CEPHALOMETRIC X-RAY FILM ANALYSIS

OVERVIEW

X-RAY films of the head and neck (roentgencephalograms) have been used for over fifty years in clinical practice in medicine, dentistry, and to some extent in speech pathology. Cephalometric x-ray films provide a means of evaluating the interrelationships of cranial, facial, and pharyngeal structures either on a longitudinal or serial basis.

Speech clinicians have utilized lateral single-exposure (static) x-ray head films to gain information about functions and dysfunctions of the velopharyngeal mechanism. Such films have been obtained while the patient sustains a phonation of /a/, /i/, or /l/. These tasks are thought to assess the functional potential of the velopharyngeal apparatus to achieve velopharyngeal closure, as seen in the two dimensions of the lateral cephalometric x-ray projection.

The dynamics of speech are better appreciated by the adaptation of motion picture x-ray techniques (Fig. 24-1). Cine-fluoroscopy is a technique that uses an electronic image-intensifier as a means of providing continuous motion with a relatively low level of radiation exposure. The fluoroscopic tube, used as an image intensifier, provides much less radiation exposure than cineradiography (without fluoroscopy). Within the past ten years, the videofluoroscope has been utilized with an x-ray source to provide dynamic studies of the speech mechanism. A multiview technique (lateral, frontal, and basilar views) has provided important information about the dynamics of the speech process and the interrelationships of activity at various valves in the speech mechanism.

Radiographic techniques are no longer acceptable for use in human research studies. The potential hazards of excessive radiation exposure and the potential damage to various tissue organs such as the thyroid and cornea preclude x-ray use on a routine, research basis. Currently, prudent use of radiographic data is practiced by most clinicians. As a consequence, the static, lateral radiograph persists as a useful clinical means of describing presenting morphology and function or dysfunction in the speech mechanism.

Instrumental techniques other than radiography are being perfected as alternatives to radiographic study. Nasedoscopy and air-flow instrumentation are examples of equipment that is commonly used in many multidisciplinary centers to
assess velopharyngeal function and other components of the speech mechanism. Results of examinations using this equipment have revealed important insights as to the status of various parts of the speech apparatus while also providing predictive information about the development of future problems.

Overall, the speech clinician has contributed much to the understanding of the characteristics of velopharyngeal closure, coarticulation components of speaking, and speech sound characteristics as viewed radiographically.

In this chapter, selected information about the evaluation of lateral cephalometric radiographic films will be presented. The purpose is to equip the speech clinician with background information utilized in dentistry and medicine, especially orthodontics, relative to the morphologic description of a patient. Such information should be especially useful to the speech clinician working in a multidisciplinary setting, as well as being useful for evaluating selected components of the speech mechanism. The lateral, static x-ray film is used for discussion, since this is the most common radiographic data obtained in orthodontic analysis of the head and neck. Also, more normative data has been developed in relationship to the lateral film than any other radiographic view.

**BASIC EQUIPMENT**

An oriented lateral cephalometric x-ray film, as obtained in an orthodontist's office, utilizes a cephalostat or head-stabilizing device. The cephalostat and the x-ray source are positioned in a fixed relationship so that the anode of the x-ray source is five feet from the midsagittal plane of the head, or center of the cephalometer. The cephalostat immobilizes the head by ear rods. Often, a fixation arm
Figure 24-2. Schematic representation of the five-foot distance between the anode of the x-ray source and the midsagittal plane of the head in an orthodontic cephalometric x-ray setup. The patient's head is stabilized in a cephalostat, and the x-ray film cassette is positioned close to the patient's head for lateral x-ray view.

resting against the nasal bridge is also used to stabilize the head in a position in which the patient is upright, looking toward “infinity.” In the absence of nasal bridge fixation, the cephalogram obtained is said to utilize a natural head position (Fig. 24-2).

Most hospital radiology units do not have a cephalostat with a five-foot anode to mid-cephalometer dimension (Fig. 24-3). All orthodontic cephalometers, however, are based upon the standardized relationships described above. A complete description of the instrumentation is reported in a text by Broadbent, Broadbent, and Golden (1975).

TRACING CEPHALOMETRIC RADIOGRAPHS

Although “eyeballing” a radiograph is a convenient way of assessing orofacial form and some functional relationships, most often the presenting morphology of the cranial and facial area is subjected to comparative judgments. The application of normative data to an individual lateral cephalometric x-ray film is best done if the x-ray film is traced on matte acetate paper. The paper is placed over the x-ray film, and various landmarks and anatomical structures are identified or outlined with a number 2 pencil. Linear and angular measurements can be made from the tracing to assess the structures and areas under consideration.

EVALUATION OF THE CRANIAL BASE

Since the facial skeleton attaches onto the cranial base and is influenced in growth by the configuration of the base of the cranium, this is a logical place to be-
gin a lateral cephalometric x-ray film analysis. The landmarks *nasion* (N) and *basion* (Ba) serve to separate the neurocranium from the facial skeleton. Nasion is the frontonasal suture, while basion is the most anterior projection of the foramen magnum. Unfortunately, a straight line drawn from Nasion to Basion does not reveal much of value about the configuration of the cranial base. The addition of another landmark, *sella* (S), permits an angular measure to be made as an expression of the cranial base area and its relationship with the facial skeleton (Fig. 24-4).

The *cranial base angle* is formed by connecting lines between nasion, the middle of sella turcica, and basion. Normal cranial base angle (N-S-Ba) is 130 degrees, plus or minus 10 degrees. That means, of

![Figure 24-4](image.png)

**Figure 24-4.** X-ray film tracing of the cranial base area from nasion (N) to basion (Ba). The configuration of the cranial base is expressed by cranial base angle from nasion (N) to sella turcica (S) to basion (Ba). Variations in cranial base angle are shown.
course, that an individual is within the normal range who demonstrates a cranial base angle from 120 to 140 degrees. This is usually written $130^\circ \pm 10^\circ$. Consequently, a cranial base angle less than 120 degrees would indicate an acute cranial base, while one greater than 140 degrees would be considered an obtuse cranial base.

Cranial base angle does not change greatly from childhood to adult form. Some fluctuation in the S-Ba arm of the angle does change, however. Nonetheless, an individual with an acute cranial base early on maintains this pattern over time.

An acute cranial base could contribute to reduction of the nasopharyngeal space while also encouraging a forward growth tendency of the face. An obtuse cranial base angle, by contrast, would encourage a downward growth pattern of the face. This is because the temporomandibular joint (TMJ) area is positioned more posteriorly, as are other cranial structures.

There are obviously exceptions to the tendencies cited here. With respect to the velopharyngeal mechanism, for example, the amount of soft tissue in the nasopharynx (the adenoid) is an important variable contributing to the soft-tissue depth of the pharynx where the bony or osseous pharyngeal depth may be influenced by the cranial base. Accordingly, observation of the cranial base area provides a useful description of the primary attachment area for the facial skeleton and upper portion of the speech mechanism.

Finding the landmarks N and S on a radiograph are not usually too difficult. Nasion represents the most inviolated point at the frontonasal area. The middle of sella turcica is most often readily seen. The most difficult of the cranial landmarks to identify is basion.

Two methods of identifying Ba are suggested. The first is to find the odontoid process of the second cervical vertebra (C2) and look for a radiopaque (light) area about 3 mm above the tip of the odontoid. Ba will appear light, or radiopaque, since it is a bony landmark and will not permit the x-ray energy to pass through. This area, like other bony areas of increased density, will therefore appear white or underexposed on the x-ray film. Spaces and soft tissues, by contrast, will appear radiolucent or dark on the x-ray film, since the x-ray energy passes more readily through these areas. In many individuals, Ba will appear as if it is resting right on top of the tip of the odontoid. This is rarely the case. In such individuals where this appears the case, it is usually calcification of the ligaments that join basion with the odontoid that accounts for this perception. Close inspection usually finds a rounded, wider area 3 mm above the odontoid. This is the true location of basion (Fig. 24-5).

The second method of locating basion is to identify the rounded configuration of the occipital condyle. If this curve is followed forward from posterior to anterior, the upswing anteriorly is usually 2 mm ahead of basion. If one looks for an opaque area just posterior to the anterior margin of the occipital condyle, the location of basion is usually confirmed.

**THE CERVICAL SPINE**

The morphology of the cervical spine area is an important component of a lateral radiographic assessment. The upper vertebral column serves as an attachment for the muscles and soft tissues of the nasopharynx. If the cranial base
angle is obtuse, for example, and the cervical spine is obliged to be positioned more posterior than normal because of the flexion of the cranial base, the bony or osseous depth of the nasopharynx is increased. This observation may be an especially important one in the patient who is a candidate for an adenoidectomy. Removal of the adenoid mass may lead to the development of excessive, hypernasal speech following the adenoidectomy because of the increased osseous pharyngeal depth. In such situations, the adenoid mass is said to have masked a morphologic problem that was there all along (Figs. 24-6 & 24-7).

The upper three cervical vertebrae are most appropriate for examination, since they are located in the area where velopharyngeal and lingual activity is prominent. It is quite common that the area of velopharyngeal closure is adjacent to the first cervical vertebra, the atlas, or C1. The normal atlas, as seen in the lateral cephalometric projection, has an anterior tubercle that extends about 2 to 3 mm anterior to the plane of the other cervical vertebrae (see Fig. 24-6). This is true whether the configuration of the cervical spine is straight (a “military” spine) or slightly curved (a lordotic cervical spine). In most adults, some normal lordosis is observed.

It is well known from cephalometric studies that a velopharyngeal gap of 3 mm is sufficient to create a hypernasal condition. Consequently, small variations in the configuration of the anterior tubercle of the atlas can potentially contribute in a significant way to the increased depth of the nasopharynx (Fig. 24-8). The most common variations in the anterior tubercle of the atlas include flattening and superoposterior rotation. These conditions are developmental variations that are not associated with any neurological deficit. Consequently, a radiologist may not attach any special significance to these findings. While they are morphological variations, they are common in the cleft palate population but not in a normal sample. Their appearance should alert the clinician to the possible deleterious consequences to normal nasal resonance bal-
ance from a total adenoidecetomy.

The atlas can be positioned in a superior position, above the usual location for velopharyngeal closure, if the occipital condyles are flattened or hypoplastic. The epitome of this situation is where the atlas is fused to the base of the skull. Occipitalization of the atlas, as this condition is called, can be potentially dangerous to the patient’s health, since the second cervical vertebra is also positioned superiorly. If the odontoid process of C2 is positioned within the confines of the foramen magnum, the space for the spinal cord is compromised. This situation is referred to as basilar invagination (of C2 or the axis into the foramen magnum). Any suspicious instances of the odontoid appearing to invade the space of the foramen magnum should be referred to a radiologist for a definitive evaluation. Such a patient needs to be positioned very carefully on the operating table for intubation if surgery is undertaken. Hyperextension of the head, as is done routinely for intubation, serves to bring the opisthion (Greek for rear) — the central, posterior margin of the foramen magnum — forward. The spinal cord could potentially be damaged between the back of the odontoid and opisthion (Fig. 24-9).

Individuals with submucous cleft deformities have a relatively high incidence of cervical spine variations. In addition to the conditions mentioned above, fusion of the bodies or spinous processes of the second (C2) and third (C3) cervical vertebrae are common variations. Fusion of C1 and C2, however, is very rare. The observation of fusion of cervical vertebrae, especially C2 and C3, should alert the clinician to look carefully for other variations, such as clefting. While cervical spine variations are more prominent in cleft than noncleft individuals, it appears that the frequency of their occurrence increases as the severity of clefts decreases.
Figure 24-8. Flattening and superoposterior rotation of the anterior tubercle of the atlas. This minor variation can contribute to an increased depth of the pharynx.

Figure 24-9. An anomalous cervical spine in a patient with a submucous cleft palate deformity. The atlas is fused to the base of the skull (occipitalization of the atlas), and the spinous processes of C2 and C3 are fused. The odontoid process of C2 has invaginated into the foramen magnum creating a potential hazard (see text for discussion).
Consequently, they are seen to occur more readily in submucous clefts and isolated palatal clefts. As such, these variations serve as clues to the examiner to look carefully intraorally and in the family history for other variations. Of course, cervical spine anomalies are also frequent in many syndromes, such as Klippel-Feil (short neck, low hairline, reduction in number of cervical vertebrae or fusion of several vertebrae).

Altogether, the cervical spine area comprises one of the components of the osseous pharyngeal depth. Its configuration also contributes to the framework for the velopharyngeal portal. The anteroposterior location of the cervical spine is determined in large part by the configuration of the cranial base.

THE UPPER FACE

The most common method of assessing the relative position of the maxilla is in relation to the cranial base. In the anteroposterior dimension, the angle formed by landmarks S-N-A provides this assessment. The S-N arm of the angle contributes the cranial component, while the line drawn from nasion to point A expresses the position of the maxilla. Point A is the most involuted portion of the anterior maxilla. This point is less variable than the anterior nasal spine (ANS), which is buried under the soft tissues of the nose and, accordingly, would not be useful for this purpose. By like token, the point where the upper teeth and alveolar bone meet (supradentale) is not useful, in that this point expresses the position of the upper incisors rather than bony maxilla. It is well known that incisors can protrude (along with supradentale) without commensurate protrusion of the maxilla (Fig. 24-10).

A normal SNA is $82^\circ \pm 4^\circ$. Therefore, an SNA of $70^\circ$ would indicate midface retrusion, while an SNA of $90^\circ$ would indicate maxillary protrusion. There are, of course, exceptions to such findings. A low position of sella would affect this angle and would have to be corrected to obtain an accurate portrayal of the SNA significance.

There are no well-established cephalometric norms for the vertical component of the maxillae. Overall facial height, as described in Chapter 21 on “Facial Esthetics,” is a suitable clinical measure. Upper facial height is usually measured from nasion to ANS, while lower facial height from ANS to Menton (lowest point on the chin). The normative data for upper facial height (N-ANS) in adult males is 60 mm $\pm 4$, and for females, 56 $\pm 3$. Caution is recommended in the use of these norms, however, as upper facial height should be viewed as a proportion of total facial height rather than an isolated finding, as pointed out in Chapter 21.

Useful information about facial height can also be obtained from the lateral radiograph by identifying the location of ANS and PNS. The palatal plane, as is determined by a line extending from ANS to PNS, is evaluated in relationship with the vertical location of the atlas shown in Figure 24-10. Usually, the palatal plane and the atlas fall on the same horizontal. If ANS is higher or lower than PNS, this may signal a vertical discrepancy in the growth of the maxilla. A “canted” maxillary plane, as this situation would be described, is often the sign of a skeletal dysplasia of the maxilla, such as posterior vertical maxillary excess where the palatal
plane is canted from PNS being displaced inferiorly. This would, incidentally, also create an anterior openbite malocclusion.

**THE LOWER FACE**

The mandible is certainly an important structure to the speech clinician and others, since it interrelates with the tongue, hyoid bone, and the oropharyngeal area. Its development and position is closely associated with the functions of breathing, eating, swallowing, and speaking.

The most frequently used measure of the horizontal position of the mandible is...
the angle S-N-B, or SNB. Point B is the most involuted portion of the anterior mandible. This area is above the chin and below the alveolus and is known as supramentale. This measurement expresses the horizontal position of the mandible with reference to the cranial base. The norm for SNB is $79^\circ \pm 3^\circ$, as seen in Figure 24-10. The SNB measurement, in comparison with SNA, provides the clinician with a basis for determining whether the patient has a true prognathism or a pseudo-prognathism. As one might expect, a normal SNB in combination with a diminished SNA might give the appearance of mandibular prognathism rather than the midfacial retrusion that is often the real cause of the jaw discrepancy (Fig. 24-11).

While SNA and SNB relate the maxilla and mandible to the cranial base area, the measurement ANB relates maxilla to mandible. An ANB of $3^\circ$ is normal, with a range from $0^\circ$ to $5^\circ$.

**THE DENTITION**

Of the many dental measurements utilized in orthodontics and other areas of dentistry, the most useful for describing the position of the teeth relative to the
bones to which they are attached involves the incisors. The angulation of the upper incisors is measured by extending a line from upper incisor tip, through the root of the incisor, and extending to intersect a line from sella to nasion. The norm for upper incisor to NS is 104° ± 6° (see Fig. 24-10). For the lower incisor, the line from incisor tip through the root is extended to intersect a line that follows the mandibular plane. This is constructed by connecting a line from the mandible angle (gonion) to the most anteroinferior point of the chin (gnathion). The norm for lower incisor to Go-Gn (the mandibular plane) is 95° ± 7°.

When the upper and lower incisor positions are considered, especially in comparison with the maxillary and mandibular positions (SNA and SNB), the examiner is provided with sufficient information to evaluate whether a dental or skeletal or a combination of variations is present.

THE PALATES

The speech clinician will be especially interested in the cephalometric appearance of the hard and soft palates. The hard palate is, of course, a bony framework for the attachment of the soft palate, as mentioned in other chapters. In the lateral cephalometric x-ray projection, the hard palate normally ends at the pterygomaxillary fissure (PTM) — a tear-shaped fissure that is seen as a radiolucent shadow on a radiograph. The front part of the teardrop is the posterior border of the maxillary tuberosity, while the posterior part is the anterior border of the pterygoid plates. The posterior nasal spine of the hard palate will never be longer than the PTM teardrop. Finding the PTM and following the contour of the maxillary tuberosity inferiorly until it intersects the palatal plane is the usual method of identifying the location of the posterior nasal spine (PNS) in the normal. In a repaired cleft palate or submucous cleft palate patient, the posterior nasal spine will be absent. Often, the end of the hard palate is identified anterior to the PTM in such patients (Fig. 24-12).

The posterior nasal spine is an important landmark in assessing the length of the soft palate, either at rest or in function. Normative data for resting length of the velum are found for age and sex in the research of Subtelny (1957) and are too numerous to include in this text. While the resting length of the velum is of some interest, especially in relationship to the soft-tissue depth of the pharynx (Subtelny, 1957), the functional length of the velum is of special importance.

Normally, the soft palate increases in length during functional activities such as speaking. The ability of the velum to increase overall length during function has been termed the "stretch factor" in soft palate function (Pruzansky and Mason, 1969). The most important radiographic finding of the elevated velum, as seen on a phonation lateral x-ray film, is the effective length of the velum (the amount of velar tissue used in attempts to obturate the nasopharyngeal space). Research has determined generally that the normal soft palate elevates up to the level of the hard palatal plane. Furthermore, the point of greatest flexion of the velum is located about 80 percent of the total length of the velum, as measured from the PNS to the tip of the uvula (Fig. 24-13). The point of greatest velar elevation is known as the velar dimple and is created by the attachment
scheme of the levator palatini muscles in the velum. The shorter the effective velar length (as measured from PNS to the velar dimple), the narrower the nasopharyngeal depth must be to maintain a velopharyngeal seal (Fig. 24-14).

The patient with an anterior (short) point of levator attachment in the velum, but who is normal in nasal resonance balance due to a velopharyngeal seal involving the adenoid mass, is not a good candidate for total adenoidectomy. This surgery could potentially create a persistent hypernasality following the operation.

An individual with a normal palate who undergoes the normal process of adenoidal involution over time is not expected to develop hypernasality with adenoid involution. This is associated with palatal stretch, which is apparently a compensatory adaptation to permit the maintenance of normal nasal resonance balance with changes in the architecture of the pharynx (Mason and Warren, 1980).

![Figure 24-12. Lateral x-ray film tracing depicting the pterygomasillary fissure (PTM), or “teardrop.” This aids in finding the posterior nasal spine in a normal patient (see text for discussion).](image-url)
Figure 24-13. Lateral cephalometric x-ray film tracing during sustained /i/ showing a broad velopharyngeal seal and the soft palate "dimple" or flexion. Notice that the velum has elevated to the level of the hard palate plane. The adenoid mass is shown as the stippled area. This patient would maintain a velopharyngeal seal if a total adenoidectomy were performed.

Figure 24-14. Demonstration of the velopharyngeal apparatus through x-ray film analysis. Effective length of the soft palate is measured from the posterior nasal spine (PNS) (which is located at the limit of the hard palate) to the velar dimple. Incomplete valving is shown (top) as well as normal valving (lower left). (Lower right) The palate is at rest, with a dashed line added to indicate the position for velopharyngeal valving. Notice the important role of the adenoid mass in the tracings presented.
THE ADENOID MASS

Information about the adenoid mass has been presented in many other sections of this text. By now, the reader should be quite conversant about the significance of the adenoid mass in velopharyngeal closure.

From a diagnostic standpoint, the adenoid should be evaluated, in part, with regard to the contiguous anatomy. That is, the cranial base angle, status of cervical vertebrae, and configuration of hard and soft palate should be closely observed.

It is tempting to look at the overall contour of the adenoid mass and incorrectly presume about the size of the adenoid. As pointed out in Chapter 19, "Postnatal Growth and Development," the adenoid is expected to be large in size from around age three to twelve years. While the portion of the adenoid at the level of the palatal plane is important as a contact site for velopharyngeal function, it is the portion of the adenoid at or near the posterior choanae that determines whether the airway has been compromised. Blockage of the posterior choanae by adenoidal tissue certainly precludes normal respiration intranasally. Hyponasality associated with adenoidal hypertrophy occurs when the posterior choanae is blocked with adenoid. It is not the amount of adenoid at the velopharyngeal hiatus that causes a hyponasal voice quality, except in rare instances. The posterior choanae, or the posterior entrance into the nasal cavity, is observed on the lateral x-ray film in two ways. One is to find the posterior border of the vomer, which is seen to project cranialward in an oblique direction from the PNS area. The other method is to find the posterior margin of the PTM, which can be considered to be a reasonable representation of the posterior opening of the nasal cavity. The adenoid mass at or near the PNS in the vertical dimension is the area in which the soft-tissue mass of adenoid should be evaluated for airway patency or blockage.

Overall, the adenoid mass as observed on the two dimensions of the lateral x-ray film represents the midline contour of the adenoid. This shadow does not reveal the amount of adenoid on the lateral walls of the pharynx. For speech purposes, nonetheless, it is the midline convexity of the adenoid that is important to identify and evaluate with regard to the presence, absence, maintenance, or deterioration of velopharyngeal closure.

SUMMARY

The lateral cephalometric x-ray film is a standard part of an orthodontic data base. It is also a potentially important tool of examination to the speech clinician. For those clinicians working in concert with an orthodontist, a sustained film of phonation can reveal several important characteristics of velopharyngeal function, current status, and predictions for subsequent history. The lateral x-ray film provides an oriented look at the morphology of the head and neck area. Normative data are available with which to evaluate the adequacy of the facial structures for speech and other functions. Some selected orthodontic norms, as well as a discussion of palatal and cervical spine variations, are provided for the speech clinician to consider. The normative data selected for in-
clusion in this chapter represents only the most common observations of interest to the speech clinician.

BIBLIOGRAPHY


