonious values (bottom).

In the sagittal plane the most important classification of the facial type is the description of the degree of prognathism, according to the sagittal relation of the maxilla and mandible relative to the anterior cranial base. As explained on pages 47/48, the SNA angle for the maxilla and the SNB angle for the mandible are used as the basis for the classification.

For the assessment of the vertical plane, the inclination of the nasal and mandibular planes in relation to the cranial base (NL-NSL and ML-NSL) are used. Furthermore, for the relationship between the midface and the lower face heights the "Index" is used.

Such a categorisation, based on the degree of prognathism and the inclinations, allows classifying a myriad of facial types. Theoretically, there could be a large number of extreme morphological combinations if these variables were completely independent of each other. The correlations mentioned above between the variables descriptive of facial bony structures significantly limit the likelihood of such extreme morphological combinations.

To illustrate the correlation between the degree of prognathism and the inclination of the maxilla as well as the angulation of the cranial base, the three examples in Fig. 85 help. A case with a small SNA angle (retrognathic maxilla) typically shows a large NL-NSL angle (posterior tilt) and a large NSBa angle (Fig. 85a). However, cases with a large SNA angle (prognathic maxilla) and small NL-NSL angle (anterior tilt) are commonly accompanied by a small NSBa angle, i.e., a significant angulation of the cranial base (Fig. 85c). For those cases with an orthognathic maxilla, the values lie between these extremes (Fig. 85b). These observations of the correlations of prognathism and midface tilting as well as cranial base angulation are also represented in the Harmony Box. On the right in Fig. 85, the three examples are plotted in the Harmony Box. It can be clearly seen that each of them lies approximately on a horizontal line.

A large number of variables could be included in the Harmony Box; but for clarity and relevance to the clinical setting, it is limited to the most important cephalometric skeletal variables.

Prognathism degree (SNB angle) and mandibular plane inclination (ML-NSL angle), which is associated with cranial base angulation, are also used for the lower face. A negative correlation between SNB and ML-NSL was found for the mandible (r =-0.61). Clinically, this means that the more prognathic the position of the mandible, the lower the posterior inclination of

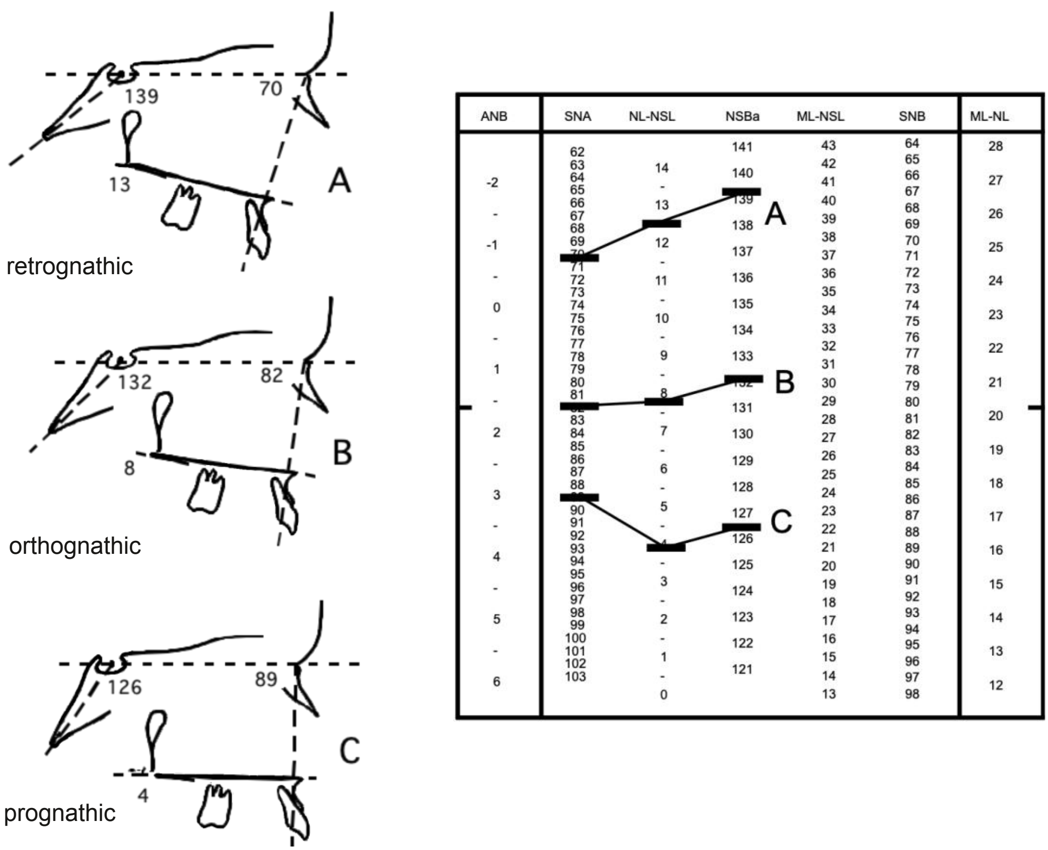


Fig. 85 Relationship between prognathism (SNA) and inclination (NL-NSL) of the maxilla and the bend of the cranial base (NSBa) shown in three examples. The corresponding values are marked in the Harmony Box .

the mandible to be expected (Fig. 86c). On the other hand, a retrognathic mandible (small SNB angle) can be expected with a greater posterior inclination of the mandible (large ML-NSL; Fig. 86a). In an orthognathic face, values are found to be close to the average (SNB 78°, ML-NSL 29°; Fig. 86b).

For the lower face, as for the middle face, the correlations can be seen in the Harmony Box. In the lower right of Fig. 86, the values for the three cases illustrated are plotted as before.

So far, all the cases shown as examples have a harmonious facial skull constitution. Naturally, there are also plenty of cases in which the prognathism and the inclination of the jaws do not fit together. Therefore, they have to be called disharmonious. Three such examples are shown in Figures 87 to 89. Figure 90 shows the corresponding measured values in the Harmony Box.

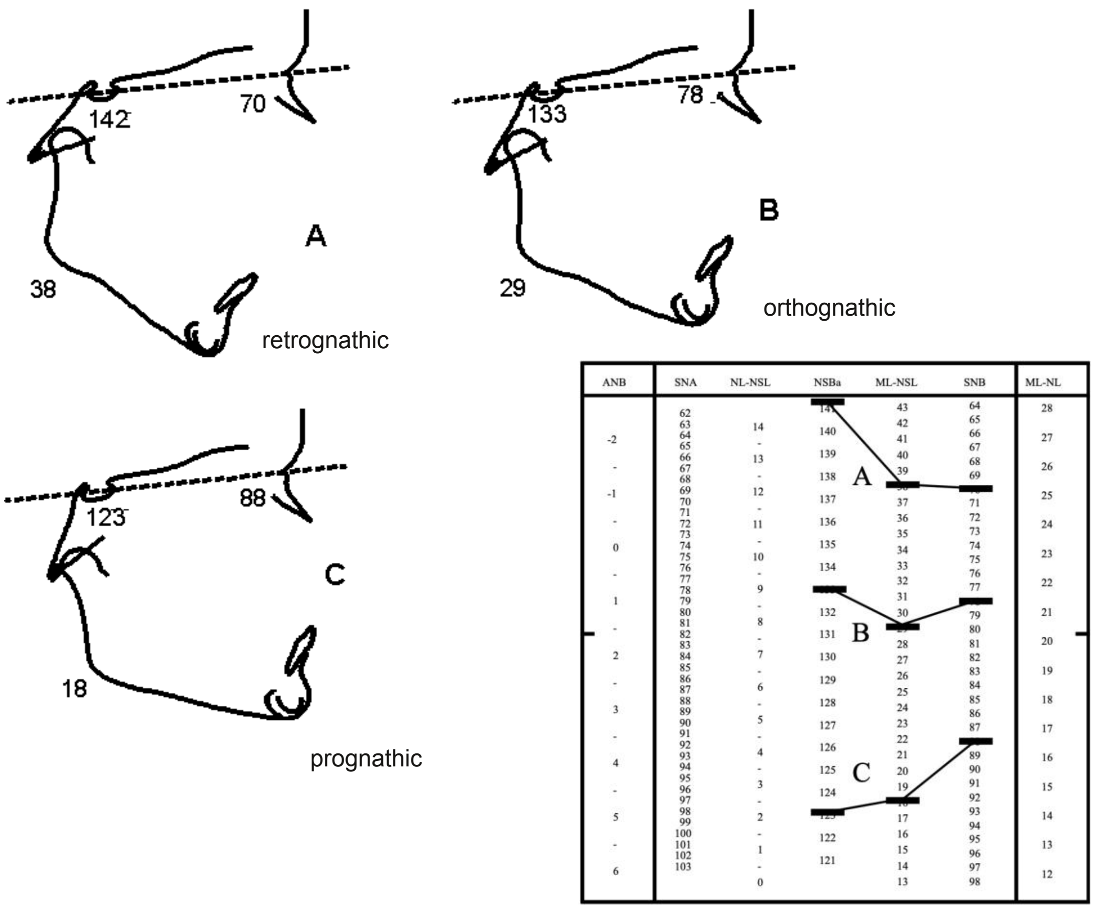


Fig. 86 Relationship of prognathism and inclination of the mandible with the cranial base angle (SNB, ML-NSL and NSBa)

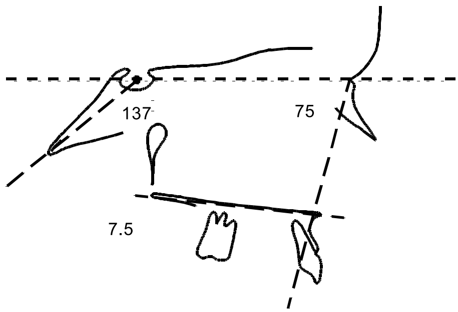


Fig. 87 Combination of values for the midface that do not follow the common pattern.

Figure 87 shows a case with retrognathic maxilla (SNA 75°) and a relatively large skull base angle (NSBa 137°) in conjunction with an orthognathic inclination of the maxillary plane (NL–NSL 7.5°). Meanwhile, in other cases, a prognathic maxilla (SNA 90°) and a smaller base angle (NSBa 126°) in combination with a distinct posterior inclination of the maxillary plane (NL-

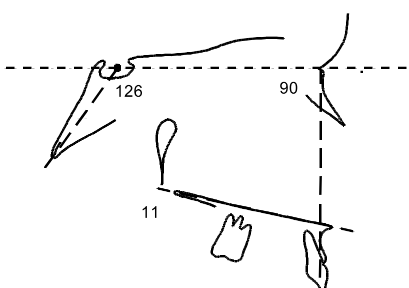


Fig. 88 Disharmonious combination of the midface

NSL 11°) may be observed (Fig. 88). The third example is shown in Figure 89. Here, a harmonious combination of prognathism (SNA 75°) and inclination (NL-NSL 11°) of the maxilla can be appreciated. The skull base angle has a value of 130°, which would rather fit an orthognathic or prognathic face.

Usually, a group of patients includes combinations of measured values that do not conform to the ideal model of harmoniously fitting values. This fact is explained by the residual variance decribed in the previous section.

With respect to clinical-cephalometric analysis, it should be possible to describe in some way the different combinations of various growth patterns in each individual, as to whether the respective facial skull morphology follows the ideal model of harmoniously fitting values or if it is accompanied by individual deviations as shown in Figure 90.

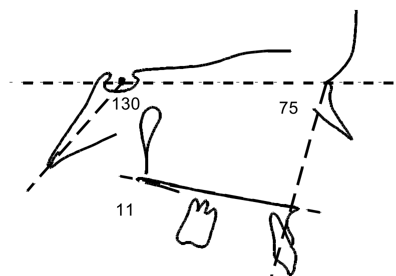


Fig. 89 Disharmonious combination of a retrognathic midface with a too pronounced bend of the cranial base

If the three variables of the mid face fit the ideal pattern as shown in the Harmony Box, this relationship is called harmonious. Figure 85a shows a harmonious retrognathic configuration, while Figure 85c shows a harmonious prognathic configuration. Figure 85b shows a harmonious orthognathic configuration, which coincides (by chance) with the respective mean values of the three variables. The Harmony Box (Fig. 83) shows a large number of harmonious combinations, namely all values that show the same vertical height in the Harmony Box.

If, however, the three variables do not follow this ideal pattern, the result is called *disharmony*. In Figure 87, there is a clear disharmony between the maxilla's prognathism degree (SNA 75°) and its inclination (NL-NSL 7.5°). In itself, this disharmony classification does not say anything about which of the variables is at fault. Only when further variables, e.g., the angle NSBa, are included in the consideration, it becomes clear that some of the variables fit together harmoniously, while at least

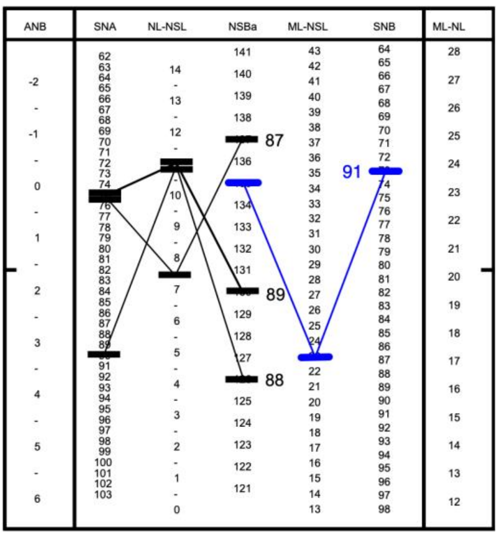


Fig. 90 Values of the disharmonious combinations from Figs. 87 to 89 and 91 in the Harmony Box

one variable is disharmonious in relation to the others. In this example, the third variable, the cranial base angle of 137° fits the prognathism degree (SNA 75°) quite well. However, the inclination of the maxilla with an NL-NSL angle of 7.5° fits neither the prognathism nor the angulation of the cranial base. Therefore, it seems that according to the individual norm for this case, there is a deviation in the inclination of the maxilla.

Figure 88 shows a disharmony between prognathism (SNA 90°) and inclination (NL-NSL 11°) as well, where again there is a good relation between prognathism and angulation of the cranial base (NSBa 126°), as can be seen from the Harmony Box. The inclination here does not follow the general facial pattern. In contrast, the Figure 89 shows harmony between prognathism (SNA 75°) and inclination (NL-NSL 11°). The combination of retrognathic position and posterior inclination of the maxilla goes together well, whereas a smaller angulation of the cranial base compared to that observed (NSBa 130°) would be expected.

The situation for the mandible is based on these same relationships. Again, the relationships among the three variables SNB, ML-NSL and NSBa can be read from the Harmony Box (Fig. 83). Figure 86c shows a harmonious prognathic combination with a large SNB angle (88°) and anterior inclination of the mandible (ML-NSL 18°) and strong angulation of the cranial base (NSBa 123°). Figure 86b shows a harmonious orthognathic combination, which again coincides (by chance) with the mean values of the three variables. Finally, Figure 86a depicts a harmonious retrognathic configuration (SNB 70°) with a pronounced posteriorly tilted mandible (ML-NSL 38°) and a wider cranial base angle (NSBa 142°). In addition to the three configurations shown, of course, any number of other harmonious combinations may occur.

If the three variables for the mandible do not follow the ideal harmonious pattern, this is referred to as disharmony of one or more of the three angles. In Figure 91, there is a clear disharmony between the prognathism (SNB 73°) and the inclination of the mandible (ML-NSL 23°). When attempting to localize the disharmony between the degree of prognathism and the inclination, it is not possible to immediately determine where the deviation occurs. Including a third variable (NSBa) in the ana-

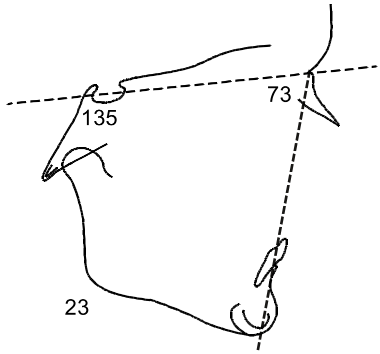


Fig. 91 Disharmony between inclination and degree of prognathism of the mandible

lysis gives a better foundation. In the present case, NSBa is 135°. From the Harmony Box (Fig. 90), it appears that NSBa and SNB fit together well, while the ML-NSL angle is the odd one out. Considering the mandible alone, a value of 34.5° for ML-NSL would produce a good harmonious fit.

Although it is dangerous to proceed with this idea without considering the maxilla, such a combination for the mandible, as in the example, could be seen in a case with a large ANB angle and Angle Class II occlusion. Evaluation of the harmony would then lead to the conclusion that the B point is too far back. As is known, this value describes either the dorsal position or the small size of the mandible. The sagittal position of the mandible is linked to the temporomandibular joint position and the three-dimensional orientation of the clivus and thus to the NSBa angle. With an angulation of the cranial base corresponding to an orthognathic position of the mandible (NSBa 131°), there seems to be no reason to assume that the position of the mandible is too far posterior. The size of the mandible seems to be more of an issue.

In any group studied, a significant number of other combinations of these three angles would be found that have to be called disharmonious. Yet, it must be added that, for both the maxilla and the mandible, a deviation from the harmonious ideal combination shown in the Harmony Box (Fig. 83) which does not exceed a few steps from the straight line does not qualify as a proper disharmony. On the one hand, the cephalometric measurements always contain some degree of measurement error. On the other hand, a certain tolerance must be exercised because of the considerable residual variance that still persists.

Clinically, the pattern of harmony of maxilla and mandible must always be considered together. Specifically, the harmony between the degrees of prognathism (sagittal harmony) and the harmony between the inclinations (vertical harmony) are of particular interest in this context.

The ANB angle is a good indicator of the disharmony between maxilla and mandible. As described on pages 49-51, the classification of the degree of prognathism in the sagittal plane is based on the value of the ANB angle. As already mentioned there, a correlation exists between the degree of prognathism and the ANB angle in the sense that the ANB angle tends to be smaller in a retrognathic face and larger in a prognathic face. This is also clear from the left column of the Harmony Box (Fig. 92). In the retrognathic facial type, an SNA angle of 73° matches an SNB angle of 73°, i.e., an ANB angle of 0° is to be expected. In the prognathic facial type, there is a harmonic combination of, for example, 93° for SNA and 89° for SNB, i.e., an ANB angle of 4°. Only in the orthognathic face, harmonic combinations of SNA and SNB show a difference (ANB) of about 2°. Therefore, it is not possible to exclude the ANB angle from an individual assessment. In fact, an individual standard for the ANB angle must be established for each patient based on the complete facial type.

As part of the clinical assessment of the ANB angle, it is of interest to identify the morphological etiology of the ANB angle in question. Here again the harmony assessment comes into play. As a rule, a large ANB angle is clinically problematic. Morphologically, such a deviation can be caused by the following factors:

- The maxilla is located too far anteriorly.
- The mandible is too small.
- The entire mandible is located too far posteriorly.
- The mandible has a severe posterior inclination.
- A retroposition of the alveolar process on the mandibular base, i.e., a large difference between the SNB and SNPg angles (>2°).

These factors can occur individually or in combination.

The assessment of the ANB angle is therefore based on the harmonic relationship between the mandible and the maxilla. This thought process has already been implemented on page 78. As another example, Figure 93 shows a patient and the cephalometric values. This patient shows a harmonious constitution of the midface. According to the Harmony Box (Fig. 83), the angular values for SNA of 86°, for NL-NSL of 6° and for NSBa of 129° are all consistent with those of the ideal pattern.

In contrast, for the mandible, there is a clear disharmony between the degree of prognathism (SNB 76°) and the inclination (ML-NSL 25°). If the base angle (NSBa) is taken as a guide, this value fits well with the value for the inclination. It is, therefore,

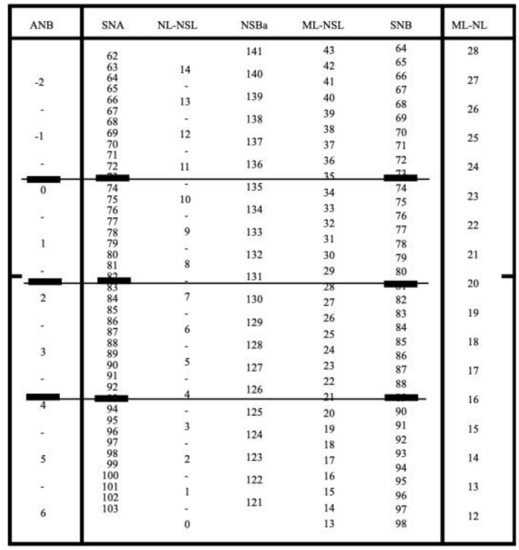


Fig. 92 Individually different "ideal" values for ANB depending on the face type, recognizable in the left column of the Harmony Box.

advisable to look a little more closely at the SNB angle. If the B point could be moved forward towards B', SNB would increase to 83.5°, which would give a more or less harmonious combination for these three angles. Furthermore, this would also result in a favorable combination of the prognathism values for the two individual jaws ensuing sagittal harmony with an ANB angle of 2.5° as well. Since the values for the inclinations of the two individual jaws are at approximately the same level in the Harmony Box, there is a good vertical harmony as well.

Based on these values, it seems reasonable to attribute to the mandible the main share of the morphological deviation that results in the large ANB angle of 10°. Since both the cranial base angle NSBa and the inclination ML-NSL fit well into the harmony pattern, there is further reason to believe that the mandible is too small in this case. Consequently, it would be advantageous to

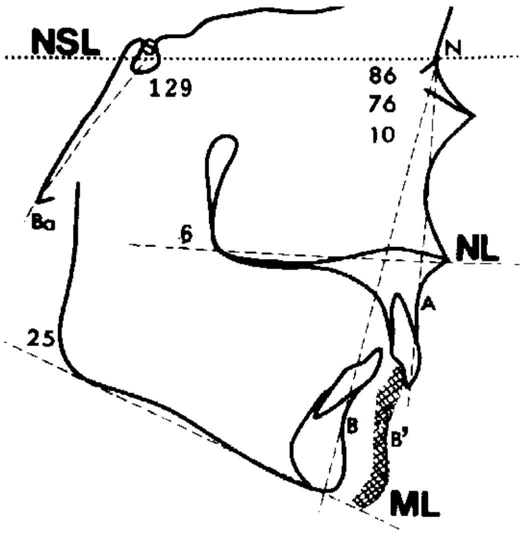


Fig. 93 Profile tracing to assess harmony. See text for explanation.

make use of its growth as much as possible. If the growth does not bring the desired result in quantity and direction, this case becomes problematic.

In other combinations, the morphological deviation might be due to the maxilla so that moving the A point posteriorly would result in a harmonious constitution. Since this is generally difficult to achieve, in such cases the aim is usually to at least inhibit the sagittal growth of the maxilla; this results in a relative reduction of the SNA angle (see also page 114).

When assessing the harmony, it will become apparent in certain isolated cases that the facial skull is composed of an intrinsically harmonious maxilla on one hand and an intrinsically harmonious mandible on the other, but that there is a disharmony between the two individual jaws regarding both the degree of prognathism and the degree of inclination.

It is then often difficult to clearly determine where the morphological defect for this deviation in basal proportions lies, and as a result some compromise in the treatment goal has to be found. Experience shows that treatment of such patients may be difficult.

The harmony of the inclinations should always be seen in terms of the interbasal angle ML-NL. According to the Harmony Box (Fig. 83), it is expected to be larger in a retrognathic face and smaller in a prognathic face compared to the mean value of 21°. Thus, a large ML-NL angle must be judged differently in a retrognathic face than the same angle in a prognathic face. Accordingly, the same is true for a small interbasal angle. Again, it becomes apparent that assessment is possible only on an individual basis.

If the values for NL-NSL and ML-NSL are at approximately the same level in the Harmony Box (Fig. 94; "2"), the value for ML-NL will be at about the same level; this is a case of vertical harmony. If the value for ML-NSL is significantly higher than that for NL-NSL, the case shows vertical disharmony. If the interbasal angle is excessively large, this is called a "high angle case".

An ML-NSL angle that lies significantly lower in the Harmony Box than that of NL-NSL results likewise in an interbasal angle that is too small. In such cases of vertical disharmony with the jaw bases running almost in parallel, a potentially pre-existing deep bite would be difficult or even impossible to eliminate during treatment.

As already indicated above, the distinctions among the designations "1", "2" and "3" for the interbasal angle ML-NL are derived from the Harmony Box. A hori-

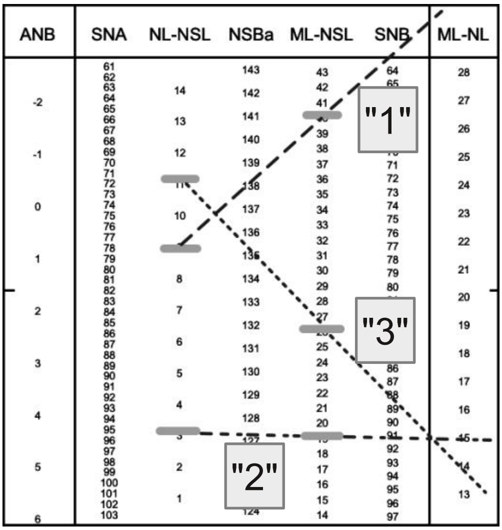


Fig. 94 Harmony assessment of the inclinations of maxillary and mandibular bases relative to each other:
1 - relatively too large interbase angle
2 - within the normal range
3 - relatively too small interbase angle

zontal line drawn to the right from the value for NL-NSL determines the expected value for ML-NSL. If the observed value for ML-NSL is more than 6° above this value, the case is referred to as "1" or a "high angle case". If the observed value is more than 6° below this line, the case is referred to as "3". The cases that lie in between are classified as "2". Graphically, an angle opening to the right at approx. 60° results for the "neutral" range ("2") with its apex at the measured vale for NL-NSL (Fig. 96) In principle, a procedure from right to left, i.e. starting from ML-NSL, would also be feasible. The interval for the neutral range of NL-NSL would then be 3° above or below the expected value.

In computer-assisted evaluation, this assessment can be refined by having the program project the vertical discrepancy between the NL-NSL and ML-NSL values onto the SNA column, allowing the program to calculate the difference. The result is then the relative interbasal angle (abbreviated RIB), which indicates the extent to which the actually measured ML-NL interbasal angle deviates from the individually expected one. Zero is the ideal value, for negative values the actual value is too large (hyperdivergent), and for positive values the actual measured value is too small (hypodivergent). The relationship between RIB and the vertical classification is:

	RIB < –8.5	:	"1"
–8.5 <	RIB < +8.5	:	"2"
	RIB > +8.5	:	"3"

For example, a RIB of –19 shows a very severe case of hyperdivergence, which is not as vivid in the simplified classification of "1", "2" or "3".

It must be noted that there can be cases where there is sagittal as well as vertical harmony between the two jaws, but where the degrees of prognathism and the inclinations do not fit each other. In these cases, although the facial type as a whole and the individual jaws appear disharmonious, there is harmony in the sagittal and vertical planes between the maxillary and mandibular bases (Fig. 95).

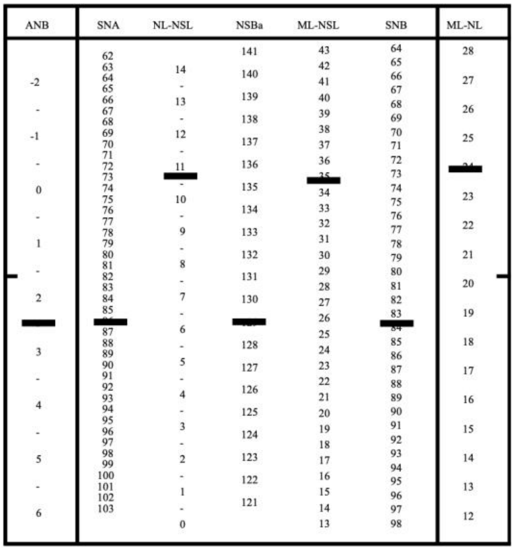


Fig. 95 Example showing harmony in the vertical and sagittal plane with simultaneous disharmony between inclination and prognathism.

4. The Harmony Pattern

A Harmony Pattern was introduced to simplify the evaluation of the face type, the sagittal and vertical harmony, and the overall harmony. This is superimposed on the measured values that are marked in the Harmony Box (Fig. 96).

The vertical tolerance range for each variable is determined by its degree of correlation with the other four variables. In statistics, this is called the standard error of the estimate of one variable based on the other four. It can be seen that the ranges of tolerance for the variables SNA and SNB are smaller than those for NSBa and ML-NSL. For NL-NSL, the range of tolerance is also slightly smaller, but since the values of this variable are more widely spaced in the Harmony Box, the range of tolerance appears larger.

First of all, the aim of placing the Harmony Pattern is to check whether it is possible to fit all patient measurements within the shaded area of the Harmony Pattern. More specifically, the following rules apply:

1. The central line must be oriented exactly horizontally.
2. The sums of the distances between the individual value markings and the central line should be equal above and below the central line (Fig. 97).
3. The variables SNA and SNB with their narrow tolerances are taken into account more than others by tripling their scales.
4. If individual measured values are situated far away from the central line, they are considered "outliers" and are ignored when determining the facial type. Their distances are not included in the calculation described in points 1 and 2.

Following this procedure, the facial type is identified by the position of the central line on the SNA column. A facial type in the range of 79° to 85° is called orthognathic, smaller values represent retrognathic and larger values represent prognathic facial types.

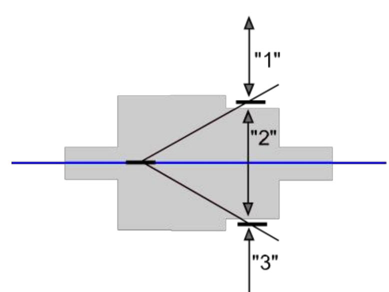


Fig. 96 Harmony Pattern for the Harmony Box. If it is possible to arrange the Harmony Pattern in such a way that all measured values fit into it, a harmonic combination is present.

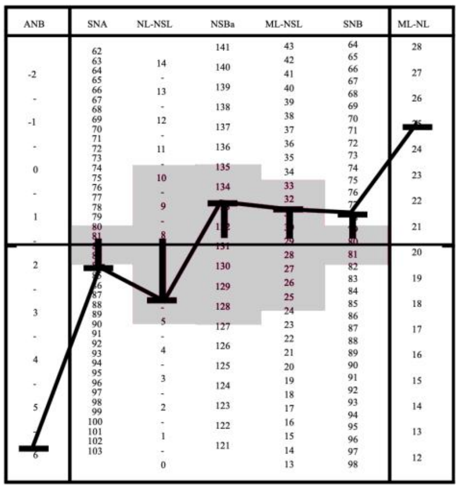


Fig. 97 Positioning of Harmony Pattern

If the contours of the Harmony Pattern include all the measured values, the face is considered to be harmonious. If individual values do not lie entirely within the pattern, it is referred to as a slightly disharmonious facial pattern. However, if the measured values are distributed all over the Harmony Box, it is considered as a disharmonious facial type. In the columns ANB and ML-NL, respectively, one can now read the ideal values for ANB and ML-NL for the individual facial type at hand.

In the next step, the sagittal harmony or sagittal basal proportion is evaluated. The central line is placed on the measured SNA value. In the column for SNB, the SNB value matching this SNA value is then found under the central line of the Harmony Pattern. The relation of the actually measured value for SNB to this expected value indicates the sagittal jaw relationship. If this difference is up to 2°, the jaw relationship is considered to be sagittally neutral. If the measured value for SNB is more than 2° above the expected value, a distal basal relation is present. However, if it is more than 2° below the central line, a mesial basal relation is indicated.

Lastly, the divergence of the jaw bases representing the vertical harmony is analyzed. For this purpose, the Harmony Pattern is superimposed with the thick central line on the actually measured NL-NSL value (Fig. 98). In the ML-NSL column, one can then see whether the measured value lies between the two thick lines ("2"), above the upper ("1") or below the lower ("3") thick line.

By themselves, the analyses of the sagittal and vertical basal relationships do not allow any conclusions as to which of the two jaws is responsible for any potential deviation. If there is a deviation, the Harmony Pattern must be moved back to the original position (determination of the facial type). Then, it is easy to determine which value (SNA or SNB; NL-NSL or ML-NSL) is further away from the central line of the facial pattern.

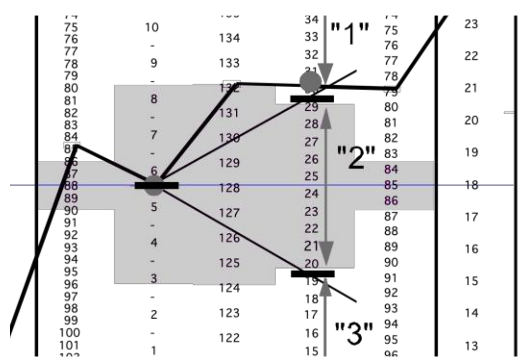


Fig. 98 Positioning of Harmony Pattern II: Analysis of vertical harmony. Here a case "1" is present.

5. Basal Cephalometric Norms

In the clinical context, a large variability must be expected in the assessment of facial types, both for the degree of prognathism and for the harmony between prognathism and inclination. If the basal cephalometric values are to be used in practical applications, it must be recognized that both occlusal abnormalities and ideal occlusions occur in all facial types (see Figs. 99, 100, and 101).

Likewise, it must be understood that the same dento-alveolar deviations can be found in differing facial types (Figs. 102 and 103).

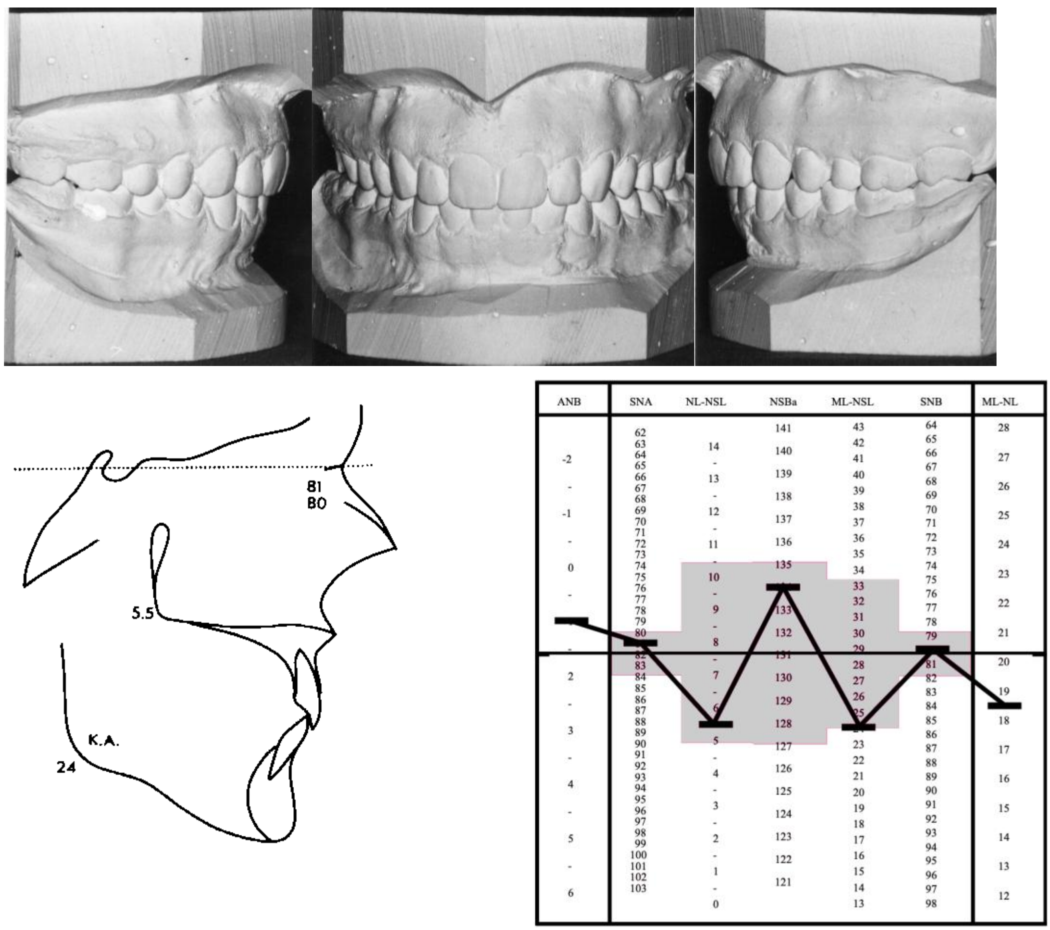


Fig. 99 Near-ideal occlusion in an orthognathic face with disharmony between prognathism and inclination of the mandible.

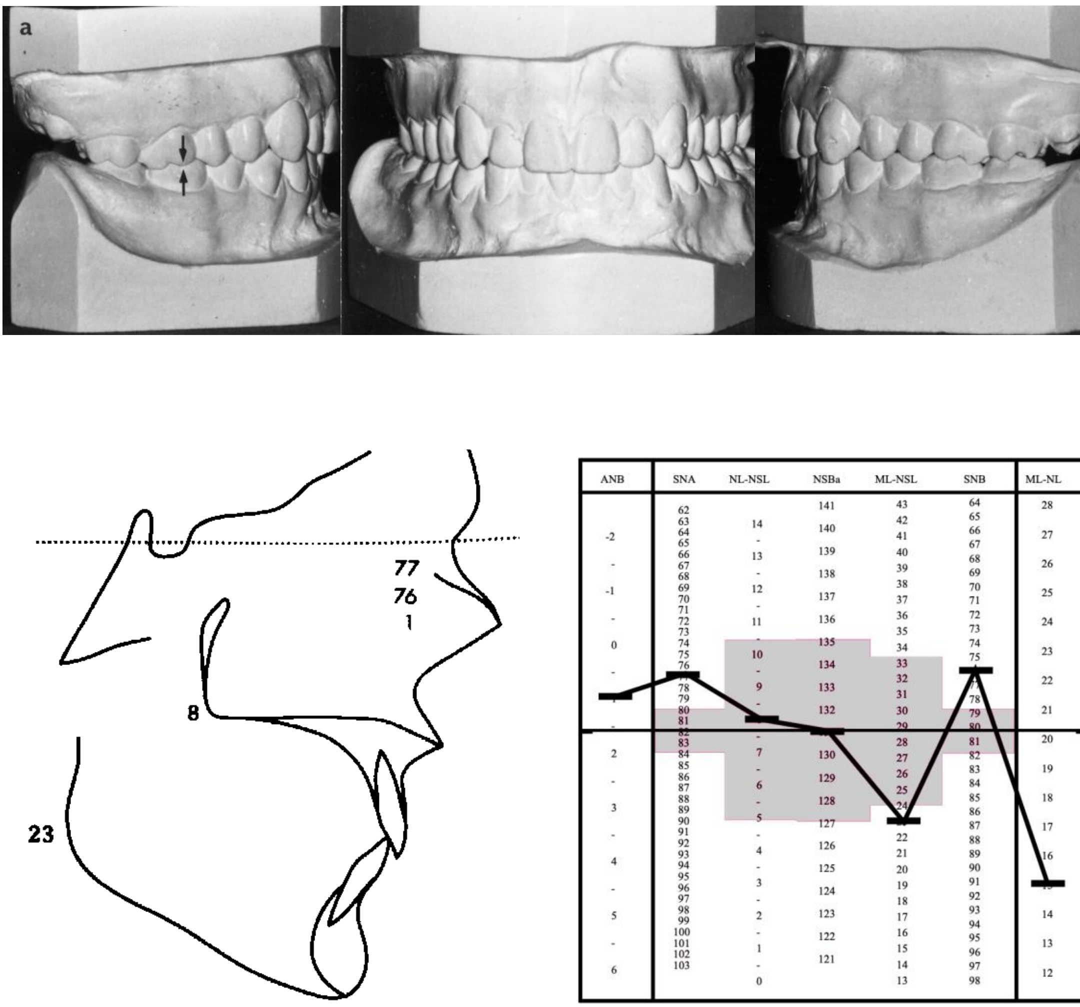


Fig. 100 Near-ideal occlusion in a retrognathic face with disharmony between prognathism and mandibular inclination.

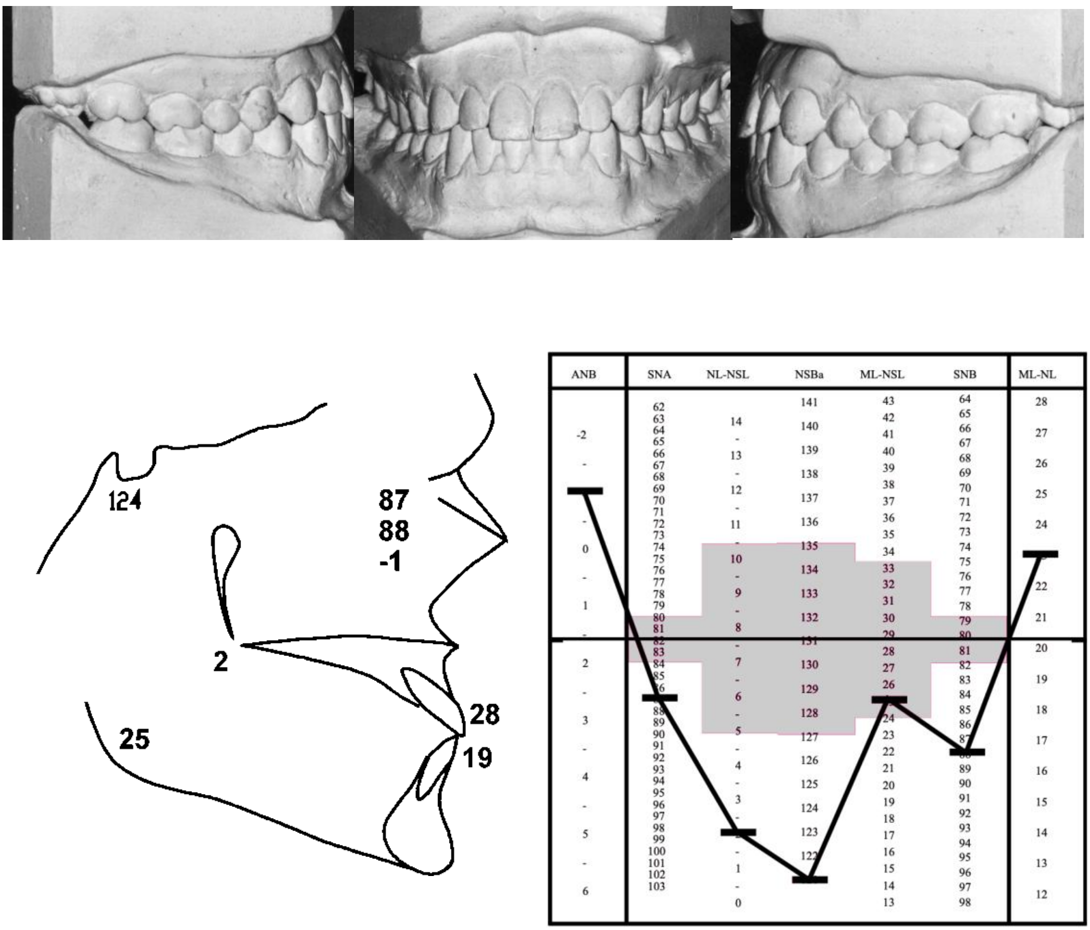


Fig. 101 Near-ideal ideal occlusion in a prognathic face. In the case shown, there is a negative ANB angle (-1°), which is compensated by the axial inclinations of the maxillary and mandibular incisors.

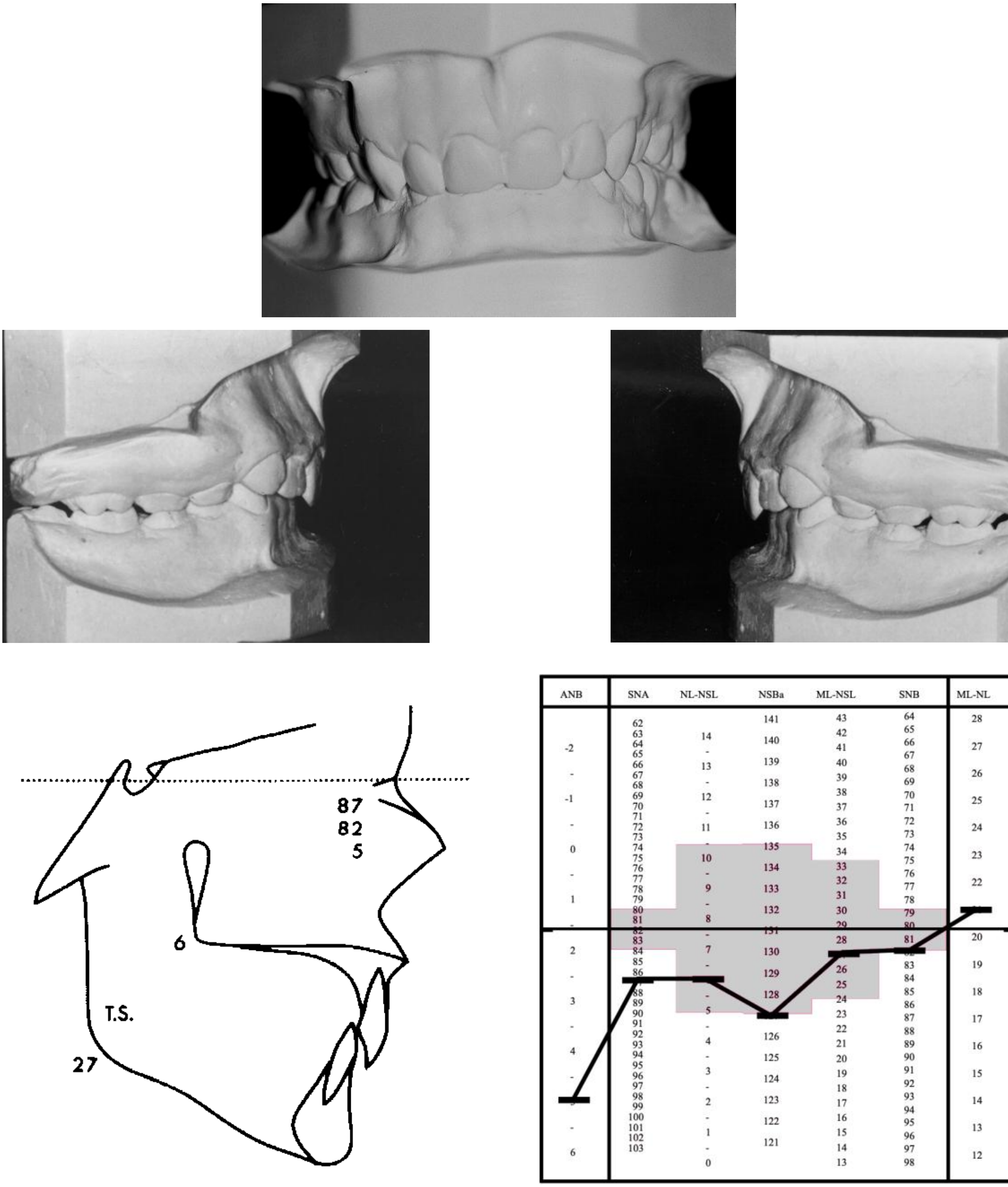


Fig. 102 Angle Class II div 2 in a prognathic face.

Therefore, there are no values for these basal cephalometric variables that would lead to a normal occlusion with high probability, but neither must necessarily lead to dental abnormalities. Consequently, these cephalometric values cannot be used in the same straightforward manner as, for example, the Angle classification in dental cast analysis. This means that no ideal norm in the sense of a neutral occlusion can be found for these angles. As for molar relationships, deviation in one or the other direction in the vast majority of cases results in an occlusal abnormality. In cephalometrics, similar lines of thought were attempted to some extent. Here, the mean value of the individual measurements was taken as the starting point for a given population. However, such an application of cephalometric measurements must be rejected. To explain this, consider the following example. For the SNA angle, the mean value ($\overline{x}$) is 82°. From this, however, it cannot be immediately concluded that, in a patient with an ANB angle of 7° and an SNA angle of 87°, the value for SNA is 5° too large (87° - 82° = 5°), and hence the deviation is mainly due to the maxilla.

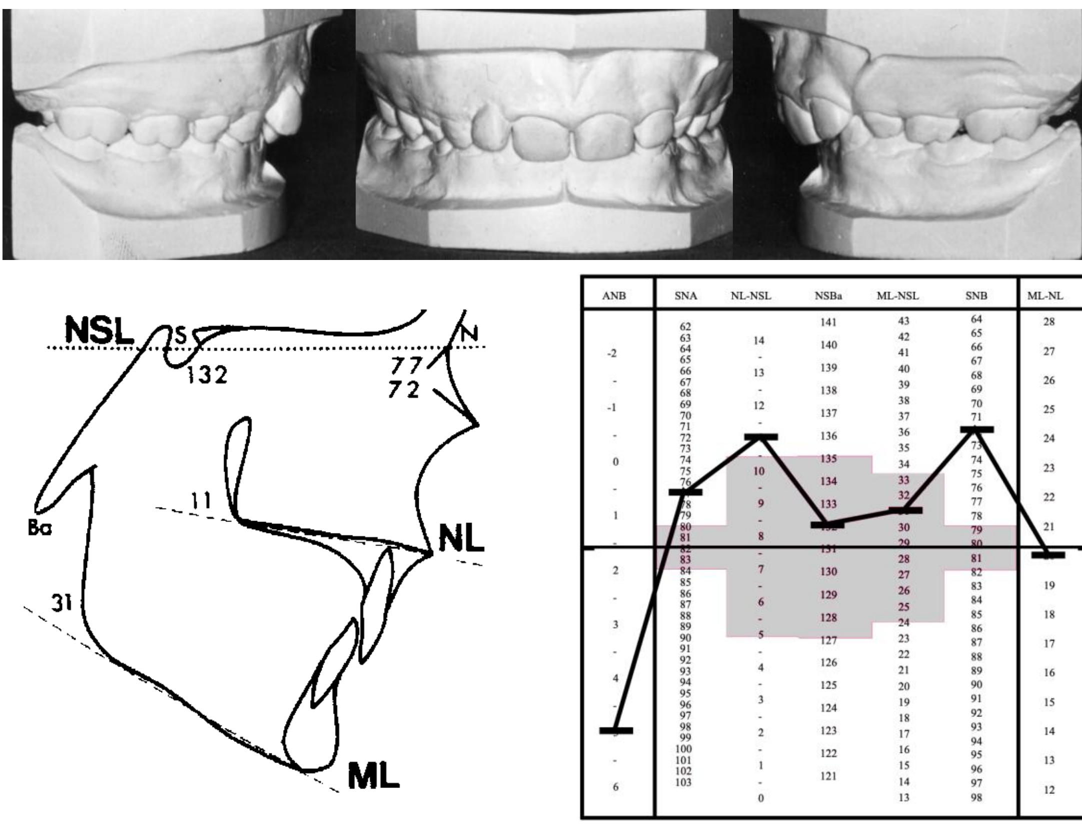


Fig. 103 Angle Class II div 2 in a retrognathic face.

If there are so many reservations regarding cephalometrics, is the high regard for it justified at all? Despite these reservations, there are several substantial reasons why cephalometric analyses are indispensable for most orthodontic treatment planning:

1. In the clinical context, it is extremely important to be clear about the facial type, since clinical experience has shown that, as a rule, jaw anomalies in retrognathic facial types pose greater treatment problems than in orthognathic or prognathic facial types. In retrognathic facial types, this is especially true for sagittal deviations, where special effort must be made when anchorage is required. As shown above, such a classification is possible.

2. Morphologically, the facial skull is composed of several components. Whether they are located in the *basal* or *dentoalveolar* portion (alveolar processes), most of them feature compensatory mechanisms which, individually or together, may reduce the unfavorable influence of other components on the morphological pattern. It is desirable to obtain information about such compensatory mechanisms or their lack in each individual case. Often severe basal deviations are concealed by such compensatory mechanisms, which then might become evident only during orthodontic treatment.

3. Dental norms are influenced by the facial type, which provides the starting point for evaluating the axial position of the teeth. This matter will be discussed in the following chapter.

4. There are cases in which the severity of skeletal deviations suggests that an orthodontic treatment alone is neither promising in the first place, nor can a sufficient stability of the treatment result be expected. It is of great importance to identify these cases *before* initiating treatment and to consider referring them to appropriate orthognathic surgery.

Addressing this challenge is greatly facilitated when a systematic assessment of the craniofacial region is performed. Thus, the patient's data are put in perspective by looking at their relationship to those values that are used as the "*norm*" for that individual patient. Since there are any number of *norms* (all combinations that are at the same horizontal line in the Harmony Box), it is important that this individual "*norm*" is placed as close as possible to the range of the patient's own values.

6. Dental Cephalometric Norms

The position of the incisors is of the utmost importance for the entire treatment planning, since there is a direct correlation between incisor position and space availability. Space can be gained by protrusion of the incisors, whereas space may be lost, or crowding may occur due to treatment-related or relapse-related retrusion.

Regarding space issues, the assessment of anterior tooth position is associated with the important decision of whether or not the extraction of teeth is necessary as part of orthodontic treatment. Nature attempts to compensate for basal deviations with the incisor tooth position, both in the sagittal and vertical directions (as discussed on pages 50 – 52 under the ANB Angle section). Furthermore, it is evident that the incisors are directly exposed to dysplastic effects due to dysfunctional muscular patterns and habits. In a clinical context, therefore, there is great interest in determining the effects of these influences.

Furthermore, the position and axial inclination of the incisors can be influenced by an orthodontic appliance. This is done either by tipping, or by bodily movement or torquing of the teeth with an appliance, where this is possible.

For classification and diagnostics as well as for treatment planning, it is necessary to identify the norm values to use to discuss the patient's values. However, this again raises the question of whether it is possible to use the dental cephalometric values in the same way as the Angle classification in dental cast analysis in the sagittal plane. Here, a deviation from a given *norm* can usually be directly identified as an anomaly, while for the position of the incisors other variables might be needed to establish a reference norm in the sense of *floating norms*.

The same question arises in treatment planning, namely whether the patient should be treated ideally according to a fixed norm for incisor position, or whether the treatment goal must be individualized. If individualization is necessary, the next question is which cephalometric variables are suitable to guide treatment planning based on individualized *floating norms*.

Floating norms are not a new principle within cephalometry; Steiner (1953) already used a kind of floating norm in his "acceptable compromises" (Fig. 104). Steiner de-

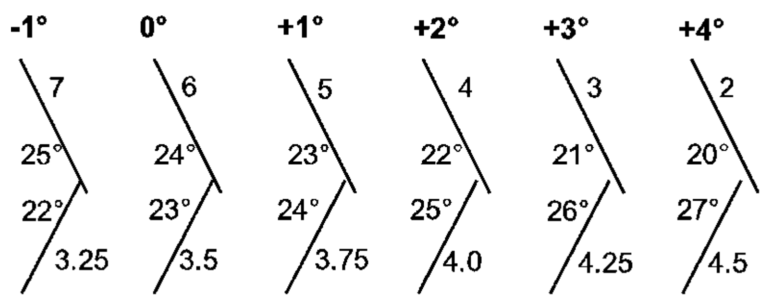


Fig. 104 Steiner’s "Acceptable Compromises" for individual positioning of incisors based on the ANB angle.

scribes, with the ANB angle as the guiding value, norms for the position of the incisors. For him, the ANB angle is the "guiding variable", both for the distance of the incisal edges from the NB or NA line, respectively, and for the incisor inclinations. For a number of common ANB angles values for ⊥-NA and ⊤-NB position are given in degrees and millimeters. From his scheme, it follows that each 1° change in the ANB angle results in a change of ⊥-NA by 1 mm and correspondingly for ⊤-NB by 0.25 mm and 1° respectively. These values serve as the basis for further interpolation.

This relationship between the position of the incisors and the ANB angle has also been evaluated in numerous European studies. It has become clear that the position of the incisors should never be assessed without considering the ANB angle. Since the position of the incisors at the *end* of treatment or growth is of interest for treatment planning, it is necessary to predict the change in the ANB angle up to that point.

Figure 104 shows that the incisor configurations in STEINER's "acceptable compromises" are a linear function of ANB angle, i.e., a regression equation with ANB as the sole independent variable. The relationship between ANB and the values for tooth position can be represented by the following equations:

$$y_{(\perp\text{-NA})mm} = a_1 x_{(ANB)} + d_1$$

$$y_{(\perp\text{-NA})degree} = a_2 x_{(ANB)} + d_2$$

$$y_{(\top\text{-NB})mm} = a_3 x_{(ANB)} + d_3$$

$$y_{(\top\text{-NB})degree} = a_4 x_{(ANB)} + d_4$$

where a and d represent the respective constants, which differ from equation to equation.

In this context, the following questions arise:

1. Are Steiner's "acceptable compromises" based on correlation analysis with calculated regression lines, or do they represent randomly fitting variables that, apparently, can be applied clinically with good results? The literature is not clear on this point. Certainly, it would seem logical to use regression coefficients based on European material for the treatment of European patients.
2. Is the ANB angle the only basal skeletal measurement that can serve as a guiding variable for the determination of incisor position? The regression analysis could otherwise be extended to a multiple regression analysis with multiple independent variables by including other independent (i.e. leading) variables. With two variables, the following formula would result:

$$y = ax + by + d$$

With the inclusion of a third independent variable that influences the position of the incisors, the following equation would result:

$$y = ax + bz + cq + d$$

Previous studies have established that the facial type plays an important role in this context. Hasund and Ulstein found that the inclination of the mandibular plane has an influence on the position of the incisors. They used the angle ML-NSL as an expression for the inclination. Norderval later found an even greater influence of the interbasal angle ML-NL on both the maxillary and mandibular incisors.

The bony chin also seems to have an influence on the position of the incisors. In connection with the above-mentioned Steiner analysis, the Holdaway difference was employed. However, this resulted in adjustments which may pose clinical problems in individual cases. Norderval found that the various combinations of incisor position could be more clearly represented by the application of the Norderval angle. Segner found an even slightly higher correlation with the linear variable $PgNB_{mm}$, which is also more convenient to measure.

After Norderval, as well as Hasund and Boe set up multiple regression equations with the independent variables ANB, ML-NL and Norderval angle achieving a multiple correlation coefficient of 0.71 for the calculation of the correct mandibular incisal edge position, Vormelker and Segner found a regression equation based on the variables ANB, $PgNB_{mm}$ and the Index. Here the NPg line was used instead of the NB line as a reference line. This resulted in higher correlation coefficients even though the accuracy of the estimate (standard error of the estimate, S.E.) did not improve.

For each patient collective studied, slightly different regression coefficients are obtained, which at first sight threatens the confidence in such an equation. On closer examination, however, it can be seen that an increase in one coefficient is compensated for by a decrease in one or more of the others, so that the result of the regression equation is quite uniform after all. The regression equations that are presented in the subsequent sections are based on a material of young, untreated adults with ideal occlusions (Angle Class I, no crowding, no congenitally missing teeth) from Hamburg and the surrounding area.

The leading variables are always the ANB angle and the distance Pg to the NB line. In some cases, the Index of anterior facial height is added. It should be noted that all linear measurements are influenced by potential magnification factors. For the regression equations shown, radiographic magnification was eliminated by means of calculation. A magnification factor of 10%, for example, can add up quickly to a half or whole millimeter difference!

Based on the equations in Table 4, a variety of other acceptable combinations can be calculated, which differ from Steiner's "acceptable compromises" in that two other basal cephalometric variables are included in addition to the ANB angle. Furthermore, any change in the ANB angle would have a somewhat greater effect on the mandibular incisors compared to Steiner's values.

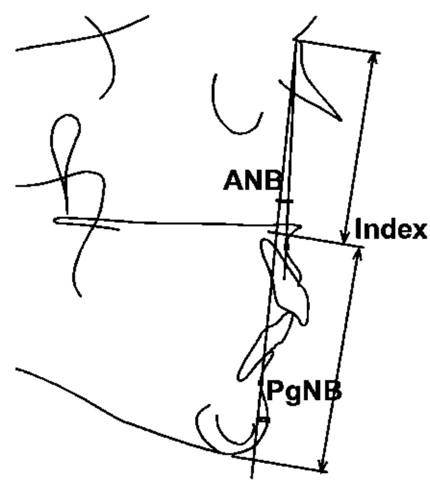


Fig. 105 Guiding variables in determining the individual optimal incisor position: ANB, $PgNB_{mm}$ and Index.

The equations show that a change in the ANB angle of one degree quite accurately produces a change in the position of the lower incisal edge of 0.5 mm. The larger the ANB angle, the more anterior (protruded) the lower incisors are. For the upper incisors, a 1° increase in the ANB angle results in a more palatal position of the upper incisal edges by almost 0.9 mm. The influence of the distance $PgNB_{mm}$ on both the upper and lower incisors is in the same direction. The more prominent the chin (large value $PgNB_{mm}$), the further retruded the anterior teeth in both jaws are. One millimeter of $PgNB_{mm}$ causes 0.23 mm in the maxillary and 0.3 mm in the mandibular anteriors. The influence of the Index is limited; a 5 percent smaller Index causes a 0.4 mm more anterior position of the incisal edges in both the maxilla and the mandible.

When assessing the axial inclination of the incisors, the inclusion of the vertical basal variable Index does not result in better predictions; therefore, the regression model is limited to two independent variables.

It is apparent that the position of the incisors cannot be assessed in isolation but must be viewed in relation to several other variables. This relationship is applicable when classifying a patient case and assessing the nature of the anomaly. In the lateral cephalogram, it is possible to measure the dental and skeletal variables easily and directly. With the help of the three variables ANB, $PgNB_{mm}$ and Index the expected value for ⊥-NA und ⊤-NB can be calculated. This provides some indication of whether specific dysfunctional factors are influencing the position of the incisors or whether the position can be explained by the given skeletal morphology.

Later, when the treatment plan is discussed, it is important to start by evaluating the position of the incisors at the end of the treatment. Here it is important to know that, of the three leading variables, the Index does not change significantly during the course of growth and treatment, while the ANB and $PgNB_{mm}$ values are significantly affected by growth. The ANB angle is also affected by treatment. In growing patients, for example, the ANB angle may be influenced by functional orthodontic appliances or by intensive use of headgear. For adult patients, significant changes occur only in association with orthognathic surgery. _

Based on the regression equations mentioned above, it is possible to determine a viable configuration of incisor positions at the

Tab. 4 Regression equations for determining the position and axial inclination of the incisors in the maxilla and mandible using basal cephalometric measurements as guiding variables.

$\perp\text{-NA}_{mm}$	=	$-0.86\ ANB - 0.23\ PgNB_{mm} - 0.083\ Index + 12.8$
$\perp\text{-NA}°$	=	$-2.19\ ANB - 0.61\ PgNB_{mm} + 27.1$
$\top\text{-NB}_{mm}$	=	$0.51\ ANB - 0.30\ PgNB_{mm} - 0.084\ Index + 10.4$
$\top\text{-NB}°$	=	$1.51\ ANB - 0.80\ PgNB_{mm} + 22.4$

end of treatment and to use it as a foundation for the treatment plan. Confidence in this prediction depends on estimating as accurately as possible the change in ANB and $PgNB_{mm}$ values that occurs during growth and/or as a result of the treatment. The prognosis for the final incisor position cannot be more accurate than the predictions for the changes in the ANB angle and the $PgNB_{mm}$ distance. The same issues affect the Steiner analysis as well as other methods for determining the correct position of the anterior teeth.

There is no doubt that the calculated values should not be believed blindly. These values serve as a guide for the alignment of the incisors, based on the information provided to the orthodontist by the cephalometric analysis regarding the skeletal relationships. It goes without saying that other diagnostic methods and clinical findings must be compared with the calculated values and taken into consideration in establishing the final treatment plan.

As an example, if the mandibular incisors are positioned more labially than the calculated position suggests and are rather spaced than crowded, a retrusion might not be indicated as this type of tooth movement may prove to be unstable.

With only slightly less accuracy, the third independent variable (Index) can be omitted. This results in the following equation:

$$\top\text{-}NB_{mm} = 0.50\ ANB - 0.35\ PgNB_{mm} + 3.9$$

$$R = 0.613$$

$$S.E. = 1.78\ mm$$

The reduction to two independent variables has the advantage that the regression model can be represented graphically in a nomogram, making calculations unnecessary. In the nomogram shown in Figure 106, the predicted ANB angle is found on the X-axis. Then, going up vertically to the line best representing the predicted value for $PgNB_{mm}$, the expected value for $\top$-NB_{mm} can be found on the Y-axis by moving due left from the intersection. This is illustrated by the example in Fig. 154.

For the alignment of the incisors, the interincisal angle is also of interest. It can be seen that there is a geometric correlation between the interincisal angle ($\perp$-$\top$) and the angles ANB, $\perp$-NA° and $\top$-NB°. If the latter three angles are known, the interincisal angle can be calculated according to the following equation:

$$\perp\text{-}\top = 180° - (ANB + (\perp\text{-}NA) + (\top\text{-}NB))$$

Assuming the standard values for the orthognathic facial type (ANB 2°; $\perp$-NA 21°, and $\top$-NB 23°), it is calculated as follows:

$$\perp\text{-}\top = 180° - (2° + 21° + 23°)$$

$$\perp\text{-}\top = 180° - 46° = 134°$$

But again, the value of 134° represents only an average value. It must be adjusted according to the morphology of the facial type. In particular, the prominence of the chin has an influence here. However, the correlation is not as clear as it is for the upper and lower anteriors. The regression equation for the interincisal angle is as follows:

$$\perp\text{-}\top = 1.59\ PgNB_{mm} + 129.3$$

$$R = 0.27;\ S.E. = 9.5$$

This equation demonstrates that for each millimeter of additional chin prominence, the interincisal angle increases by slightly more than 1.5°. The influence of the ANB angle is not sufficiently significant to appear in the formula. Although a smaller interincisal angle may be useful in treating an excessive overbite, this equation indicates that without additional long-term retention efforts, the interincisal angle may not remain stable.

In clinical treatment, the interincisal angle is not directly relevant because the axial inclinations of the upper and lower anterior teeth are aligned individually in a proper way. If both anteriors are correctly positioned, the interincisal angle is also correct due to the interrelationship explained above.

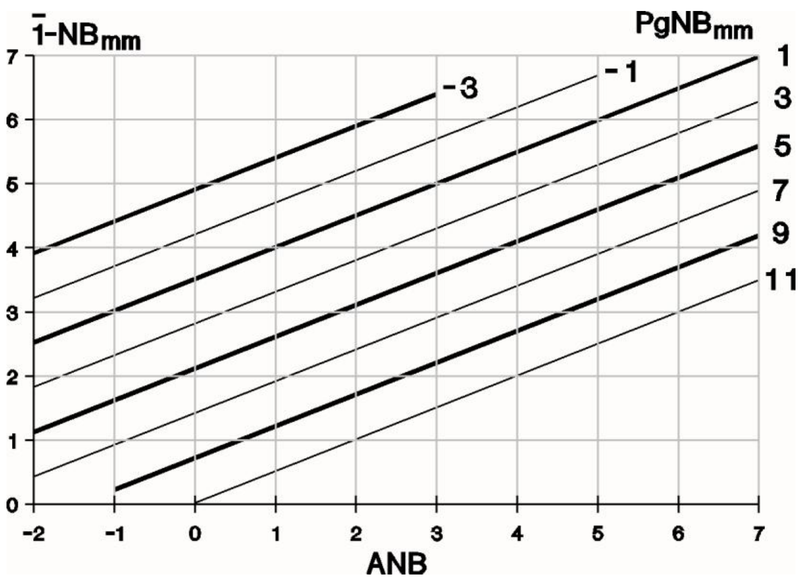


Fig. 106 Nomogram for determining the individually optimal value $\bar{1}$-NB$_{mm}$ from the values ANB and PgNB$_{mm}$. From ANB on the X-axis one goes to the corresponding PgNB$_{mm}$ line and finds the searched for value on the Y-axis.

7. Soft tissue norms

The soft tissue angle according to Holdaway and the Nasolabial angle are the only soft tissue measurements used for this analysis. Holdaway provides *floating norm* values based on the ANB angle. According to this *floating norm*, if the ANB angle is between 1° and 3°, the H-angle should be between 7° and 9°. The H-angle should increase by 1° as the ANB angle increases by 1°.

Our own cephalometric investigations confirm that the H-angle shows a strong correlation to the ANB angle and the prominence of the chin ($PgNB_{mm}$). Using the following equation, the expected H-angle can be calculated:

$$\text{H-angle} = 1.0\ \text{ANB} - 1.3\ PgNB_{mm} + 10.5$$

$$R = 0.75;\ S.E. = 3.2°$$

The relation of 1° change in H-angle per 1° change in ANB angle as stated by Holdaway can be confirmed. However the size of $PgNB_{mm}$ has an even greater influence. The larger $PgNB_{mm}$ is, the smaller the expected H-angle, more precisely by 1.3° per millimeter of $PgNB_{mm}$. The corresponding nomogram is shown in Fig. 107.

Caution is advised in applying the described norms for the H-angle. While *floating norms* for the anterior teeth alignment are primarily concerned with the stability of the treatment result, the H-angle must be seen primarily in the context of aesthetics. It is not surprising that with a sagittally mesial base relationship a relatively small H-angle is to be expected. It remains to be seen whether this also represents the aesthetic optimum.

The calculated value represents the H-angle that would be expected under the assumption of average soft tissue thickesses and responses based on the given morphology of the facial skeletonl. A favorable situation exists if the actual value lies between the calculated value and 7° to 9°, which is desirable from an aesthetic point of view. In such cases, the soft tissues compensate for an aesthetically suboptimal skeletal relationship in the sagittal plane. In contrast, if the measured H-angle deviates from the aesthetically ideal value and also lies beyond the expected value for the given facial type, the profile can be considered unfavorable.

It is always considered advantageous if treatment measures change the H-angle in the direction of the aesthetically ideal value. Unfortunately, this is often not compatible with other treatment objectives so that a compromise must be found. If the potential treatment would result in the H-angle not only moving away from the aesthetic range (7°-9°), but even falling beyond the value expected for that particular facial type (as calculated above), then this treatment option should best be avoided.

Generally, a more aesthetically favorable outcome is achieved when differential soft tissue thicknesses allow some compensation for the skeletal discrepancy; the H-angle then falls closer to the value for the orthognathic face.

The Nasolabial angle is much less dependent on the skeletal relationships. Here, the variations in the shape of the nose and the morphology of the soft tissues are more important; there is no need to calculate an individual expected value. The only stan-

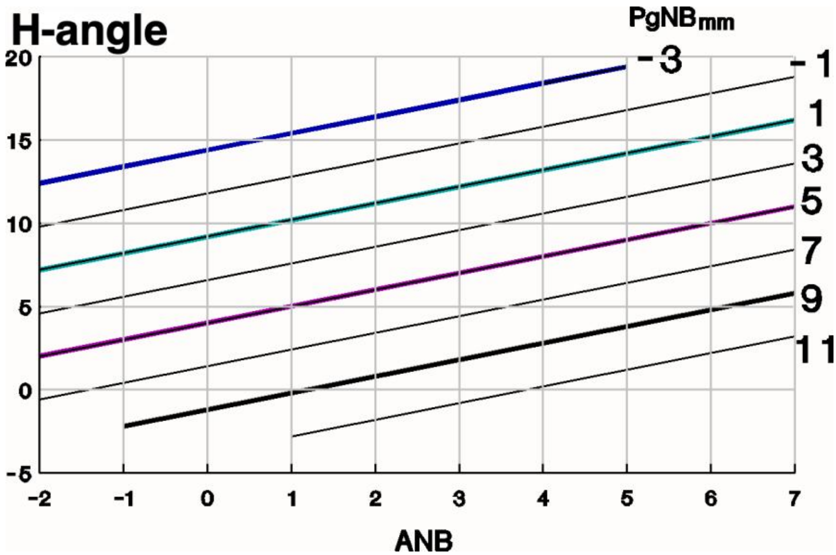


Fig. 107 Nomogram for determining the individual expected H-angle. With the predicted ANB angle on the X-axis, go to the corresponding $PgNB_{mm}$ line to find the expected value on the Y-axis.

dard here, even more so than for the H-angle, is the aesthetically favorable value of 110° +/- 10° for the Nasolabial angle. If both the Nasolabial angle and the H-angle are too large or too small, an unfavorable additive effect is produced. If, on the other hand, they deviate in different directions from the aesthetic ideal value, to a certain extent a compensating effect arises.

E. Growth

Any orthodontic treatment of children and adolescents is significantly influenced by growth. Growth can support the therapy, but it can hinder it or even make it impossible. Therefore, it is of paramount importance to reliably predict the expected growth in terms of intensity, time, and direction. Unfortunately, not all of these three factors can be predicted with good accuracy. While the timing and intensity of growth can be reliably and accurately predicted, the prediction of the direction of growth is very problematic so it must be carried out with caution. The potential growth, i.e., the total amount of remaining growth, can be derived from the summation of the expected growth intensities up to the end of the growth spurt. This value is of interest when deciding whether treatment with functional orthodontic appliances is still appropriate.

1. Timing

The timing of treatment within the patient's growth period may affect the treatment for three reasons. First, the intensity of growth and thus the speed of changes depend on the stage of growth. Second, the amount of remaining growth to be expected depends on the remaining duration of the growth period. Third, the end of growth can enable ending the retention phase or beginning a treatment, such as surgically assisted treatment of mandibular prognathism.

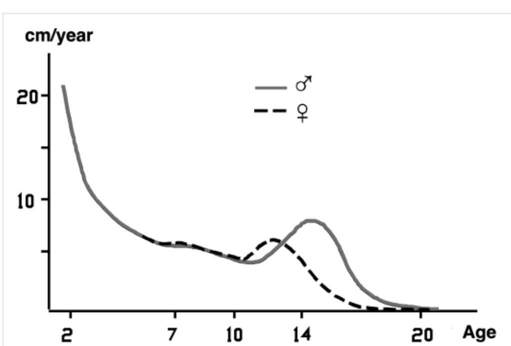


Fig. 110 Growth intensity curves depending on age for girls and boys.

Growth that can be utilized orthodontically occurs at any time until the end of the growth period. However, the intensity of growth varies over time (Fig. 110). After an infantile peak in intensity the growth

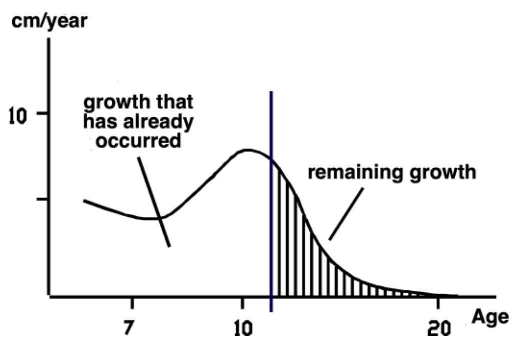


Fig. 111 Estimating the amount of residual growth from the growth intensity curve. The marked area to the right of the vertical line representing the patient's age (skeletal) corresponds to the amount of residual growth to be expected.

rate decreases until a minimum is reached prior to puberty. Then growth velocity increases again to reach a second peak during puberty. After this pubertal growth spurt, the intensity of growth finally decreases to near zero at the completion of growth.

The amount of residual growth that can be expected is given by the area under the growth intensity curve between a line representing the patient's current stage and the end of growth (Fig. 111).

Both the absolute intensity of growth and the relative intensity of the individual phases to each other are quite different between individuals. The timing of the individual phases is also subject to individual variation and is independent of chronological age and stage of dental development. The pubertal growth spurt is less expressed in girls and occurs chronologically one to two years earlier than in boys. The intensity of growth in the prepubertal stage is approximately 40 to 60% of the maximum intensity of growth that takes place during the pubertal growth spurt. Therefore, a treatment taking advantage of growth is also possible in this phase, even if the maximal possible efficiency is not reached. However, this disadvantage is often outweighed by other advantages such as better cooperation.

Since the stage of growth is not linked to the patients' chronological age, a straightforward determination of the growth stage is not easily achieved. A clue is provided by the degree of expression of the secondary sexual characteristics (Hägg and Taranger, 1980). If these are already present, the patient is already in the pubertal growth spurt. In girls, the onset of menstruation is a sign that the growth peak has already passed (on average by 17 months) and only limited residual growth can be expected. Since the growth in body height correlates quite closely with the growth of the jaw bones, regular monitoring of the body height is also suitable for deriving information on the growth stage. However, for such a method to be successful, similar records of the patient must already have been taken over a certain period of time.

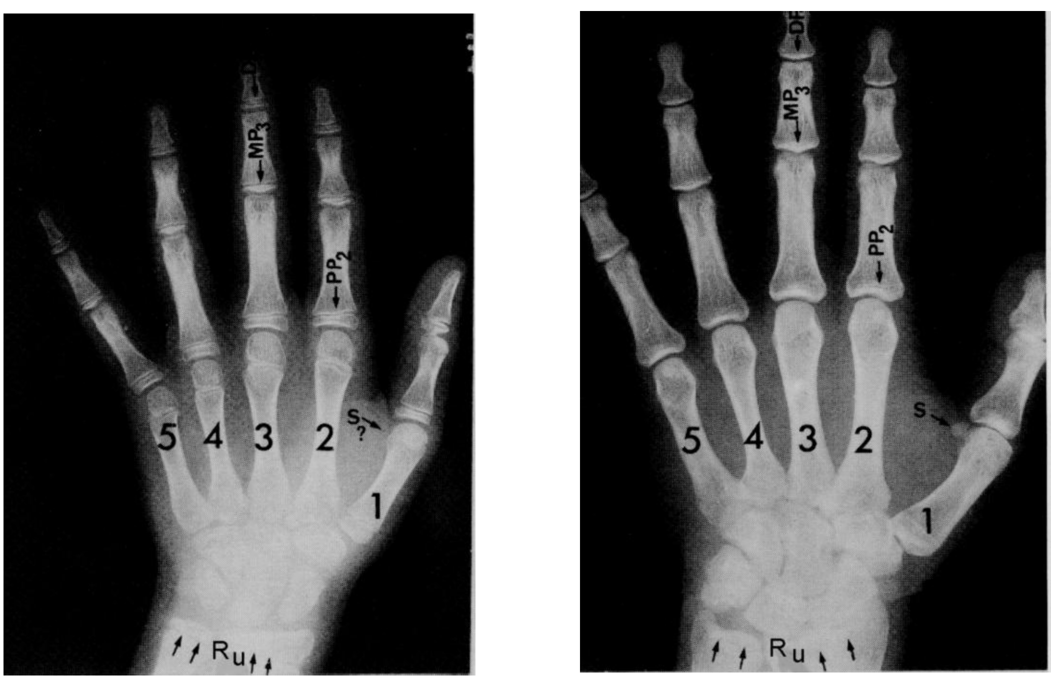


Fig. 112 Hand wrist radiographs of an individual before the pubertal growth spurt and after completion of growth. The changes between the two provide clues for the assessment of skeletal age.

If the assessments mentioned above are not sufficient for treatment planning and an exact determination of the growth stage is necessary, this can be done by evaluating a hand-wrist radiograph. Björk and coworkers as well as Hägg and Taranger have conducted studies on the skeletal development of the hand and wrist in relation to the maximal growth in body height; they have defined eight skeletal stages of maturation. The degrees of ossification of the epiphysis and diaphysis of the second and third fingers (index and middle fingers) as well as the radix and ulna are evaluated.

The fingers are numbered consecutively beginning with the thumb, and each segment is referred to as the distal, medial, or proximal phalanx respectively (Fig. 112). The individual stages are selected by indicating the corresponding phalange and finger with a description of the relevant findings.

a) Stage 1 (prepubertal stage)

None of the features described for the following stages are present. The patient is before or in the prepubertal growth minimum.

b) Stage PP_2=

The relevant site here is the proximal phalanx of the index finger. The stage is reached when the epiphysis has become as wide as the diaphysis (Fig. 113). This stage always occurs well before maximum growth intensity. During this stage of development, the growth intensity is relatively low.

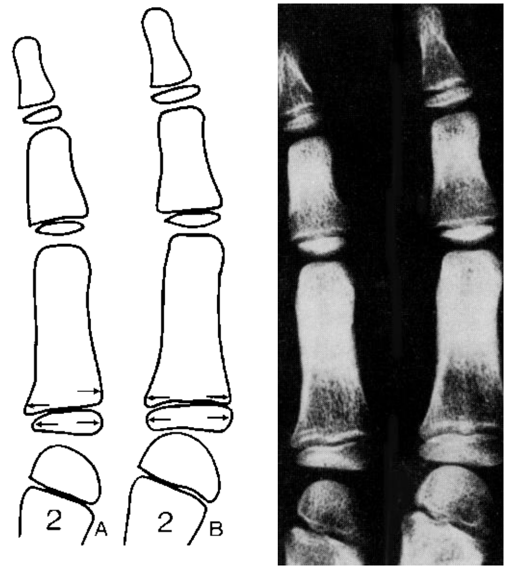


Fig. 113 Developmental stage PP_2=
A. Shortly before reaching this stage
B. After the onset of PP_2=

c) Stage MP_3=

Here, the middle phalanx of the middle finger is assessed. When the epiphysis has reached the same width as the diaphysis (Fig. 114), this stage has been reached. The time of maximum growth is about to occur or has just begun.

d) Stage S

This stage of development addresses the presence of the ulnar sesamoid at the metacarpophalangeal joint of the thumb (Fig. 115). The stage has been reached when the first signs of ossification appear. The stage of growth and the intensity of growth correspond to the stage MP_3=; however, the distribution in Stage S is lower and the assessment easier; therefore Björk recommends the use of Stage S. Note, however, that in 20% of Björk's data, the sesamoid was already visible two years or more prior to the maximum peak in growth spurt. Moreover, in 0.5% it is not forming at all. Thus, absence cannot be taken as a completely sure sign that the Stage S has not been reached yet.

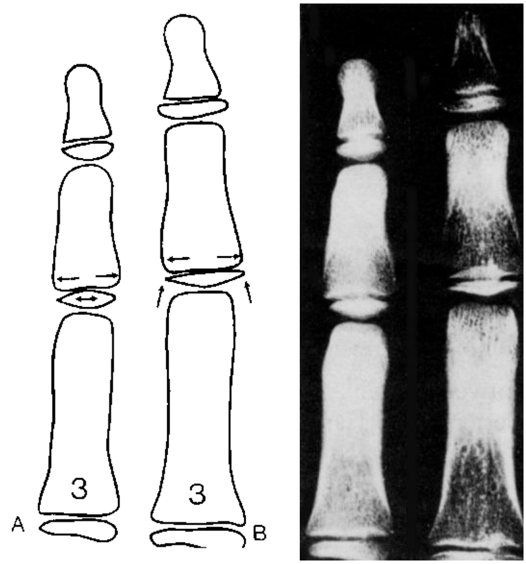
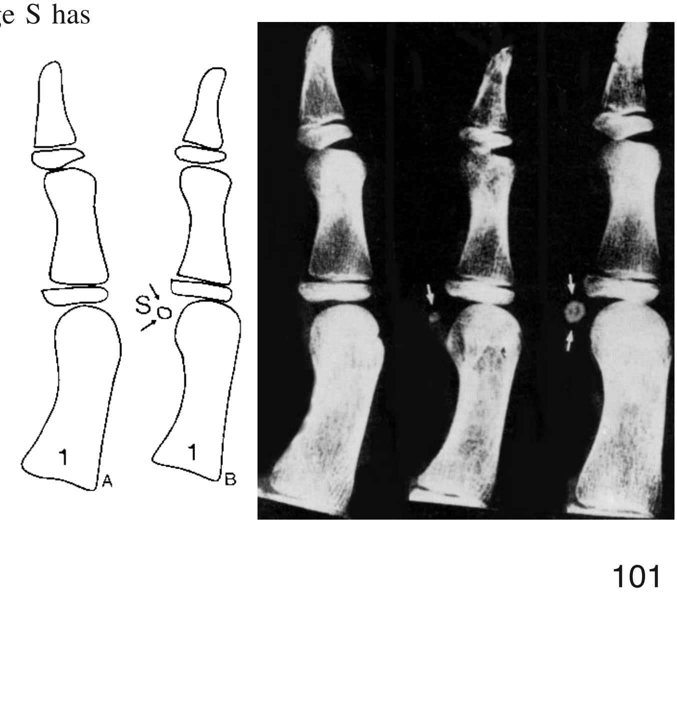


Fig. 114 Developmental stage MP_3=
A. Shortly before reaching this stage
B. After the onset of MP_3=

Fig. 115 Developmental stage S
A. Before the sesamoid becomes visible
B. First signs of ossification
C. Fully developed sesamoid



e) Stage MP_3cap

Also, for this stage, an assessment is made of the medial phalanx of the middle finger. In this stage, the epiphysis of the medial phalanx is wider than the diaphysis and shows a tendency to cap the diaphysis (Fig. 116). Its shape becomes like a cap (capping). Björk found that this stage occurs in conjunction or up to one year later than the maximum growth velocity. The period between the sesamoid and MP_3cap stages usually indicates the period of maximum growth rate.

f) Stage DP_3u

This stage is reached when the distal phalanx of the middle finger shows complete ossification ("unification") of the epiphyseal line (Fig. 117). In this and the next two stages, the time of

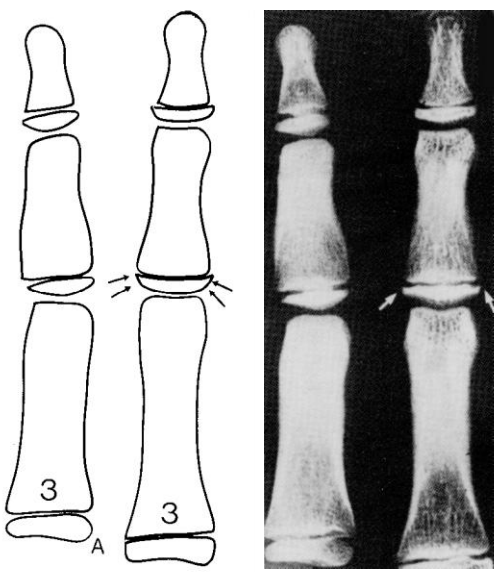


Fig. 116 Developmental stage MP_3cap
A. Before reaching the stage MP_3cap
B. After reaching the cap stage

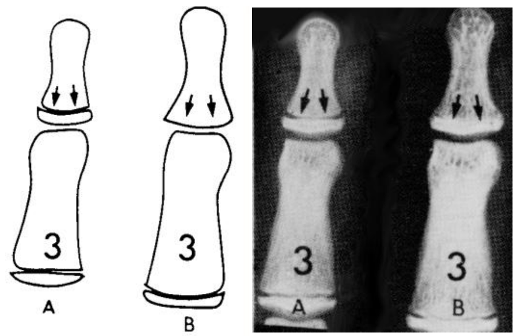


Fig. 117 Developmental stage DP_3u
A. Before reaching the DP_3u-stage
B. Obliterated epiphyseal line

maximum growth has been clearly surpassed. Growth intensity is again low to very low, and residual growth that can still be expected is minimal.

g) Stadium PP_3u

When the proximal phalanx of the middle finger is completely ossified (Fig. 118), this stage has been reached.

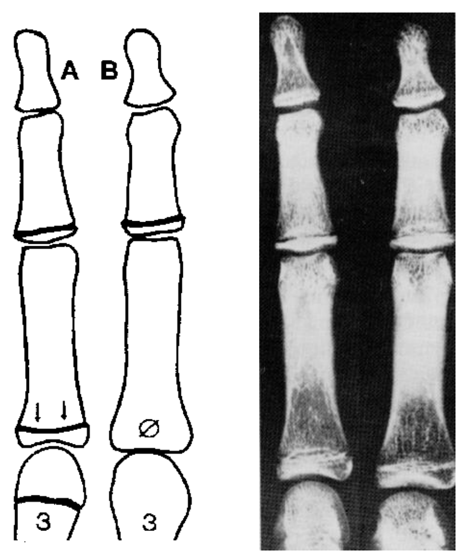


Fig. 118 Developmental stage PP_3u
A. Before reaching the PP_3u-stage
B. Complete ossification

h) Stage MP_3u

The second to last stage is reached when the epiphyseal line of the medial phalanx of the middle finger is fully ossified (Fig. 119).

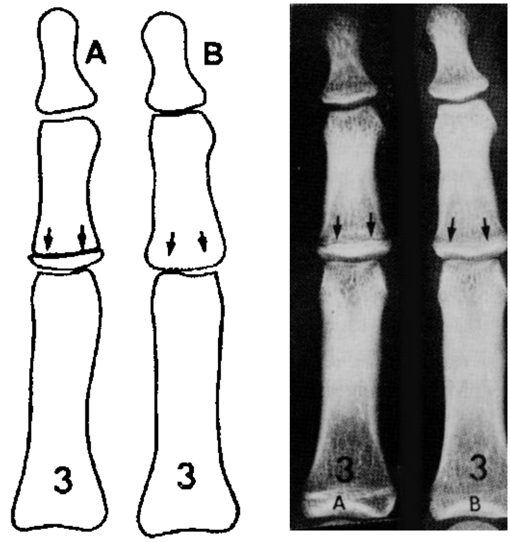


Fig. 119 Developmental stage MP_3u
A. Before reaching the MP_3u-stage
B. Complete ossification

i) Stage Ru

This final stage is reached when complete ossification of the distal epiphyseal lines of the radius and ulna has occurred (Fig. 120). Once this stage is reached, growth is considered to be complete. Only slight residual growth can be observed in some cases, especially in the mandible, which lags somewhat behind the growth in body height and the growth of the rest of the facial skeleton.

Fig. 120 Stage Ru
A. Before reaching Ru stage
B. Complete ossification

2. Direction

The direction of growth, particularly of the maxilla and mandible, is of interest for clinical treatment planning. By the typical time of orthodontic treatment, there is no longer any clinically relevant growth in the cranial base. The only effect on cephalometry is apposition, which takes place in the region of the Nasion. This always causes an anterior displacement of the Nasion, often also associated with minor displacements in the vertical plane.

The growth of both jaws can be seen as a combination of a rotation and a translation (Fig. 121). The translatory movement causes all parts of the jaw to be displaced in the same direction by the same distance. Rotation, on the other hand, causes a different direction of movement and a different extent of movement for each part of the jaw. Near the center of rotation, the extent of movement is virtually zero; however, the further a point is from the center of rotation, the greater the movement. Mathematically any combination of translation and rotation can be expressed as rotation alone with a corresponding displacement of the center of rotation. However, it is more advantageous for an understanding of the growth processes to leave the center of rotation near the center of the jaw under investigation and show the translation separately. A combination of translation and rotation is found almost without exception. Translation primarily affects sagittal changes, while rotation primarily (but not only!) affects the vertical relation (interbasal angle ML-NL).

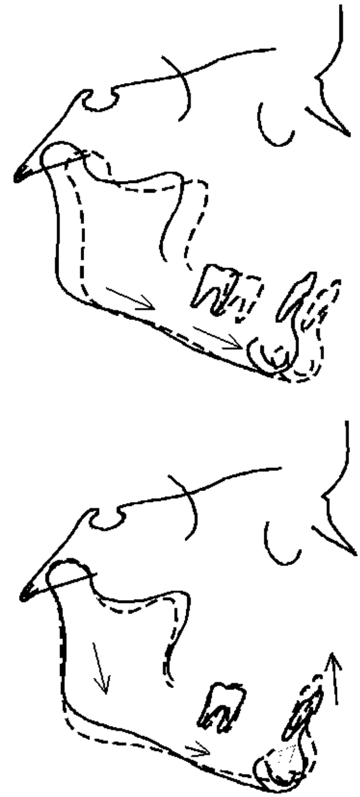


Fig. 121 Translation (top) and rotation (bottom) using the mandible as an example. Note the length and direction of the individual vectors of movement

A prediction of the growth direction in terms of translation and rotation for both the maxilla and the mandible would be desirable. Unfortunately, it has been shown that predicting the direction of growth of the maxilla is practically impossible because, firstly, there are no radiographically stable structures, and secondly, there are no consistent or predictable patterns. All that can be said is that the maxilla normally grows forward and downward, with a variation ranging from almost purely forward to purely downward. Despite the impossibility of predicting the growth of the maxilla, this does not cause any major problems clinically, since the maxilla can be influenced and directed in the desired direction by orthodontic measures much better than the mandible. In the following text, when the direction of growth is discussed, solely that of the mandible is meant.

As mentioned above, a prognosis of the growth direction is very problematic. All prognosis methods are based on the extrapolation of morphological characteristics that have manifested themselves by the time of the examination. It is assumed that growth proceeds uniformly and, in particular, that the direction of growth does not change. There are numerous studies that contradict this assumption.

Baumrind et al. (1986) investigated how accurately clinicians with many years of experience could predict or only anticipate growth-induced rotation of the mandible based on lateral cephalograms taken prior to the treatment. The results were staggering. None of the experts was able to make predictions that were significantly better than random.

There are numerous morphological characteristics and cephalometric variables (e.g. Björk 1969, Ødegaard 1970) that correlate with the growth direction in terms of translation and rotation. However, their significance in estimating the expected growth is so low that in most cases there is no apparent advantage over the assumption that growth is proceeding in an average direction. Ari-Viro and Wisth (1983) found acceptable reproducibility in the assessment of structural characteristics, but no significant correlation with the direction of growth that actually occurred.

The multiple regression-based prediction method proposed by Skieller et al. (1984) shows reasonably useful correlation coefficients in the study material they used. However, this material consists to a large extent of retrospectively selected extreme growth patterns. Applied to an average population, the results are again no better than the mean values (Lee et al. 1987 as well as our own studies).

According to Johnston (1968), even when the best prediction model is used, the explained (correctly predicted) proportion of the variation in growth direction increases only from 64% to 78%.

Even the use of supercomputers (Rocky Mountain Data System), in a study by Witt and Köran (1982), does not result in any higher accuracy or reproducibility than other common methods.

An evaluation of the morphology is nevertheless necessary in order to be able to isolate extreme growth patterns. Such individual cases, which are far from the average with respect to the direction of growth, can be predicted with some confidence (Skieller et al. 1984, Ari-Viro 1983) regardless of the prediction method used. Exactly these cases must be given special consideration in treatment planning. For more average cases, average values can be assumed without any drawbacks.

3. Structural Method

In order to recognize extreme growth patterns at an early age and adjust the treatment accordingly, the structural method, which was originally developed by Björk, is often helpful. In this method, the expression of certain morphological features of the mandible is evaluated. Each of these features is assessed with a score between +3 and -3, with a positive score always suggesting anteriorly directed growth. The structural features used are:

1. the shape of the condyles
2. the shape of the mandibular canal
3. the lower margin of the mandible
4. the anterior shape of the chin (prominence) as described by $PgNB_{mm}$.
5. the Index of anterior facial heights
6. the mandibular angle

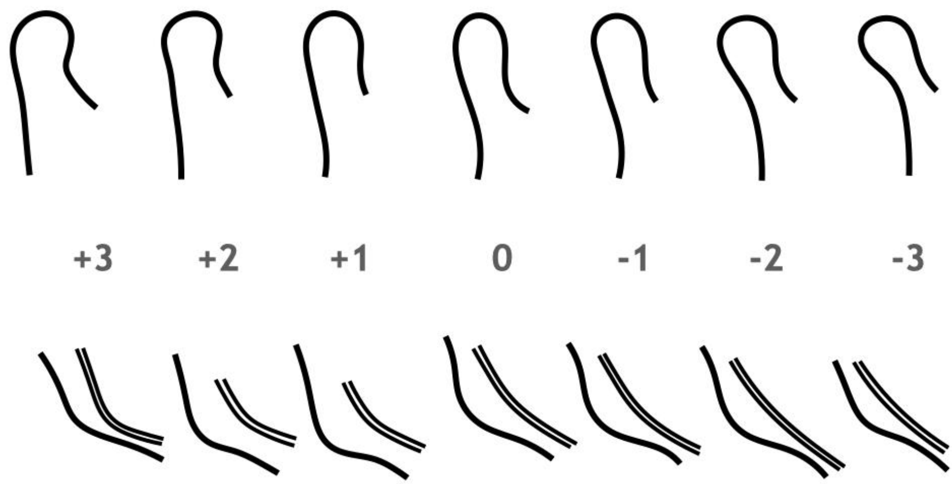


Fig. 122 Typical range of variations in the structural features of condylar and mandibular canal shape

The first three features are assessed by comparing them to the examples shown in Figures 122 and 123. For the remaining three features, the corresponding cephalometric numerical values can be used to determine the associated score using Table 5.

In order to make a prediction of the expected growth pattern of the mandible, all the points are added together. Then, for a second summary measure, only the points of the first and last features are added together. The first value allows a statement about the tendency of the expected rotation of the mandible, the second about the expected tendency of translation.

The average value for the sum of all six features is about +3. If this value is less than -6, a distinct posterior rotation of the mandible, i.e. a growth-related opening of the basal relation between the mandible and the maxilla, must be expected. If the sum is above +12, a clearly anterior rotation and a corresponding deepening of the basal relation of the jaws must be expected. Accordingly, with a value of less than -3 for the sum of the first and sixth structural features the mandible cannot be expected to grow anteriorly; it will not become more prognathic as a result of growth. On the other hand, with a value of +6 for this sum, a significantly above-average growth towards prognathism of the mandible can be expected.

All values that lie between these suggest a rather average growth, the exact direction of which cannot be predicted with any degree of accuracy due to the problems mentioned above. A prediction of the cephalometric values at the end of the treatment or growth should then be made based on average values as described in section 4.

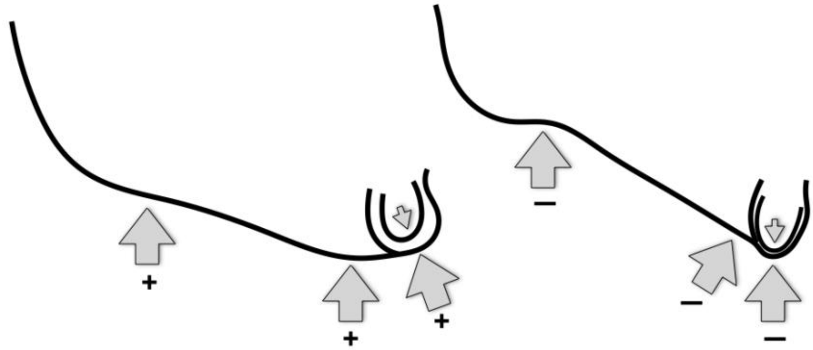


Fig. 123 Assessment of the structural features at the lower border of the mandible. Representing an extreme appearance of an anterior growth pattern (left) and a posterior growth pattern (right). The arrows indicate the areas of analysis

3. Superimposition of Cephalometric Images

Since an exact prediction of the expected growth direction of the mandible is subject to so many problems that it cannot be made with sufficient accuracy, another method of determining the expected growth direction often proves to be very advantageous. Here, a lateral cephalogram is taken during the first examination of the patient. Thereafter, a waiting period of at least one year is required before a second cephalometric image can be taken.

Usually, this period of waiting can be easily achieved if the parents bring in the child at an early stage, which allows for some delay prior to the start of the treatment. Alternatively, an early treatment may be necesary, which does not affect the growth of the

Tab. 5 Scheme for evaluating the variables $PgNB_{mm}$, Index and mandibular angle for predicting the direction of growth by the structural method

Rotation tendency	Chin prominence ($PgNB_{mm}$)	Index %	Mand. angle (Me-tgo-Ar) °
+++	> 3.0	> 88	< 118
++	2.0 - 3.0	84 - 88	118 - 123
+	1.5 - 2.0	80 - 84	123 - 127
0	1.0 - 1.5	75 - 80	127 - 133
-	0.5 - 1.0	71 - 75	133 - 136
- -	0.0 - 0.5	66 - 71	136 - 140
- - -	< 0.0	< 66	> 140

child at all or to any significant extent. Such treatment may consist, for example, in controlling the eruption of teeth or protrusion of the anterior maxillary dentition, if appropriate. Instruction in oral hygiene measures in conjunction with the evaluation of the patient's cooperation may also take place during this phase.

After the second radiograph has been taken, the two images can be superimposed so that the growth that has occurred in the meantime can be assessed in terms of direction and magnitude. Superimposition can be performed on the mandible as well as on the anterior cranial base. However, it is usually more advantageous on the cranial base, since the differences in the anterior region of the maxillary and mandibular bases (Spina, A point, B point, Pogonion) all involve changes due to growth in the fossa articularis, condyle and maxilla combined, i.e. they represent as a whole the findings that are of interest for treatment.

The superimposition should be done on the anterior border of the sella turcica and anterior cranial base radiographs (Fig. 124; Houston 1987). Since the point Nasion moves ventrally due to growth, it does not usually correspond on the two radiographs. Superimposition on the mandible can be performed by superimposing the inner margin of the symphysis, the mental canal, and often the inferior margin of the wisdom tooth germ in maximum alignment (Fig. 124; Björk and Skieller 1983). With this type of superimposition, it must be remembered that the caudal and anterior margins of the mandible do not necessarily coincide, since apposition and resorption processes occur here.

Although the direction and intensity of growth may change within certain limits over time, a fundamental change is not to be expected without external factors. Thus,

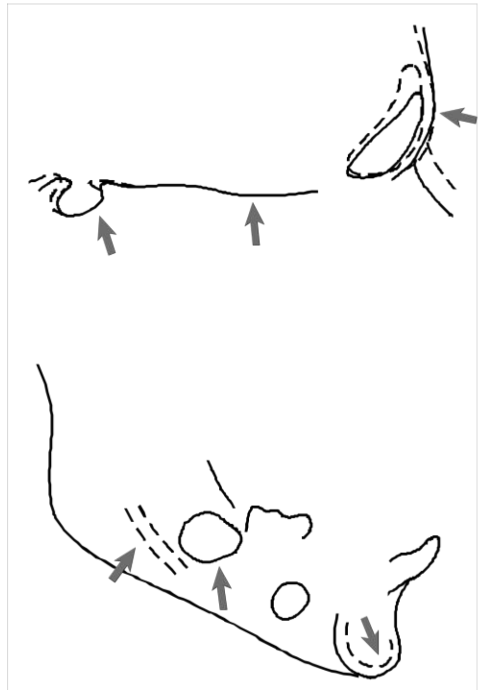


Fig. 124 Structures for superimposition on the skull base (top) and on the mandible (bottom). According to Houston (1985) and Björk and Skieller (1983)

an estimation of the expected growth direction can be made by extrapolating the change evident on the superimposition. This also allows an assessment of the maxillary growth. Since no correlation between morphological features and maxillary growth direction is known so far, this is the only way to assess maxillary growth.

However, even with this method, a cautionary remark is appropriate. The extrapolation of the growth processes during the observation period involves some uncertainties, since limited changes in the growth pattern may well occur during the course of growth. Still, this method must arguably be regarded as the most reliable.

4. Prognosis of the Change in Cephalometric Values

For the correct positioning of the anterior teeth during the treatment, it is important to have an idea of the facial morphology after the completion of the treatment and/or growth. Therefore, it is necessary to attempt to predict the change in some variables resulting from growth and/or treatment. These variables are the ANB angle and the PgNB distance in mm. Considering the problem of predicting the direction of growth, the following approach is suggested for patients without extreme growth patterns:

Without orthodontic treatment that influences the ANB angle, an average reduction of the ANB angle by 2.5° can be expected in the age interval between 6 and 16 years. At the same time SNPg increases by 2.5° and $PgNB_{mm}$ by 2.6 mm. The anticipated annual changes can be assumed to be approximately 1/10th of the total changes until the end of growth.

More accurate estimates can be obtained by applying Table 6, which is based on a longitudinal study of 141 untreated subjects. It can be seen from Figures 125 and 126 that the annual changes in both ANB and $PgNB_{mm}$ depend on sex and age. In Table 6, the annual changes are cumulatively added up starting on the right (completion of growth). They can therefore be used to estimate the changes that can be still expected.

This growth-related change can be influenced within certain limits by orthodontic treatment with appliances that have a skeletal effect. For example, the growth of the maxilla in the sagittal as well as in the vertical direction can be slowed by the influence of headgear. On the other hand, treatment with functional orthodontic appliances can lead to a change in the direction of mandibular growth and thus to

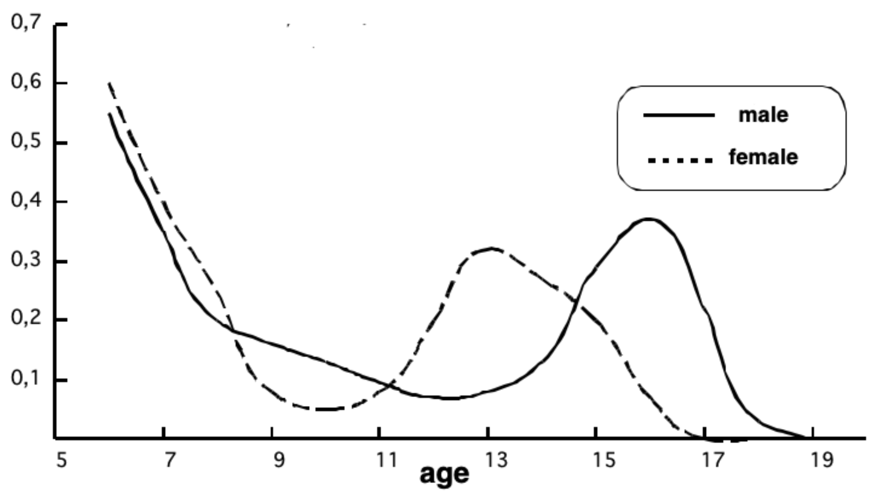


Fig. 125 Mean annual decrease in ANB angle according to age and gender

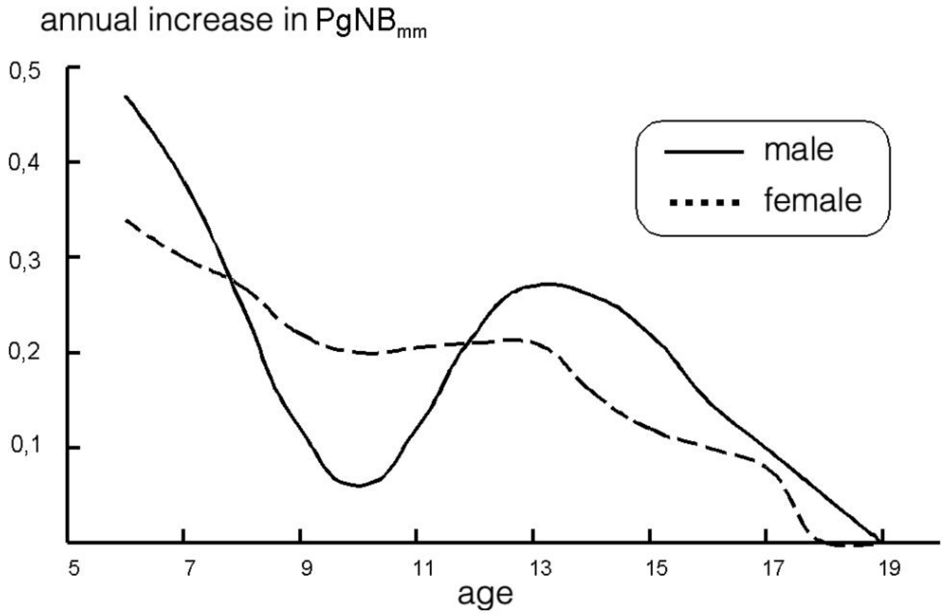


Fig. 126 Mean annual increase in distance $PgNB_{mm}$ according to age and gender

an advancement of the mandible. A treatment to correct a Class II malocclusion will likely also have a skeletal effect. In this case, a further reduction of the ANB angle occurs in addition to the above-mentioned growth-induced reduction of the ANB angle. The more distal the original situation, the greater this additional reduction may be. In this context, the extent of the dental deviation (sagittal overjet) also has an effect, since the treatment of a skeletal distal relation should not lead to a mesial occlusion. The additional reduction of the ANB angle will be 2° in most cases with a distal relation; in pronounced cases even 3°.

Because the distance $PgNB_{mm}$ cannot be significantly changed by orthodontic treatment measures, the predicted growth-related changes can thus be directly applied.

Thus, in Tab. 6 the changes in the values for ANB and $PgNB_{mm}$ from the moment of examination to the completion of growth are given. The data "with treatment" refers to treatments with appliances that have a skeletal effect aimed at correcting an average distal jaw relationship. As mentioned above, the values presented are average values for patients with an Angle Class I or Angle Class II occlusion. If certain growth patterns have been identified with some degree of certainty (for example, by means of serial superimpositions), the average values should be modified accordingly. For example, if there is a pronounced sagittal growth pattern with significant horizontal translation of the mandible, it can be expected that the ANB angle will be reduced more and the $PgNB_{mm}$ will increase more than indicated in the table. On the other hand, the values in Table 6 must be reduced

Tab. 6 Changes in ANB and PgNBmm still to be expected by the completion of growth in **male** (left) and **female** (right) patients. "Treatment with functional orthodontic appliances (FOA)" refers to a class II treatment with FOA devices, such as activator, Hansa device, or mandibular advancement double plate

boys				girls			
age	$\Delta PgNB_{mm}$	Δ ANB no functional tx	Δ ANB with functional tx	age	$\Delta PgNB_{mm}$	Δ ANB no functional tx	Δ ANB with functional tx
6	+2.7	–2.7	–4.2	6	+2.4	–2.5	–4.0
7	+2.2	–2.1	–3.5	7	+2.1	–1.9	–3.3
8	+1.8	–1.8	–3.1	8	+1.8	–1.5	–2.9
9	+1.6	–1.6	–2.8	9	+1.5	–1.3	–2.6
10	+1.5	–1.4	–2.4	10	+1.3	–1.2	–2.3
11	+1.4	–1.3	–2.0	11	+1.1	–1.1	–1.9
12	+1.3	–1.2	–1.7	12	+0.9	–1.1	–1.8
13	+1.1	–1.1	–1.6	13	+0.7	–0.9	–1.4
14	+0.8	–1.0	–1.4	14	+0.5	–0.5	–0.8
15	+0.5	–0.9	–1.1	15	+0.3	–0.3	–0.5
16	+0.3	–0.6	–0.7	16	+0.2	–0.1	–0.1
17	+0.2	–0.3	–0.3	17	+0.1	0.0	0.0
18	+0.1	0.0	0.0	18	0.0	0.0	0.0

if the growth pattern is clearly vertical.

In cases with extreme growth patterns, especially in the presence of a mesial jaw relation, the prediction of the changes in the variables of the ANB angle and $PgNB_{mm}$ has to be made on an individual basis. General guidelines, including the values in Table 6, cannot be applied in these cases. A favorable development of the ANB angle is usually not to be expected, especially in the case of mesial skeletal relationship.

F. Clinical relevance of the analysis

In the following section the significance of the cephalometric analysis for the practical clinical treatment will be presented. This will be followed by examples of clinical case reports in part G.

1. Classification of the Facial Type

The classification of the facial type is related to the difficulty of orthodontic treatment. Experience shows that orthognathic and prognathic facial types are much easier and more convenient to treat than retrognathic ones. This is true for orthodontic (tooth) movement as well as for orthopedically influencing growth. The reason for this phenomenon is not well understood, but in all likelihood the significantly smaller space availability in sagittal and vertical directions plays a decisive role (Fig. 130). Sequential examinations also indicate that the growth potential of the mandible is lower in retrognathic facial types in comparison to orthognathic and prognathic ones. A lower growth potential provides fewer possibilities of influencing the growth and thus poorer treatability of skeletal misalignments.

Fig. 130 Cephalometric lateral radiograph of a patient with retrognathic facial type. Note the constricted spatial relationships

Evaluation of the facial harmony also influences the treatment efficiency. Any dental malocclusion is significantly easier to treat if the skeletal structures are in a harmonious relationship. An increase in facial disharmony is likely to lead to more difficulties in treatment. These may include, for example, a more complicated anchorage situation or the risk of unwanted bite opening or deepening. Furthermore, the treatment result may be less stable if the facial morphology is distinctly disharmonious. A prolonged or even permanent retention may then be required.

Above a certain level of disharmony, it is no longer advisable to treat patients only orthodontically. The reason is the instability of the treatment result, the extent of unfavorable side effects, or simply the impracticability of such treatment. In such cases, a reasonable treatment concept can be found only within the framework of a combined orthodontic-surgical approach or at least the use of skeletal anchorage.

2. Basal Trend of the Anomaly

The dentoalveolar relation can both reinforce and provide compensatory masking of an unfavorable skeletal condition in all three spatial planes. For treatment purposes, it is of great interest to determine whether the situation visible in the mouth or on the study models is representative of the dental anomaly at hand. In particular, cases presenting dental compensation of a skeletal malformation may present difficulties in orthodontic treatment. Therefore the analysis distinguishes between the basal parts of the jaws as opposed to the dentoalveolar process; the former determine the basal trend of the anomaly.

An Angle Class II occlusion, no matter how slight, will be extremely difficult to correct if there is a severe skeletal distal relationship. Even more problematic are the cases with an open skeletal configuration where dental compensation eliminates an open bite (Fig. 131). In such cases, almost every orthodontic intervention will result in a spontaneous and unwanted bite opening, which is extremely difficult to correct once it has occurred. If such cases are treated purely orthodontically, it is essential that every conceivable bite-closing procedure is applied from the very beginning. However, the use of appliances with a bite-opening side effect, such as an activator in its conventional design or a cervical-pull headgear, is to be avoided.

Fig. 131 Basally open configuration (O1), that is compensated dentally. Deep bite is present

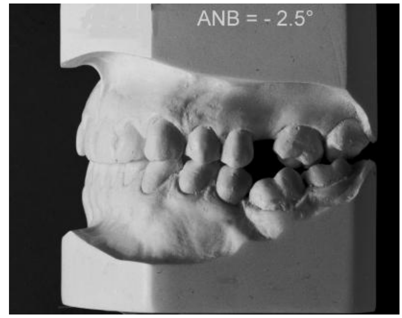


Fig. 132 The basal trend and dentoalveolar malocclusion are opposing and compensating each other. An Angle Class II is present with a mesial relation of the jaw bases

In cases with a deep skeletal bite relation, the same applies, although the surprises are generally not quite as dramatic. However, even in these cases, the choice of treatment appliance, the decision whether to extract or not, and e.g. the direction of pull of the extra-oral anchorage is influenced by the basal trend of the anomaly.

Fortunately for the clinician, there are also patients who have opposing skeletal and dental malocclusions. For example, a slightly mesial skeletal relation may occur in conjunction with an Angle Class II (Fig. 132) or a frontal open bite with a neutral or deep basal jaw relation. These malocclusions can usually be treated quickly, easily and with a stable result.

The complex decision as to whether or not to extract patients' teeth, and if so, which ones, is also influenced by the basal trend of the anomaly, among other factors. In a distal skeletal relation, the isolated extraction of two bicuspids in the maxilla may be an option, whereas in neutral or mesial relation of the maxilla and mandible, the extraction of four bicuspids is more likely to be the choice. A deep bite configuration tends to be an argument against extractions, while an open bite configuration may favor tooth extractions. Of course, the decision whether or not to extract teeth must always be considered in conjunction with the analysis of space and the profile.

One of the most important statements regarding the skeletal relationships is the objective differentiation between those cases that can be treated with orthodontic therapy alone and those that show such severe skeletal anomalies that conventional treatment does not lead to the desired results. In such cases, it is essential to make the distinction before treatment is started. If conservative orthodontic treatment is not promising and a combination of orthodontics and orthognathic surgery is required, then a completely different treatment plan is necessary. Instead of compensating for the skeletal deviation by dental adjustments, such a treatment requires decompensation, i.e., the teeth need to be moved exactly in the opposite direction. To avoid round tripping of teeth (with an increased risk of root resorption!), and more importantly, to prevent unnecessary extractions, the decision on the treatment concept must be made at an early stage, i.e., as a rule, before treatment interventions are initiated.

When the lack of success with purely orthodontic measures is clear from the analysis of the basal trend, it is often advantageous

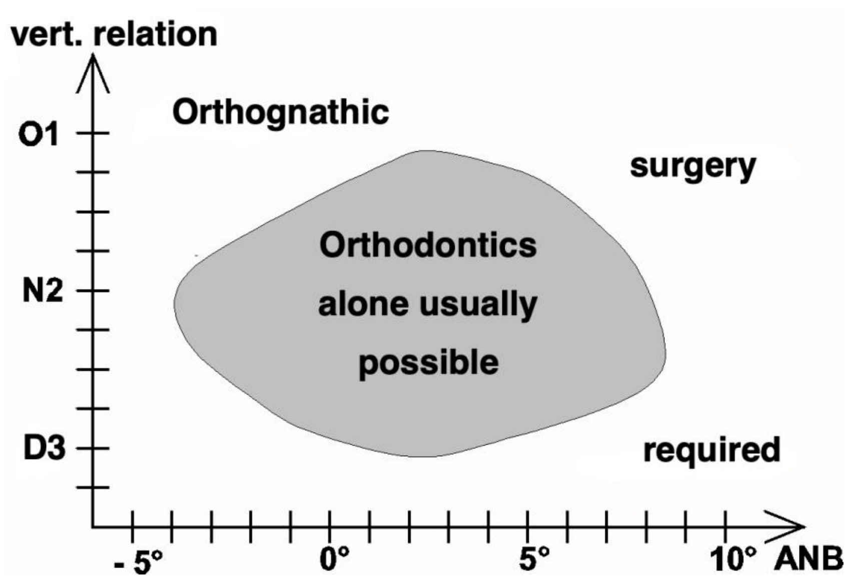


Fig. 133 Differentiation between cases that can be treated purely orthodontically and those that require combined orthodontic and orthognathic surgery treatment according to the sagittal and vertical basal relation

for the patient to interrupt any orthodontic treatment until the right time for surgical intervention is near.

Where are the limits of purely orthodontic treatability? When answering this question, the deviations in the various planes must be evaluated in association with one another; thus, isolated limiting values cannot be given either for the ANB angle or for the vertical measurements. Rather, a two-dimensional decision field (Fig. 133) with the sagittal and vertical jaw relations on the X- and Y-axes is used. The position of the intersection can be taken as an indication of treatability. The diagram shown can, of course, only serve as a guide for this extremely difficult and grave decision. A multitude of other factors such as the transversal skeletal relationship, the soft tissue profile and, to a certain extent, the dental situation must be considered, just to name a few.

From the diagram in Figure 133, it is clear that with a neutral vertical relationship, a significantly wider range of malocclusions in the sagittal plane can be treated conservatively than with increasingly deep or open skeletal configurations in the vertical plane. The combination of a sagittal and a vertical discrepancy quickly exceeds the limits of what is feasible by orthodontics alone.

It has to be stated that an isolated abnormality in the sagittal or vertical plane can make an orthognathic surgical procedure unavoidable if it is severe enough. Figure 134 shows two cases that do not exhibit significant sagittal misalignment. However, both cases show such serious deviations in the vertical plane that they should be treated only in collaboration with maxillofacial surgery. Even if the pattern in Figure 133 only serves as a indication, the importance of the cephalometric analysis in recognizing the limits of conservative treatment alone cannot be overemphasized. Diagnosis of

Fig. 134 Two cases with severe vertical disharmony of the jaw bases with almost neutral relationship in the sagittal plane

the basal trend of the anomaly also provides information as to which jaw is predominantly responsible for the corresponding deviation. This can be seen in the Harmony Box, as explained in the chapter "The concept of '*norm*'". Many treatment options selectively allow more changes in one jaw or the other, making it possible to achieve better overall harmony by applying individually tailored treatment interventions.

In a growing patient, a distal relationship between the maxillary and mandibular bases may be treated, for example, with headgear or with a bimaxillary functional orthodontic appliance. Both methods act on the maxilla as well as on the mandible. However, the relative contribution of each is different: an extra-oral traction can be expected to have a much stronger effect on the maxilla than a slow-acting functional orthodontic appliance. Thus, in the case of excessive prognathism of the maxilla, the choice of headgear would be appropriate, while in the case of mandibular retrognathia, it would be desirable to have an effect mainly on the mandible. The use of a slow-acting functional appliance could be favorable in such cases.

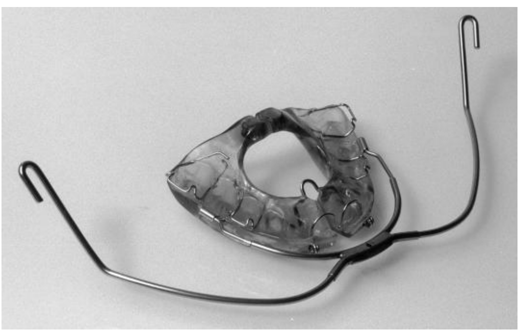


Fig. 135 Hansa appliance with headgear in which the mandibular component was removed to primarily affect the maxilla

Although generally speaking an isolated effect on the mandibular base is not attainable with orthodontic appliances, nevertheless the proportion between the effect on the maxilla and the effect on the mandible can be varied to a certain extent. Modern functional orthodontic appliances are so variable in most cases that their mode of action can be adapted to the prevailing conditions. Selective extraoral traction can be applied to the mandibular part of the appliance or it can be omitted. The degree of sagittal activation can be varied as required (Fig. 135).

Fig. 136 Open skeletal configuration with *maxilla* being responsible (Index 67%, NL-NSL 3°, ML-NSL 40°, ML-NL 37°, SNA 77°)

Deviations in the vertical plane may be caused by an unfavorable inclination of either the maxilla or the mandible. Of course, combinations of both frequently occur as well. Experience has now shown that vertical skeletal anomalies caused by the mandible are much more difficult to influence than those in which the inclination of the maxilla does not match the facial type. To influence the maxilla, the practitioner has many more options. The use of extraoral forces to control maxillary growth or moving teeth within the alveolar process are possible. In the mandible, vertical extraoral forces cannot be applied due to the rotational freedom of the mandible within the temporomandibular joint. Also, a chin cap has only a very limited effect on the mandible; the main effect occurs via the occlusion in the maxilla. Furthermore, a posteriorly inclined mandible is associated with an unfavorable musculature, which makes even a surgical correction difficult.

Fig. 137 Open skeletal configuration with *mandible* responsible (Index 76%, NL-NSL 10°, ML-NSL 50°, ML-NL 40°)

Since skeletal deviations of the mandible in the vertical plane are so much more difficult to treat than those of the maxilla, an important criterion for the differentiation between purely orthodontic and combined orthodontic-orthognathic surgical treatment arises. While "O1" cases with an Index of 65% may be treated purely orthodontically if the deviation stems from the anterior inclination of the maxilla, the same Index of 65% resulting in a posterior inclination of the mandible will usually be impossible to treat successfully without surgical assistance (Figs. 136 and 137). Similar principles apply to skeletally deep configurations. An anteriorly inclined mandibular plane that forms a small angle with NSL is much less favorable to treat than a severely posteriorly inclined maxilla. Thus, the differential diagnosis of whether the skeletal vertical discrepancy is caused by the maxilla or the mandible is of great interest to the practitioner.

Another distinction lies in the origin of the posterior inclination. If the underlying cause is the mandibular shape (a large Ar-tgo-Me angle), the anomaly should be considered more serious than if it is a positional problem of the mandible (normal mandibular angle).

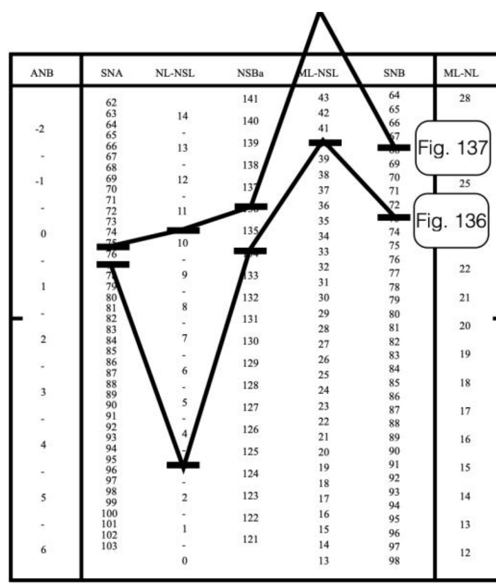


Fig. 138 The two cases from Figures 136 and 137 presented in the Harmony Box. In Fig. 136 the maxilla is at fault, in Fig. 137 the mandible

3. Influence of Growth

Growth can have a positive or negative influence on the treatment. Positive effects can be achieved if the amount and direction of growth can be exploited to favorably influence the existing dental and/or skeletal misalignment. Thus, in most cases, the relatively more pronounced growth of the mandible will favorably influence the treatment of an Angle Class II with a skeletally retrognathic mandible.

However, the same growth pattern can also have a negative influence. When the treatment of the above-mentioned case has been finished and the desired neutral dentition has been achieved, further moderate growth of the mandible may in certain cases lead to a (tertiary) crowding due to retroclination of the lower anterior teeth with simultaneous spacing in the maxilla, and in severe cases even to an Angle Class III tendency. Thus, the type and duration of retention will depend on the growth that is still to be expected. Often, retention cannot be discontinued until growth is complete. In this context, sound dental cusps with good interlocking must be considered as one of the best retention measures.

For the treatment of Class III cases, such a growth direction and amount would also be unfavorable and would cause major problems in the treatment or even render it impossible. In these cases, special effort should be made to determine the growth direction as accurately as possible. Experience shows that mandibular growth can be hindered only minimally or not at all. Also, the direction can only be influenced to a very limited extent. If the growth direction is unfavorable, it can easily happen that the treatment cannot keep up with the unfavorable growth. In addition to extremely long treatment times, this often leads to aesthetically and functionally unsatisfactory results. Since the possibilities of influencing the growth are so limited, it may be better in such cases to wait for its completion in order to then establish an accurate and conclusive treatment plan (Figs. 139 and 140). This can often significantly reduce the overall treatment time and the burden on the patient. Any interceptive procedures

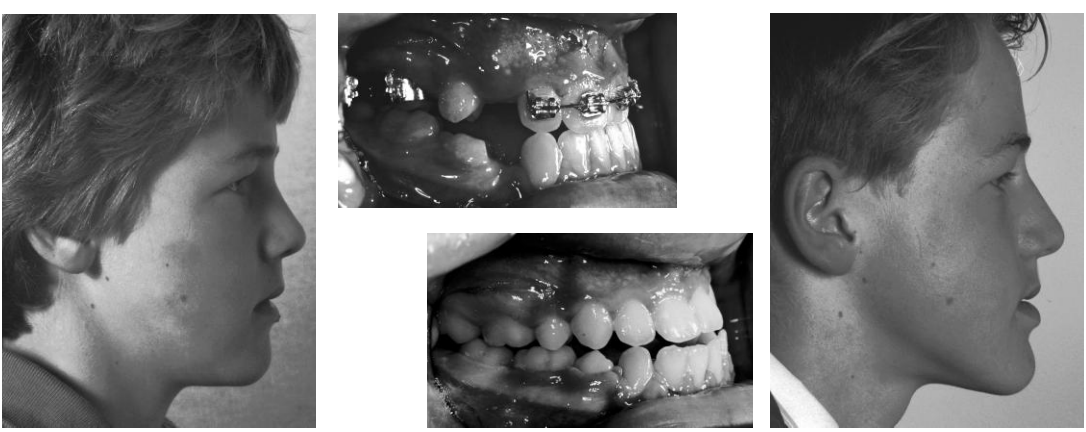


Fig. 139 Angle class III malocclusion. Left at age 12. After the tooth-size related crowding was resolved, debracketing took place and a retainer was bonded in order to await further growth. On the right, the patient can be seen 3 years later

remain unaffected by these considerations. It is very important to discuss such a concept in detail with the patient and parents.

The utilization of the pubertal growth spurt is often considered desirable for the treatment of distal relations in the sagittal plane. However, the curves on pages 109/110 show that growth occurs at all times from prior to the growth spurt to the end of growth; functional orthodontic treatment is always possible then. The possible advantages of the greater growth rate during the growth spurt are counterbalanced by other factors, such as better patient cooperation before the onset of puberty. The treatment in the mixed dentition has the further advantage of lacking intercuspation due to absence of the cusps in the deciduous molars. It seems that the modern functional orthodontic appliances, especially in combination with extra-oral anchorage, can be effective at any stage of growth. According to research by Teuscher, the skeletal effect of a functional appliance is rather small compared to the growth that occurs naturally.

The greatest clinical relevance of growth processes lies in the assessment of the incisor tooth position. The stability of the anterior teeth is influenced by the morphology of the skeletal components so that the growth-related changes in this morphology affect the position of the incisors. In the growing patient, the anterior teeth can only be positioned by taking into account the growth that is still to be expected.

If the status quo of the initial lateral cephalogram is used as the basis for analyzing the anterior tooth position, it is only possible to determine which tooth position would have been ideal at the time of the radiograph. However, any changes in the skeletal morphology due to growth during treatment or thereafter would render this individual target for the anterior tooth position virtually worthless.

Only by predicting the growth- and treatment-related changes in the variables ANB and $PgNB_{mm}$ is it possible to make a sensible projection in which direction the incisors should be moved. Thus, the accu-

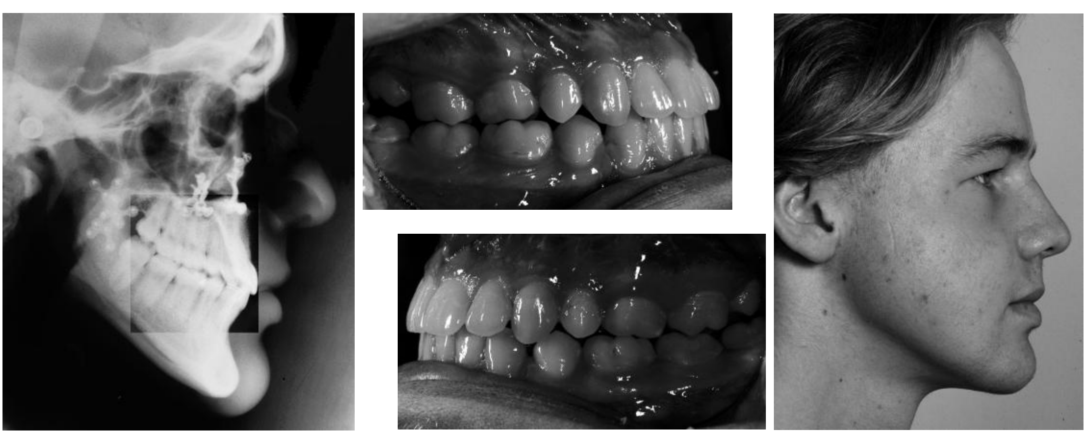


Fig. 140 Angle class III malocclusion. The patient in Fig. 139 after completion of growth and after surgery. Following decompensation and harmonization of the dental arches, the patient was skeletally adjusted by bimaxillary osteotomy. Profile and occlusion could be harmonized.

racy of the anterior tooth position analysis depends not only on the precise estimation of the regression model used, but also on the precise estimation of the growth-related morphological changes. For this reason, it is often useful to verify the anterior tooth position by taking a lateral cephalogram at a later stage of treatment. At this later stage, more growth will have occurred and the amount of residual growth that needs to be predicted will be minimal. Another advantage is that the assessment of the changes in the anterior tooth position already achieved by the treatment can only be made by means of such an X-ray.

In the adult patient, there are no significant growth-related changes in skeletal morphology. However, if orthodontic treatment and orthognathic surgery are used in combination, there will be changes in the facial skeleton which must be taken into consideration when planning the positioning of the anterior teeth. For this reason, it is essential to plan the surgical procedure in collaboration with the maxillofacial surgeon before starting orthodontic treatment, and then to decide on the orthodontic treatment approach with particular attention to the positioning of the anterior teeth. Based on the analysis of the space and tooth position, it can be determined whether teeth have to be extracted or not. Since the orthognathic treatment can be planned with great accuracy, the uncertainty of the growth prognosis is irrelevant, which makes possible an exact positioning of the anterior teeth.

4. Soft Tissue Cephalometry

Certainly, the main focus of the orthodontist remains the function of the stomatognathic system and in particular the occlusal relationship. However, the patient often has completely different priorities. The aesthetic aspects are usually rated as high or even higher than the occlusal aspects. This sometimes happens subconsciously or without acknowledgement by the patient. However, awareness of the tooth position and the surrounding structures is awakened at the latest during orthodontic treatment, so that the patient then also pays more attention to such details.

In addition to well-positioned maxillary and mandibular anterior teeth, the soft tissue profile and in particular the lip profile are important (Fig. 141). Both an excessively convex and an excessively concave profile are perceived as unpleasant by the patient. Similarly, an oversized Nasolabial angle or a too-thin strip of vermilion has an unfavorable effect. Sunken lips, especially in conjunction with deficient vermilion, are associated with an aged appearance (Fig. 142).

Fig. 141 Harmonious soft tissue profile

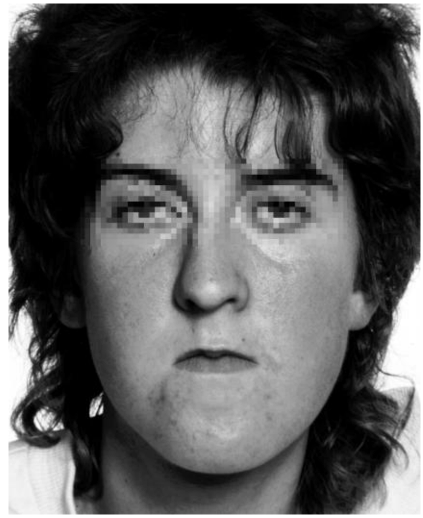


Fig. 142 Unfavorable soft tissue profile with receding lips and only a thin strip of vermilion

Unfortunately, the desired favorable soft tissue profile cannot always be achieved during orthodontic treatment. Particularly in adults, in whom the alignment of the dentition can often be achieved only by extracting teeth, an unfavorable effect on the soft-tissue profile may occur. This usually involves a retrusion of the lips and thus a seeming enlargement of the nose and chin (similar to Fig. 143). Such unfavorable effects must be known before treatment is started and taken into account when weighing the advantages and disadvantages of various treatment options. It may be necessary to modify the treatment plan to include minor compromises or to change it altogether. At the very least, the patient must be informed of the impact of the treatment on the profile and an informed consent must be obtained.

Fig. 143 Adult patient in whom treating the malocclusion by extracting bicuspids would lead to an unfavorable soft tissue profile. Extractions would result in a further reduction of the H-angle

The example in Figure 143 shows an adult case where the treatment of malocclusion (Angle Class II) requires the extraction of at least two bicuspids in the maxilla. With the retrusion of the maxillary incisors, the upper lip will move back slightly. This will make the H-angle smaller and the nasolabial angle larger. This would bring an unfavorable change in the profile because the H-angle is already quite small due to the prominent chin. The nose-lip-chin profile would then become unflatteringly concave.

The patient in Figure 144 shows a similar situation in purely dental terms with Angle Class II in an adult. However, here the H-angle remains rather large and has been favorably influenced by the extraction treatment including retraction of the maxillary anterior teeth. The problem for this patient lies in the Nasolabial angle. Retrusion of the upper lip after extracting the teeth increased the already large Nasolabial angle even more, producing a significantly less favorable profile. For the reasons mentioned above, the patient was advised prior to treatment against a purely orthodontic treatment in favor of a combination of orthodontic treatment and orthognathic surgery—unfortunately without success.

Fig. 144 Adult patient in whom the treatment of the malocclusion by extracting two bicuspids has resulted in an unfavorable increase in the Nasolabial angle

5. Cephalometry of the Tooth Position

The aim of orthodontic treatment for both maxilla and mandible is to establish a harmonious dental arch within the given limits. These "limits" refer to the tooth position in the oro-vestibular direction that can provide a stable treatment result. If these limits are exceeded, there is an increased probability of relapse, e.g., recurrence or emergence of crowding.

What exactly are these limits? They are determined by the unchangeable inter-canine distance and the shape of the alveolar ridge in the distal region in the medial-lateral direction (Fig. 145). On the other hand, the anterior limit is not immediately apparent. No measurements on the model or directly in the mouth can provide a reliable conclusion as to where this anterior border lies. Only the evaluation of the skeletal morphology of the facial skull in conjunction with an appropriate method of analysis can provide this information.

This methodology is referred to as “incisor tooth position analysis” and plays an important role in the process of treatment planning. Anterior tooth position analysis provides the link between cephalometric analysis and plaster model analysis. The connection is based on identifying the incisal edges of the lower incisors, which are clearly visible on both the radiograph and the model (Fig. 145). In this specific case, at the end of the treatment, an ANB of 5.2° and a $PgNB_{mm}$ of 1.3 mm are expected. The position of the mandibular incisors as measured on the radiograph is 4.5 mm. By inserting it into the formula or the nomogram on page 93, the calculated value is 6.1 mm. This calculated value is 1.6 mm larger than the actual measured value. The anterior border thus lies in front of the current incisor position by this amount (Fig. 145).

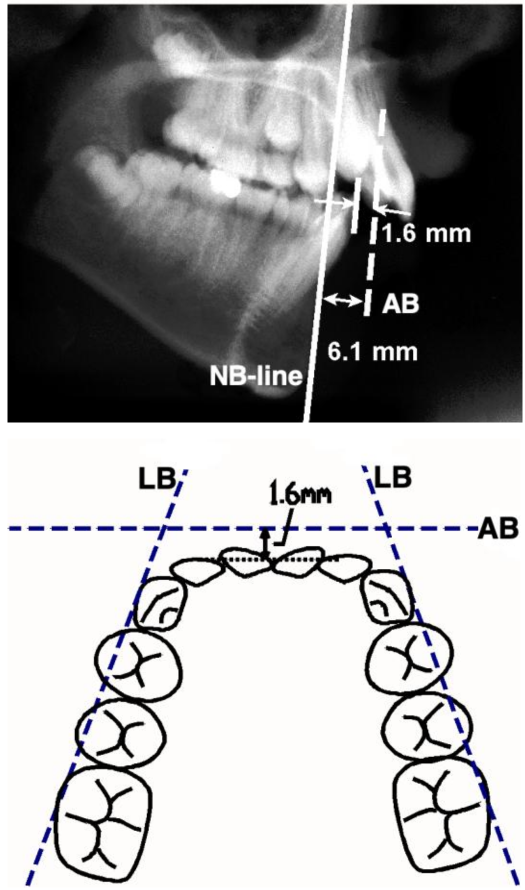


Fig. 145 At the top,, the anterior border is drawn on the lateral cephalogram. Below, a drawing indicates the borders within which the mandibular arch must be placed.
AB = anterior border; LB = lateral borders

While the lateral cephalogram provides information on where the anterior teeth should be positioned in relation to the maxillary and mandibular bases, the model analysis subsequently shows where the incisors should be moved to. Also, whether the space available is sufficient or if IPR or extraction is necessary. However, the model analysis alone

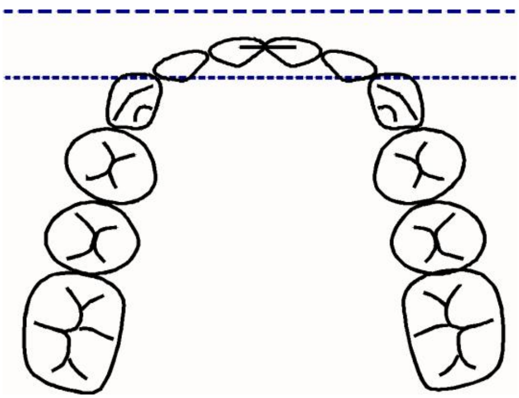


Fig. 146 Dental arch with anterior border vestibular of the anterior teeth (dashed), and lingual of the anterior teeth (dotted). In the first case, protrusion is permitted, in the second case, retrusion is required

is not a sufficient basis for these important decisions.

The analysis or prediction of the anterior tooth position is performed on an individual basis with the expected skeletal values in mind. The difference between the calculated value (target position) and the measured value (⊤-NB_{mm} from the lateral cephalogram – the actual position) determines where the anterior border lies. The dashed line in Fig. 146 shows an example in which the target position is anterior to the actual position of the anterior teeth. In this case, the value calculated using anterior tooth position analysis is larger than the measured value; the anterior teeth may thus be protruded and the additional space used for other purposes.

However, there are also cases where the anterior border lies lingual to the actual position of the lower incisors (dotted line in Fig. 146). In these cases, the value calculated in the anterior tooth position analysis is smaller than the measured value ⊤-NB_{mm}. Then the incisors must be retruded. This requires roughly 2 mm of space per millimeter of retrusion. Under certain circumstances, this space requirement can be met by using existing space surpluses, but often these are insufficient. Then the required space must be created, either by inter-proximal enamel reduction or by extracting teeth.

Instances in which the incisors may be protruded can also cause problems. It is often favorable for the aesthetics of the lip profile if the incisors are positioned not too far lingually with respect to the anticipated end position. Failure to do so often results in narrow, retrusive lips that have an unfavorable effect on the appearance (Fig. 142). If the incisors are positioned lingually to the anticipated end position and there is no space requirement to resolve any crowding, protrusion will lead to the formation of unintended spacing due to the inevitable space gain. These spaces would then have to be closed from the posterior direction, which presents a very difficult situation regarding anchorage. Without specific anchorage measures, such as inter-maxillary class II elastics, a Delaire mask, or bone supported anchorage, there is a risk of unwanted, recurrent retrusion of the incisors. Such situations usually occur in conjunction with teeth that are congenitally missing or too small in size. It is clear from the above that treatment involving complete space closure can be problematic; a space opening with subsequent auto-transplantation, implantation, or prosthetic restoration may be more appropriate.

The space analysis is performed only in the mandible. If it is possible to establish an ideal dental arch within the given borders of the mandible, it is also possible to achieve a harmonious dental arch in the maxilla. The connection between the upper and lower jaws is made via the Angle Class I relationship in the canine region, which is to be aimed for in almost all cases. If there is no tooth size discrepancy between the mandibular and maxillary teeth and the axial inclinations of the upper incisors are correct, a proper occlusal relationship is produced (automatically). If it is not possible to easily arrange the canines in Class I due to insufficient growth or a severe Class II occlusion, extractions for bite correction or orthognathic surgery will be necessary. It is always sufficient to perform the space analysis in the mandible only. An "isolated crowding" in the maxilla is usually a sign of a malocclusion in the sagittal plane. It is due to either an Angle Class II div 2 or a loss of space due to caries in or premature loss of primary molars . This brings a reduction of the arch length in the maxilla, resulting in a different Angle Class for the molars and canines. If this sagittal problem is solved and the canine relation is correct, a correct alignment of the anterior teeth will be obtained. It is therefore sufficient if the link between the dental models and the lateral cephalogram is established using lower incisal edge position as the reference.

Another possible application of the anterior tooth position analysis is the examination of the incisal position at the beginning of the treatment. For this purpose, the current measured values for ANB and $PgNB_{mm}$ are used in the regression equation. From the comparison of the actual and the anticipated position, it is possible to draw conclusions as to whether the patient shows an atypical incisor position at the beginning of the treatment. Such an atypical position is often caused by a habitual dysfunction such as thumb sucking, lip sucking, tongue thrusting, or by increased tension of the perioral musculature. These diagnostic findings provide information on the stability that can be expected after growth has been completed. If, for example, from the very beginning of treatment the incisors are situated considerably more lingually than the anticipated position suggests, an increased muscle tone of the perioral musculature or dysfunction of the lower lip may be the underlying cause. In the first case, an increased overbite with retroclined maxillary anterior teeth would be expected, whereas in the second case, a large overjet could occur.

G. Clinical examples, treatment approaches and results

1. Angle-Class II div 1

Figure 149 shows an 8-year-old boy. The initial diagnosis reveals an Angle Class II div 1 malocclusion in the mixed dentition. There is a distal malocclusion of ½ premolar width on the right side and of a whole premolar width on the left. Additionally, an overjet of 6 mm is present (Fig. 150). The analysis of the lateral cephalogram reveals the following:

Fig. 149 Patient J.K. before the treatment 8 $^1/_2$ years of age

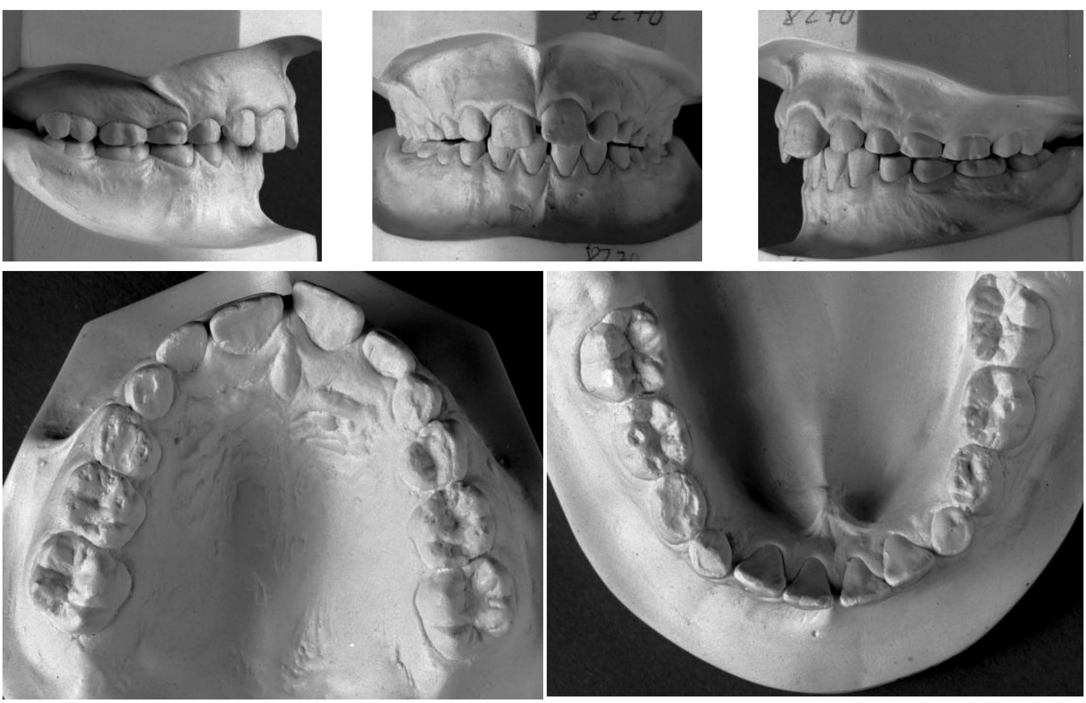


Fig. 150 Initial casts of patient J.K.

Fig. 151 Cephalometric X-ray before the treatment

Tab. 7 Cephalometric measurements

	8,5 years
SNA	75.7
SNB	70.6
ANB	5.1
SNPg	72.4
NSBa	134.6
Me-tgo-Ar	120.7
ML-NSL	34.7
NL-NSL	10.5
ML-NL	24.2
H-angle	12.1
Nasolabial angle	120.8
⊥ - ⊤	128.9
⊥-NA°	23.9
⊤-NB°	22.1
⊥-NA$_{mm}$	5.2
⊤-NB$_{mm}$	3.1
PgNB$_{mm}$	3.3
N-Sp'	51.8
Sp'-Gn	60.3
Index	85.9

Facial Type

The harmony line in the Harmony Box (Fig. 153) shows that the facial type is only slightly disharmonious and retrognathic. The values for the maxillary and mandibular prognathism are 6° to 10° less than the mean values for the orthognathic facial type.

All values except SNB are almost on a horizontal line and therefore fit together well. Only the degree of the mandibular prognathism creates some disharmony in the sagittal skeletal relationship.

Skeletal Relationshhip

Sagittally, there is an obvious distal relation with an ANB angle of 5.1° in a retrognathic face. The deviation of the value for SNB in the Harmony Box indicates that the underlying problem is in the mandible. In order to localize the underlying issue more precisely, the five potential causes listed on page 79 are evaluated individually: since the SNA angle fits well with the facial type, the cause cannot lie in the position of the maxilla. The inclination of the cranial base (NSBa angle) also corresponds to the expected value; a posterior displacement of the entire mandible, on the other hand, would have led to an excessively large NSBa angle.

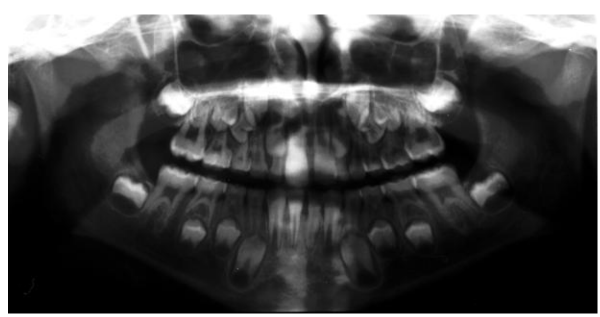


Fig. 152 Panoramic radiograph before the treatment

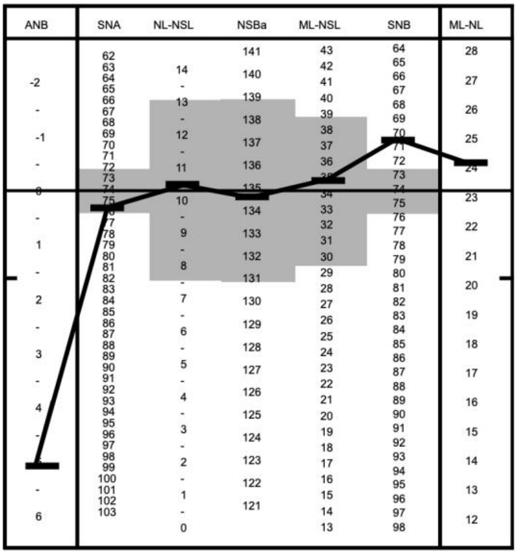


Fig. 153 Harmony Box for patient J.K.

Retroposition of the alveolar process on the mandibular base would have produced a large difference between angles SNB and SNPg and a large value for $PgNB_{mm}$. The difference of 1.8° and the chin prominence $PgNB_{mm}$ of 3.3 mm are slightly larger than expected for the patient's young age, but not large enough to speak of a distinct retroposition. Finally, the inclination of the mandible (ML-NSL) fits the facial type as well, so this cannot be the causative factor either. The only remaining reason for this distal relation of the maxillary and mandibular bases is the size of the mandible, which is too small. However, the extent of this skeletal disharmony in the sagittal plane is moderate so that no major problems are expected, especially since the patient still has considerable growth potential.

In the vertical plane, there are neutral relationships both with respect to the Index of anterior facial heights and with respect to the ML-NL Interbase angle in relation to the facial type. The values for NL-NSL and ML-NSL are exactly at the same level in the Harmony Box so that it is a case of good vertical harmony. The Index of 86% is slightly higher, but still within the normal range ("N"). It has to be taken into account that the Index is usually somewhat larger during the mixed dentition (page 65).

In summary, the sagittal and vertical relation of the maxillary and mandibular bases is favorable for orthodontic treatment, e.g., with functional orthodontic appliances.

Growth

At the age of 8½ years the patient's pubertal growth spurt has clearly not begun. Therefore, the hand-wrist radiograph is not required. A later initiation of treatment could be discussed. However, the patient had earlier suffered a trauma to the deciduous incisors. It was therefore decided to start treatment at this time to reduce the trauma risk to the permanent incisors.

Regarding the direction of growth, no extreme growth patterns are expected, so that the mean values from Table 6 may be used. It can be expected, that the ANB angle will be reduced from 5.1° to 2.2° and the $PgNB_{mm}$ value will increase from 3.3 mm to 5.0 mm. These values will be needed later to analyze the occlusion and to evaluate the profile. By resolving the lower lip dysfunction during treatment, a favorable influence on mandibular growth can be expected. In this case, the dysfunction causes not only the retroclination of the lower incisors; it also inhibits mandibular growth.

Dento-basal Relationship

At the start of treatment, neither loss of space in the deciduous molars nor crowding is present (in the dentition). A prediction of the widths of the permanent teeth (canine to 2nd bicuspid; e.g. Gross 1990) suggests that no crowding will occur in the lateral segments as a result of the change in the dentition. This raises the question of whether the lower incisors are in a stable position or whether they have to be retruded to prevent future crowding.

For this purpose, the values for the skeletal variables ANB angle and $PgNB_{mm}$ (2.2° and 5.0 mm, see above) that are anticipated at the end of treatment or growth are inserted into the regression equation on page 94:

$$\top\text{-}NB_{mm} = 0.50 \cdot 2.2 - 0.35 \cdot 5.0 + 3.9$$

The result of $\top$-NB_{mm} = 3.3 mm can also be obtained by applying the nomogram on page 95 (Fig. 154).

The value for ANB (2.2°) is found on the lower axis (1). From there, a vertical line is drawn up to the 5 mm line of $PgNB_{mm}$ (2). From the intersection with the 5 mm line, horizontally to the left the anticipated value of $\top$-NB_{mm} is found on the Y-axis (3).

Before starting the treatment, the lower incisors are 3.1 mm in front of the NB line. Since the calculated value of 3.3 mm for after treatment and growth is slightly larger than the measured value before treatment, the incisors could be protruded by 0.2 mm during the treatment. In practice, such a small movement is neither controllable nor relevant. Therefore, the position of the lower incisors should not be changed in this case.

When the initial position of the incisors is evaluated considering the ANB angle and the $PgNB_{mm}$ value at the beginning of the treatment, it becomes clear that they are positioned 2 mm lingually from the anterior border. A lip dysfunction is often associated with an increased overjet and may be one of the underlying factors. The fact that the same incisor position (3.1 mm) is described as relatively lingual at the beginning of treatment but can be described as

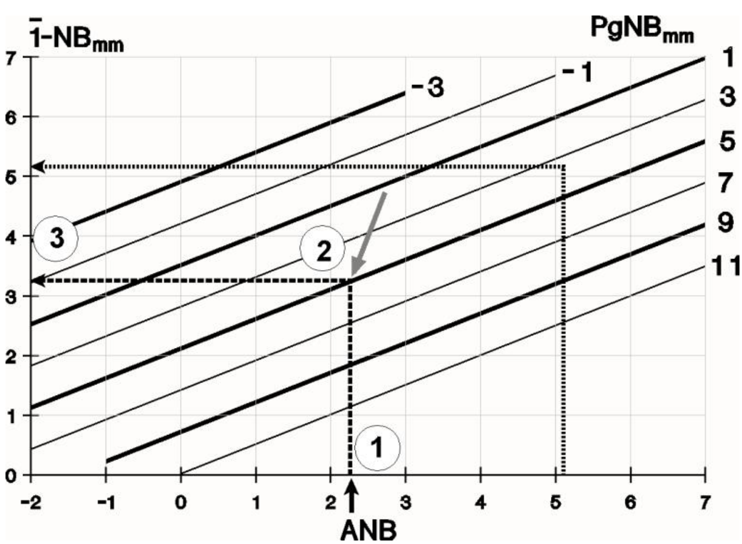


Fig. 154 Determination of the anterior border with the nomogram. The dashed line represents the border at the end of growth, the dotted line represents the border at the beginning of treatment

ideal when growth is completed, may be explained by the growth-related changes in the morphology of the facial skull. Due to the relatively more pronounced growth of the mandible, the lower incisors can be expected to end up in this more retruded position.

Neither the position nor the inclination of the upper incisors nor the Interincisal angle has an unusual value that would require special attention. These values should not be influenced by the treatment in an unfavorable way. It is therefore important to avoid undesirable side effects of potential treatment appliances (protrusion of the lower front teeth, retrusion of the upper front teeth).

Soft Tissue Profile

The patient shows an H-angle of 12° and a Nasolabial angle of 121°. Both values are not unusual for a patient of this age. The H-angle is expected to decrease with both growth and the non-extraction treatment with a functional appliance. It is likely to end up close to the aesthetically ideal value of 8° when growth is completed. Using the regression equation on page 96, an H-angle of 6.2° can be expected for the anticipated skeletal condition after the completion of treatment and growth. Application of the nomogram on page 97 provides the same result.

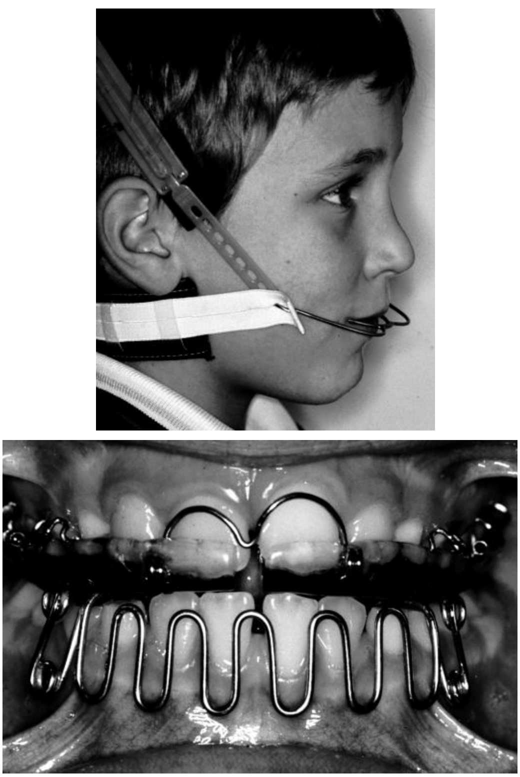


Fig. 155 Treatment appliance: Bimaxillary Hansa appliance with combination pull headgear

Fig. 156 Lateral cephalogram after 6 months of initial treatment with Hansa appliance

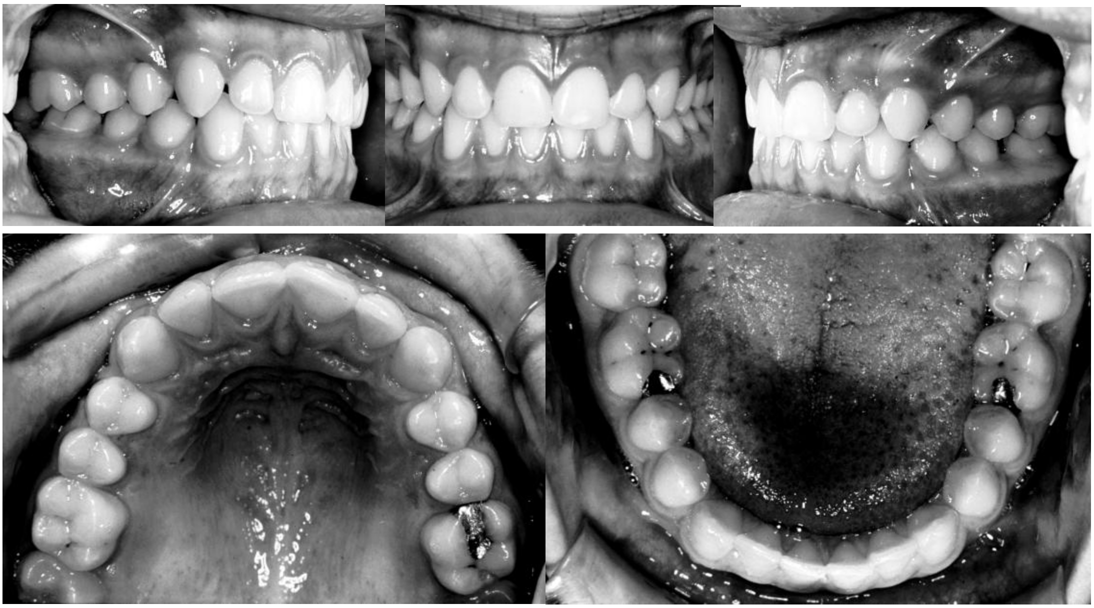


Fig. 157 Intra-oral situation at the end of treatment

Regarding the soft tissue profile, no difficulties are expected so that treatment with a functional appliance would have a beneficial effect.

Treatment Concept

Since the space analysis of the mandible showed no space deficit while the patient still has a high growth potential, a non-extraction treatment should be planned. To achieve Angle Class I occlusion, a functional appliance is used; in this case the bimaxillary Hansa appliance with extra-oral anchorage was chosen (Fig. 155). Since there are no deviations in the vertical plane, the direction of the extra-oral pull is directly to the posterior parallel to the occlusal plane. In practice, this is achieved by a combination of occipital and cervical pull ("combination pull") (Fig. 155).

Since the problem in the sagittal plane is due to the undersized mandible, it would be also possible to

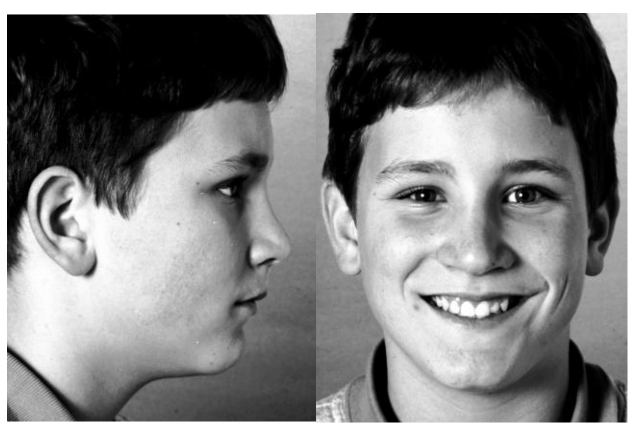


Fig. 158 Patient J.K. after treatment. 12 years of age

use an orthodontic appliance without extra-oral anchorage. This would result in a greater effect on the mandible, although a longer treatment time would be expected. In the present case, the headgear was worn for about six months at the beginning of treatment until an Angle Class I occlusion was achieved (Fig. 156). After that, the appliance was worn without extra-oral anchorage in order to stabilize the treatment results.

Once a stable occlusion has been achieved, the eruption of the permanent dentition is monitored; in most cases, this can be done without the use of an appliance. Following or shortly before the completion of the permanent dentition, the decision is made on whether or not fine-tuning of the occlusion is required. If so, it is done in a short treatment phase with a fixed appliance.

Figure 157 shows the occlusion after a ten-month fine tuning with braces only in the maxilla. Figure 160 shows a superimposition of the cephalometric tracings made at the beginning and at the follow-up visit after achieving the Class I occlusion. It is evident that during the initial treatment, maxillary growth in the anterior direction was prevented and the molars were distalized. At the same time, the mandible developed in an anterior-posterior direction, enabling the Class I alignment. In the following treatment phases with braces and during retention, both jaws showed further growth in the anterior-posterior direction.

Fig. 159 Cephalometric image at the follow-up visit

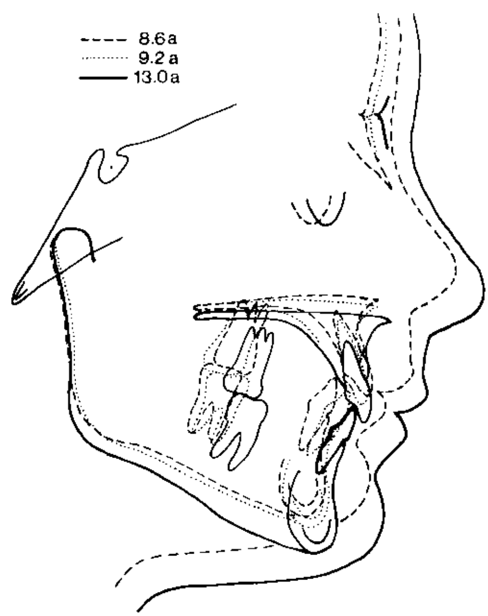


Fig. 160 Superimposition of the tracings before treatment, after initial treatment and after the end of treatment

2. Angle-Class II div 2

Figures 162 and 163 show the lateral cephalogram and panoramic X-ray of the patient L.K. (Fig. 161). The intra-oral situation is shown in Fig. 164. The initial diagnosis shows an Angle Class II div 2 malocclusion. Due to the initial diagnosis, the clinician should pay particular attention to the skeletal relationships in the vertical plane and the tooth position.

The cephalometric measurements in Tab. 8 and the Harmony Box (Fig. 165) allow the following assessment:

Fig. 161 Patient L.K. before treatment. 12½ years of age

Facial Type

This is an example of a disharmonious facial type. The prognathism and the inclination of the maxilla are harmonious, but the mandible is disharmonious both in itself and in relation to the cranial base and the maxilla.

Fig. 162 Cephalometric radiograph before treatment

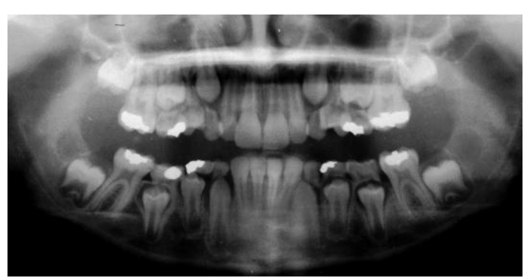


Fig. 163 Panoramic radiograph

Fig. 164 Initial intraoral images of patient L.K.

Basal Relationship

In the sagittal plane, a distal relation with mandibular retrognathia is clearly present (the value for SNB deviates from the Harmony line). The value of 7.1° for the ANB angle is too large for this facial type. However, it should be noted that in this specific case, due to the extreme retroclination of the maxillary incisors, the A point appears to be more anterior than would be representative for the maxillary base. This is due to the "bulging" of the vestibular cortical bone covering the roots of the maxillary central incisors. Therefore, in this case, it is reasonable to assume that the sagittal relationships of the maxillary and mandibular bases are somewhat more favorable than the numerical values suggest.

In the vertical plane, there is a slight reduction in the lower anterior face height; the Index of 88% is still in the "N" range, but it is close to the "D" range. The ML-NL interbase angle is also on the borderline between neutral ("2") and too small ("3"). The inclination of the mandible is responsible for the deviation. To summarize, the vertical relation can be described as $N3_{mand}$.

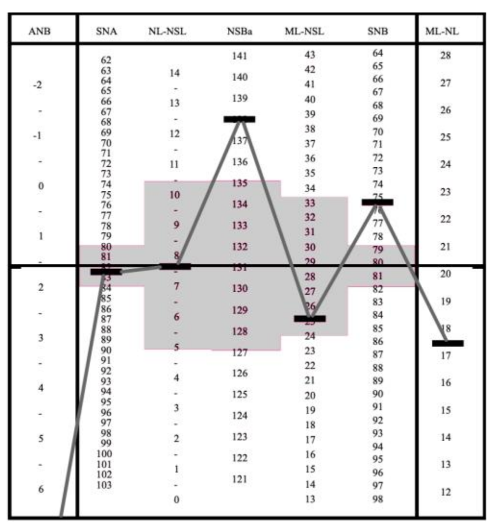


Fig. 165 Harmony Box

Tab. 8 Cephalometric measurements: in the column to the right are the values after protrusion of the incisors.

	12,5 y	13 y
SNA	82.5	
SNB	75.4	
ANB	7.1	
SNPg	78.8	
NSBa	138.0	
Me-tgo-Ar	118.1	
ML-NSL	25.2	
NL-NSL	7.7	
ML-NL	17.4	
H-angle	16.4	
Nasolabial angle	100.5	
⊥-⊤	165.7	138.6
⊥-NA°	- 6.6	+ 20.4
⊤-NB°	13.9	
⊥-NA_{mm}	- 4.9	+ 3.6
⊤-NB_{mm}	1.0	
$PgNB_{mm}$	6.1	
N-Sp'	49.7	
Sp'-Gn	56.5	
Index	88.0	

Although the existing skeletal relationship cannot be described as favorable, considerably more unfavorable situations are often seen in Class II div 2 cases. The interbasal angle, in particular, may well be less than 10°, and it is not uncommon for the Index to exceed 100%.

Growth

The patient is a 12 ½ year-old boy. Based on his age and developmental status (voice pitch, body size), a significant growth potential can still be expected. A hand-wrist X-ray was not taken.

The facial morphology does not suggest an extreme growth pattern. Therefore, the prognosis of the anticipated values for ANB and $PgNB_{mm}$ at the end of growth can be made using Table 6 in Chapter E. Under the assumption that treatment is carried out with functional orthodontic appliances, the expected values are 5.5° for ANB and 7.3 mm for $PgNB_{mm}$ Since during the treatment, among other things, the inclination of the of the upper incisors is going to be corrected, it can be expected that the "bulge" caused by their roots in the area of the A point will disappear. This reduces the expected value for the ANB angle by a further 1°, resulting in a value of 4.5°. These values are used in the further analysis of tooth position and soft tissue.

Dento-basal Relationship

The present situation with an interincisal angle of almost 166° clearly shows an excessive overbite combined with retroclined incisors. The inclination of the long axis of the upper incisors in relation to the NA line is –6.6°, significantly lower than usual. By inserting the expected values for ANB and $PgNB_{mm}$ into the regression equation regarding the position of the mandibular incisors or by graphical evaluation in the nomogram (Fig. 106), the target value is obtained: the mandibular incisors should be 3.6 mm anterior of the NB line at the end of the treatment. Since they are only 1.0 mm in front of the NB line at present , they may be protruded by 2.6 mm during treatment.

The 2.6 mm of potential protrusion could produce a space gain of about 5 mm, which can be used to eliminate crowding or to solve other issues requiring space. In this case, in addition to resolving the existing crowding, space is needed to level the curve of Spee and eliminate the flaring of the lower incisors.

According to the equation on page 94, the anticipated individual interincisal angle can be obtained as follows:

$\perp$-$\top$ = 7.3 mm · 1.59°/mm + 129.3° = 140.9°

Since the current interincisal angle is 166°, it should be reduced by approximately 25°. The protrusion of the mandibular anterior teeth will increase the inclination of the lower incisors by approximately 8°. Accordingly, the upper central incisors should be protruded by around 20°. Due to geometry, the interincisal angle is increased by the reduction of the ANB angle (see page 94). The 8° protrusion in the mandible, the 20° protrusion in the maxilla and the 2.6° reduction of the ANB add up to the 25° required reduction of the interincisal angle. Approaching the treatment with appropriate care, a protrusion of this amount should be feasible in this case without any problems.

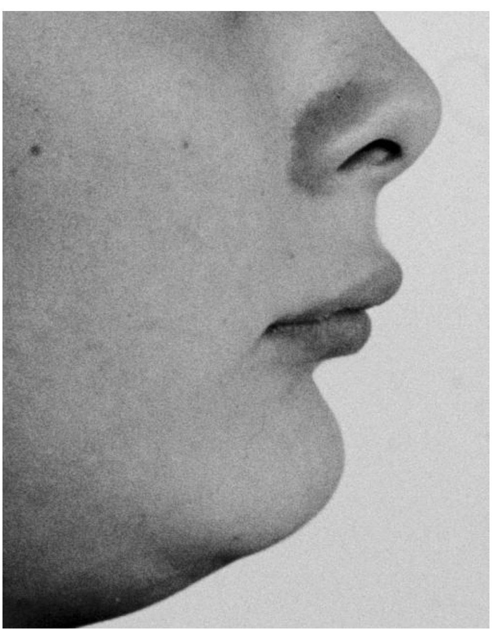


Fig. 166 Lip profile before treatment

Protrusion of the upper incisors should preferably be performed at the beginning of treatment, since the treatment with functional appliances is only possible after an overjet has been created. The Angle Class II div 2 malocclusion is first transformed into a Class II div 1 malocclusion and then treated accordingly.

Soft Tissue Profile

After completion of growth, the expected facial morphology would have an H-angle of 5.5° (see nomogram in Fig. 107). Currently, the H-angle is 16° and the Nasolabial angle is 100.5°. However, it must be taken into account that, due to the compression of the lips, the upper lip point appears further anteriorly than would be representative (see Fig. 166). After normalization of the tooth position, a reduction of the H-angle and an increase of the Nasolabial angle can be expected (Fig. 168).

The planned treatment would actually increase the H-angle in the first step (protrusion of the upper incisors and to a smaller amount the upper lip). In this case, the elimination of the lip compression will eliminate the protrusion effect. The following interventions (functional appliance) in combi-

Fig. 167 Utility arch for protrusion of the upper incisors

nation with growth will then significantly reduce the H-angle. A favorable development of the soft tissue situation can be expected.

Treatment Concept

Since growth potential is still present and there is a skeletal deviation in both the sagittal and vertical planes, the use of a functional appliance is strongly indicated, if possible in conjunction with a headgear. Even if an Angle Class I occlusion is not fully achieved in this way, there will nevertheless be a favorable influence on the skeletal harmony and the profile. It also brings a significant reduction of the extent and duration of the subsequent treatment with fixed appliances. Before a functional appliance, in this case a bimaxillary Hansa appliance, can be placed, the retroclined upper incisors must be corrected. For this purpose, the maxillary anteriors are first proclined with a small, fixed appliance (utility arch) or a protrusion plate (Fig. 167).

Fig. 168 Cephalometric image after the protrusion of the upper incisors.

In this case, a bimaxillary Hansa device is used after protrusion of the upper incisors by 8.5 mm or 26° (Figs. 168, 169). Due to the deep bite and the insufficient interbase angle, the Hansa appliance is combined with extraoral pull in the occipital direction, which is attached to the anterior region of the appliance. This mainly influences the inclination of the maxilla, even though the inclination error lies mainly in the mandible. However, as explained in the previous chapter, it is almost impossible to skeletally influence the vertical position of the mandible . For this reason, the treatment attempts to improve the inclination of the maxilla and thus the vertical harmony. The direction of the force vector also favors dentoalveolar bite opening by anterior intrusion. Furthermore, the grinding of the appliance's posterior bite plane allows free molar extrusion for a further bite-opening effect.

The case is then re-evaluated after 6 to 15 months. In principle, there are now two possibilities:

1. The combined skeletal and dentoalveolar effect of the functional appliance has been sufficient to establish an Angle Class I occlusion. Then only fine tuning of the occlusion in a relatively short treatment phase with fixed appliances will be necessary. A treatment phase with braces will be necessary to achieve the correct axial inclination of the upper incisors with a lot of torque. Braces are also needed for good vertical adjustment with the leveling of the curve of Spee and the correction of flared lower anterior teeth.

2. The combination of skeletal and dento-alveolar effects from the functional orthodontic appliance has not been sufficient to establish a proper Angle Class I occlusion. In this case, it becomes necessary to extract two bicuspids *in the maxilla only* to bring the canines into a proper Class I occlusion while the first molars are positioned in Class II. Due to the effects of the functional appliance, in most cases it will be sufficient to distalize the canine by about ½ premolar width, which allow reciprocal space closure.

   The equally conceivable extraction of four bicuspids would have the advantage that the molars could also be brought into Class I. However, there are several disadvantages: the treatment complexity and duration are significantly higher. Since the tooth position analysis has shown that the lower front teeth don't need to be retruded, the extraction spaces in the mandible would have to be closed completely from the distal. This is necessary to avoid an unfavorable, unstable interincisal angle and an unfavorable influence on the lip profile. This results in an extremely difficult anchorage situation, which could probably only be solved by using extraoral, frontal anchorage (Delaire mask). Lastly, the task of bite-opening in the vertical plane would be much more difficult.

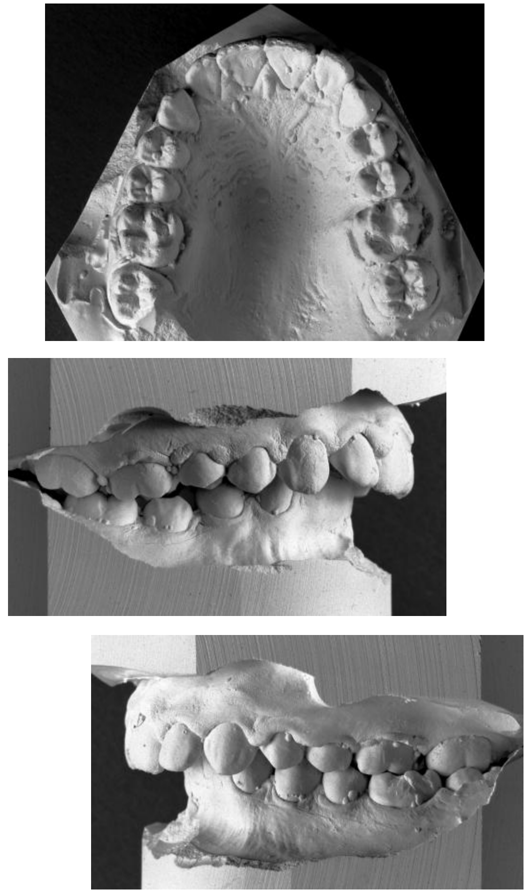


Fig. 169 Dental situation after protrusion of the incisors. Treatment with functional orthodontic appliance can now be started.

The retention phase following the treatment with the fixed appliance is also influenced by the cephalometric analysis. Due to the deep and distal basal tendency, a slight deepening of the bite after treatment cannot be ruled out completely. The anterior rotation of the mandible due to residual growth has a bite-deepening effect. To counteract this, the use of a retention activator with a moderate construction bite, which allows the vertical eruption of the molars and premolars (by grinding the acrylic accordingly), is recommended in the present case.

3. Angle-Class I, adult patient

The third case shows an adult patient (age 25). The intra-oral examination (Fig. 171) shows the initial diagnosis of an Angle Class I with severe crowding in both jaws. The cephalometric records show the following picture:

Facial Type

A disharmonious, retrognathic facial type is present. The disharmony originates from the excessively anterior inclination of the maxilla; all other measurements fit together quite well.

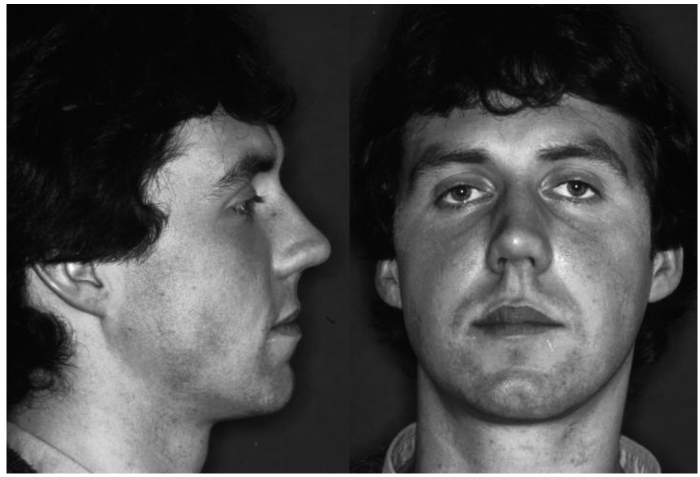


Fig. 170 Patient H.K. before treatment. 25 years of age

Fig. 171 Initial intra-oral images of patient H.K.

Fig. 172 Cephalogram

Basal Relationship

The sagittal relationship of the maxillary and mandibular bases is still neutral with an ANB of 2.1° in a moderately retrognathic face. The expected value for ANB in this face type would be 0.3°. The vertical relation is defined as N1max. The Index of 76% is well within the normal range. While ML-NSL is only slightly larger than expected, the NL-NSL angle deviates significantly from the Harmony Line. The resulting interbase angle ML-NL is clearly too large for this face. However, since the Index is neutral and the defective inclination lies in the maxilla, the case should be quite manageable orthodontically, even though the risk of an undesired bite opening during treatment must be taken into consideration.

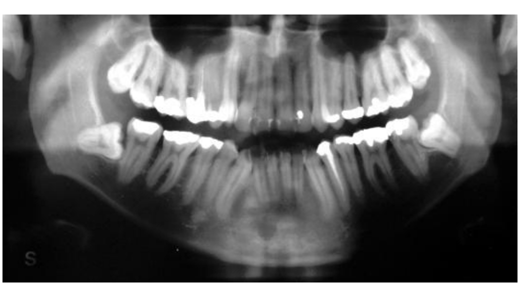


Fig. 173 Panoramic radiograph

The large interbase angle would suggest extracting teeth, especially if the space closure can be done from the distal direction, at least to some extent. Due to an "inverse wedge effect", the mandible can then rotate anteriorly, which would reduce the Interbase angle and close the bite.

Growth

Since this is an adult patient, there will be no significant growth-related changes in skeletal morphology. Any rotation of the mandible in the anterior direction as a result of potential extraction therapy is not significant enough to require consideration.

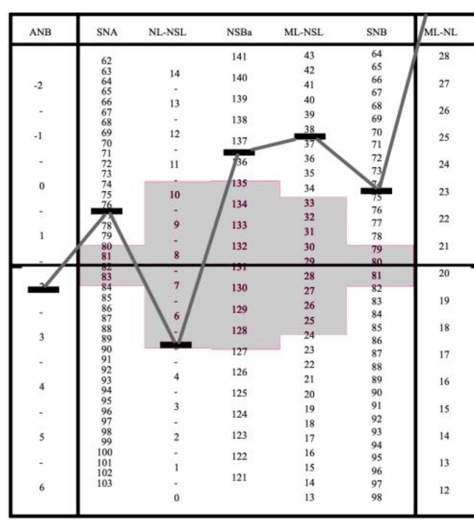


Fig. 174 Harmony Box

Tab. 9 Cephalometric measurements

	25 years
SNA	76.8
SNB	74.7
ANB	2.1
SNPg	76.7
NSBa	136.4
Me-tgo-Ar	121.2
ML-NSL	37.4
NL-NSL	5.0
ML-NL	32.4
H-angle	6.1
Nasolabial angle	114.1
⊥-⊤	138.0
⊥-NA°	18.4
⊤-NB°	21.5
⊥-NA$_{mm}$	4.2
⊤-NB$_{mm}$	4.3
PgNB$_{mm}$	4.6
N-Sp’	59.3
Sp’-Gn	78.1
Index	75.9

Dento-basal Relationship

The main question here is whether the existing crowding can be resolved by expansion or whether it will be necessary to perform interproximal reduction ("stripping") or the extraction of premolars. There is a space deficiency of around 10 mm. Since the inter-canine distance cannot be changed in a stable manner, a protrusion of about 5 mm would be required to solve the space deficiency in the mandible. Inserting the measured values (ANB 2.1° and PgNB$_{mm}$ 4.6 mm) into the regression equation for the analysis of the tooth position or into the corresponding nomogram gives a value for ⊤-NB$_{mm}$ of 3.3 mm as the anterior border for the lower dental arch. Since the incisors are at 4.3 mm before treatment, there cannot be any protrusion; in fact, 1 mm of up-righting towards the lingual must be performed in order to remain within this anterior limit. In addition to the 10 mm space deficiency due to crowding, this requires an additional 2 mm of space. The resulting total space requirement of 12 mm can only be met by extracting teeth. In this case, the first bicuspids may be extracted, since they are the closest to the crowded area, which minimizes the total amount of tooth movement. The resulting combined spaces of about 15 mm must be closed almost completely from the anterior. This requires maximum anchorage; a reciprocal gap closure is not sufficient in this case. Furthermore, we cannot use the mesialization of molars to reduce the oversized ML-NL interbase angle or to lower the bite.

The interincisal angle prior to treatment is roughly equivalent to the expected value of 137°. The only thing that needs great care during treatment is to ensure that the axial inclination of the incisors does not change in an unfavorable manner.

Soft Tissue Profile

The patient shows an H-angle of 6.1° and a Nasolabial angle of 114° prior to the start of treatment. For the skeletal morphology, an H-angle of 6.6° is expected so that there is hardly any deviation in either the H-angle or the Nasolabial angle. In this case the treatment option involving the extraction of four bicuspids likely will not lead to a noticeable change in the soft tissue profile since the incisal edges are moved only minimally (retrusion of 1 mm). The extraction spaces are closed by resolving the crowding. Only if, after resolving the crowding, residual spacing was eliminated from the front, a slight retrusion of the incisors with a minor flattening of the lip profile could result. Hence, in this case, the soft tissue analysis does not reveal any contraindications for the planned extraction treatment.

Treatment Concept

To ensure maximum anchorage of the molars in both jaws, lingual arches are cemented in both the maxilla and the mandible (Fig. 175). In this context, we refer to the palatal arch that rests against the palatal surfaces of the maxillary teeth as a lingual arch as well. After extraction of four bicuspids (15, 24, 34, 44; 15 endodontically treated!) and the wisdom teeth, the canines are distalized and the crowding of the anterior teeth is then resolved. Any extrusion of molars and premolars must be avoided. To maintain the Angle Class I and to exert vertical control, the patient wears an occipital pull headgear at night. The intruding component of the occipital pull provides intrusion of the upper molars with a bite-lowering effect.

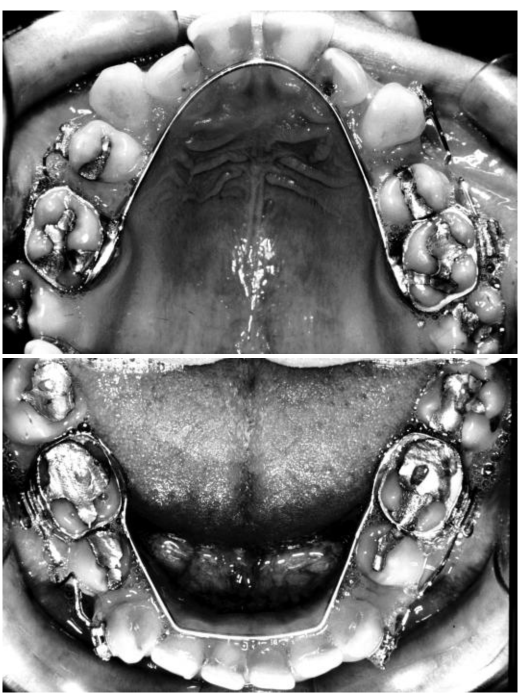


Fig. 175 To ensure space closure from the mesial direction (maximum anchorage), lingual arches were placed in both the mandible and maxilla.

Fig. 176 Cephalometric image after retention

After adjusting the occlusion, a custom-made positioner may be beneficial as a retention device for patients who had an open bite or an open skeletal configuration. The suction effect, especially on the anterior teeth, results in good retention of the vertical position while also enabling settling and improving intercuspation.

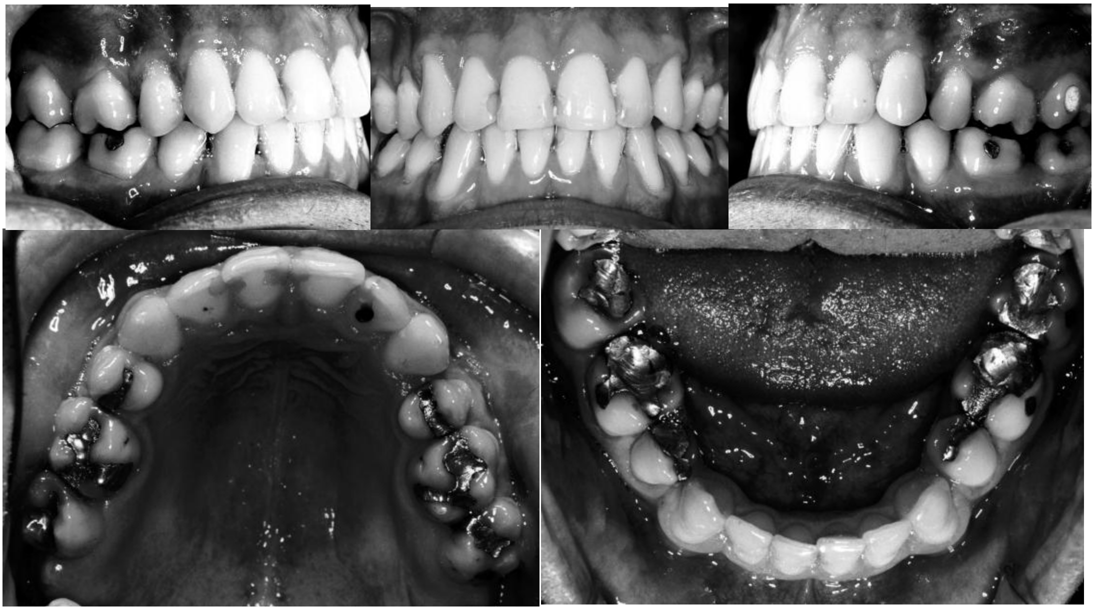


Fig. 177 Dental situation after retention

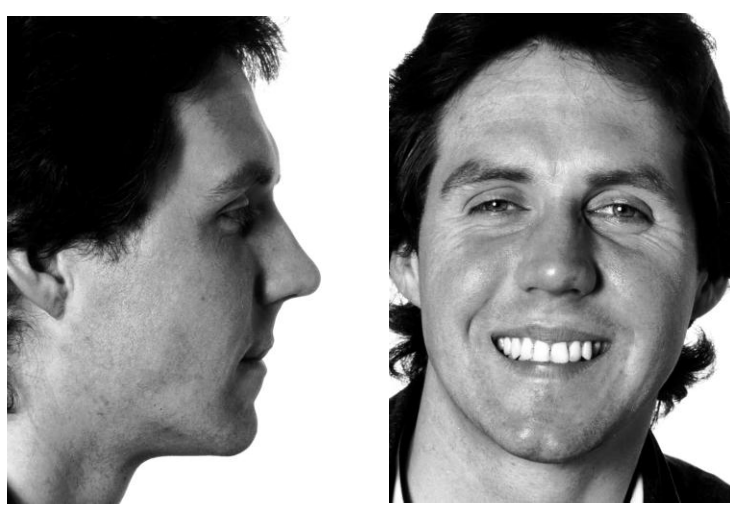


Fig. 178 Patient H.K. after the treatment

4. Angle-Class III

The last case shows an adult patient (age 23 years) who presents a mesial relationship of the jaws even from an extra-oral perspective (Fig. 181). The intra-oral findings (Fig. 182) are the basis for the initial diagnosis of Angle Class III with moderate crowding in both jaws. The cephalometric records reveal the following picture:

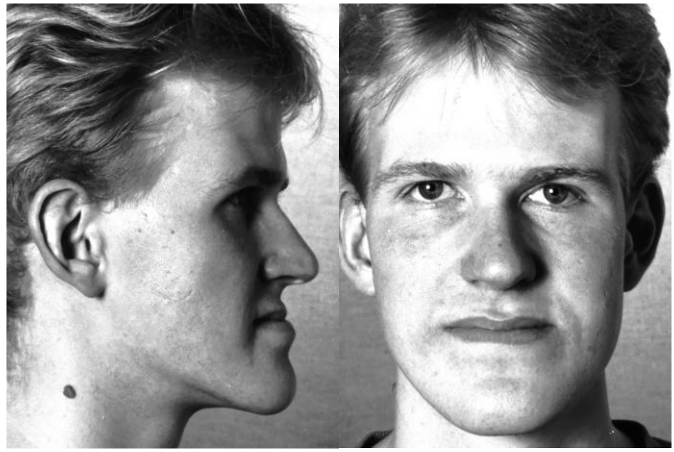


Fig. 181 Patient B.S. before the treatment. 23 years of age

<u>Facial Type</u>

The Harmony Box shows a strongly disharmonious and clearly prognathic facial type. There is disharmony both in the sagittal and vertical planes. The inclinations of the individual jaws do not match the corresponding degrees of prognathism.

Although the SNA angle is 5° greater than the mean value for the general population, the Harmony Box clearly shows that the patient has a retrognathic maxilla in a markedly prognathic facial type.

Fig. 182 Initial intraoral images of patient B.S.

Fig. 183 Lateral cephalogram

Basal Relationship

An ANB of -8.2° indicates a strong mesial relationship of the mandibular base in the sagittal plan. The large discrepancy results from the combination of a maxillary retrognathia (SNA is too small for this facial type) with a strong mandibular prognathism (SNB is too large). The sagittal skeletal discrepancy is even more severe when considering the individual optimal ANB angle for this prognathic patient. The Harmony Box in Fig. 185 shows an optimal ANB of +4.4° for this patient. The total skeletal deviation is thus -12.6°.

Vertically, an open configuration "O1" is present. The Index of 69.7% indicates a significantly increased lower facial height, while the interbase angle ML-NL is far too large for the given facial type. The deviation is mainly due to a posterior tilt of the mandible. Thus, this is an "$O1_{mand}$"-case.

Each jaw on its own represents an unsolvable task for the orthodontist in both the sagittal and the vertical planes. Together the two make the decision to treat the patient

Fig. 184 Panoramic radiograph

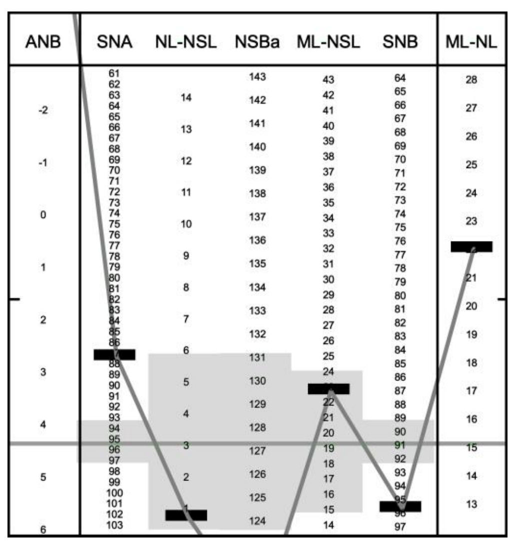


Fig. 185 Harmony Box

Tab. 10 Cephalometric measurements

	20 years
SNA	87.4
SNB	95.7
ANB	-8.2
SNPg	98.2
NSBa	119.8
Me-tgo-Ar	125.0
ML-NSL	22.7
NL-NSL	0.7
ML-NL	22.0
H-angle	-5.1
Nasolabial angle	98.3
⊥-⊤	143.3
⊥-NA°	29.7
⊤-NB°	15.3
⊥-NA_{mm}	6.3
⊤-NB_{mm}	0.4
$PgNB_{mm}$	5.1
N-Sp’	50.1
Sp’-Gn	71.9
Index	69.7

with a combined orthodontic and orthognathic surgery treatment seem straightforward.

Growth

Although the patient is fully grown, the skeletal morphology will be significantly altered by the orthognathic surgery. These changes must be considered during orthodontic treatment planning.

Soft Tissue Profile

The H-angle is -5.1° prior to the start of the treatment and the Nasolabial angle is 98.3°. In this case, there is no point in calculating the individually anticipated H-angle by applying the regression equation on page 96. An H-angle of -5.1° is definitely too small because it is aesthetically unfavorable. This fact is a further indication for orthognathic surgery.

The soft tissue profile is influenced much more strongly by the surgical interventions than by the orthodontic treatment measures. That is why the planning of the soft tissue changes should be done by the team of orthodontists and maxillofacial surgeons. The relevant principles and guidelines are described in the literature.

Dento-basal Relationshhip

The dento-basal relationship plays a paramount role for the orthodontist when planning orthognathic surgery cases. In order to be able to analyze the tooth position, the values for the skeletal relationships that are to be anticipated after the completion of surgical treatment are required – as in the cases of growing patients. However, these

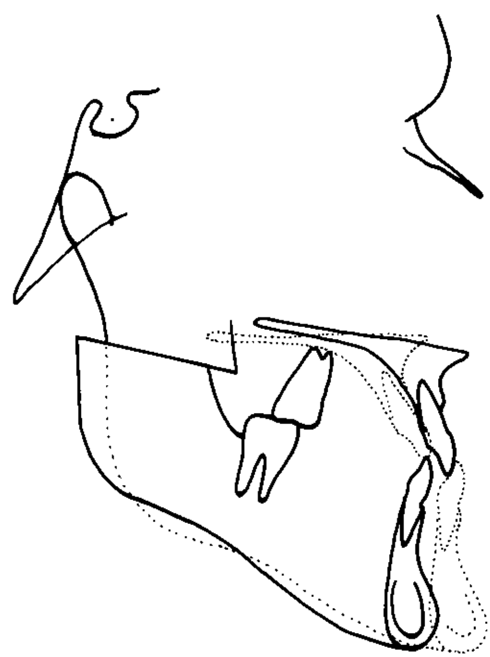


Fig. 186 Joint orthodontic and surgical planning of the orthognathic procedure (prediction tracing)

values are only attainable if the planned surgical changes are known. It is therefore essential to discuss and plan the surgical procedure and the amount of the changes with the surgeon prior to treatment. For this specific case, the treatment plan is shown in Figure 186. The skeletal values derived from this "prediction tracing" are then used as the foundation for orthodontic treatment planning.

At the end of the treatment, the ANB angle is planned to be 4.1° and the value for $PgNB_{mm}$ is to be 5.9 mm. By inserting these values into the tooth position analysis, a target value of 3.9 mm for $\top\text{-}NB_{mm}$ is obtained. Based on the actual value of 0.4 mm, a protrusion of 3.5 mm is required. Regarding the maxilla, the equation on page 93 gives a value of 1.6 mm; hence, a retrusion of 4.7 mm is required. The described combination of protrusion in the mandible and retrusion in the maxilla will increase the negative overjet making the anomaly initially worse. This treatment concept, called decompensation, is of great importance when combining orthodontic treatment with orthognathic surgery in the management of such anomalies. However, the dento-basal treatment goals become clearly apparent by applying the tooth position analysis just as in any other orthodontic case. The only difference is that the skeletal predictions are modified in the combined orthognathic treatment planning.

Fig. 187 Mandibular alveolar process: hardly any bone vestibular to the roots of the incisors.

Treatment Concept

For the correction of the skeletal malocclusion in the sagittal and vertical planes, a bimaxillary surgical procedure is required. Due to the extensive sagittal deviation and the open skeletal relationship, it must include a mandibular sagittal split osteotomy and a LeFort I osteotomy in the maxilla. Once the treatment goal for the skeletal relationships has been established, the goals and procedures of the preoperative orthodontic treatment can be defined. For this purpose, the dental arches must be aligned preoperatively, particularly with respect to their width, and the axial inclinations of the incisors must be adjusted according to the dento-basal analysis.

In this case, teeth must be extracted in the maxilla to allow retrusion of the incisors and elimination of the crowding. In the mandible, the protrusion of the incisors will create enough space to resolve the anterior crowding. Therefore, the orthodontic treatment plan for the initial treatment of this Class III case includes the isolated extraction of two bicuspids in the maxilla and the anterior-posterior positioning of the anterior teeth in the maxilla and mandible.

However, the protrusion of the lower incisors poses a problem for the orthodontist in this specific case: as can be seen in Figure 187, the alveolar process is extremely thin in the mandibular anterior region, and there is almost no bone in the vestibular region of the roots. This observation explains the clinically visible tendency to gingival recessions. For these reasons, it appears unfavorable to perform the required amount of protrusion. The alternative suggested from the orthodontic point of view is to extract one lower incisor and to carry out only a smaller amount of protrusion. When the case is discussed again with the oral surgeon, as it must be, a modified surgical concept with different values for the skeletal variables will be developed. This means that the analysis of the tooth position must be redone. This highlights the fact that the orthodontic pre-surgical treatment for such a case is not possible without first specifying the surgical treatment concept.

Fig. 189 Patient B.S. after treatment (surgeon: Prof. W.-J. Höltje)

Postoperatively, the achieved skeletal situation must be retained. This is done by applying inter-maxillary elastics (Scheuer 1993) until the orofacial soft tissues have adapted to the new situation. The subsequent fine tuning of the occlusion and orthodontic retention is only slightly different from that in conventional orthodontic treatment.

Fig. 188 Lateral cephalogram at the follow-up visit.

Fig. 190 Intraoral images at the follow-up visit

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ISBN 3-9802709-5-5