6 Cephalometric Radiography

Athina Chatzigianni

6.1 Basic Principles and Interpretation

In the medical and dental science, radiographic examination of patients' bony, dental, and soft tissue structures has been an important diagnostic adjunct tool to clinical examination to reach a final diagnostic assessment of a disease or condition. Many radiographic techniques have been proposed, with divergent outcome, depending on the target structures under investigation and the orientation of the head to the X-ray beam.

The first X-ray images of the whole skull in a standardized lateral view were taken in 1922 by Pacini and Carrera [1]. Pacini's method consisted of a large, fixed distance from the X-ray source to the cassette. Cephalometric radiography gained full acceptance in 1931, when Broadbent [2] in the USA and at the same time Hofrath [3] in Germany introduced radiographic films of the head, taken under standardized conditions. The method consisted of mounting film, positioning the subject and setting the X-ray source in a fixed standardized reproducible position.

By means of a standardized cephalometric radiograph, it was possible to study the craniofacial skeleton through time. The craniofacial growth changes in the size and shape of craniofacial skeleton and soft tissue with age could be studied [4]. In 1988, cephalometry was defined by Moyers [5] as a radiographic technique for converting the human skull into a measurable geometric shape.

Moreover, craniofacial variation within a population sample of same or different ethnic origin could be analyzed and anatomical differences between males and females could been examined. For example, the comparison of the craniofacial morphology between the sexes showed that on average, the cranium was significantly smaller in women than in men, except as regard to the nasal bone, the foramen magnum and the inner orbital distance. Regarding the cranial shape a more prominent frontal bone and a less prominent nasal bone were found for females. The average sex determined shape differences revealed that the female skull is significantly smaller than the male [6].

Cephalometric radiographs are also indicated for cephalometric tracing of anatomical structures and have a significant importance in the field of orthodontics and in orthodontic and orthognathic treatment planning. For many decades cephalometry has been one of the main diagnostic tools available to the orthodontist. A variety of cephalometric analysis applied on

A. Chatzigianni (✉)
Department of Orthodontics, Faculty of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece
e-mail: achatzigianni@dent.auth.gr

A. Delantoni, K. Orhan (eds.), *Atlas of Dentomaxillofacial Anatomical Imaging*,
https://doi.org/10.1007/978-3-030-96840-3_6

cephalometric radiographs have been proposed throughout the years with the aim to describe the dental, skeletal, and facial characteristics of patients. Relationships between teeth, bone, and soft tissue based on cephalometric anatomic landmarks are being analyzed according to many different methods. It has been widely used for the identification and measurement of the craniofacial structures, not only in patients with normal craniofacial development, but also in patients with deviated craniofacial shape. With the use of cephalometric radiographs, the comparison of a patient's dentofacial relationships with a normal reference group of the same racial or ethnic groups was possible, while deviations from norms are revealed. Cephalometric radiographs are used to evaluate the craniofacial complex, dentofacial proportions, malocclusion, soft tissue, and the changes related to growth or treatment, all of which are crucial for orthodontic treatment planning and evaluation.

To obtain cephalometric radiographs, ear rods are used to prevent the rotation of the head about the vertical, sagittal, and transverse axes. Additionally, a nasal stabilizer may be used to prevent the nose from rotating about the transverse axis [2, 7]. Despite all those, a slight rotation of the head may be inevitable and occur, despite the technical configuration. Thus a major limitation of cephalometric radiography is the difficulty in the correct and reproducible position of the head. In the limitations the identification of landmarks due to the superimposition of anatomical structures or poor radiographic quality are included, and also the exposure of patient to radiation [8–12]. Another concern arises in cases where the size of an anatomic structure is calculated, or angular or linear measurements are applied. It is essential to know whether the measurements accurately reflect the true dimensions of the object and, if not, whether the error can be calculated and corrected. The standardized film-object distance eliminates the problem of magnification errors, while the incorporation of a ruler in the radiograph is a common method to control magnification levels.

Moreover, it is worth mentioning that there are inherent limitations in two-dimensional (2D) radiographic projections: magnification, distortion, superimposition, and misrepresentation of anatomic structures [13]. Recently, the validity of 2D cephalometry was examined and it was found that scientific evidence on the usefulness of this radiograph technique in orthodontics is still lacking [14].

The traditional cephalometric radiographs provide a partial description of the overall craniofacial shape, due to the 2D projection of a three-dimensional (3D) object. Unfortunately, despite the wide acceptance and use of 2D cephalometric imaging, it seems that much information of the 3D anatomic elements is missing, while detailed description of anatomic structures is not possible. To solve the above-mentioned problems the transition from 2D to 3D cephalometry has been introduced [15, 16].

Computed tomography (CT) and cone beam computed tomography (CBCT) are available to provide a 3D reconstruction of the craniofacial complex, nevertheless, their application in dentistry and orthodontics has been limited until now in the everyday practice, mainly because of cost and dose considerations compared to traditional radiography [13]. It is however of no doubt that advances in 3D software have led to actual 3D imaging and measurements becoming a reality.

Despite the limitations of cephalometric radiographs, the deep knowledge of the craniofacial anatomical structures that can be identified in different cephalograms is of great importance for the interpretation of the images, as well as for the identification of anatomic landmarks and proper cephalometric analysis by the clinicians. Through knowledge of the anatomy of the skull and the comprehension of the radiographic appearance of each structure, which are described below, errors in the identification of each anatomical cephalometric point will be minimized [17].

6.2 Cephalometric Radiographic Anatomy

6.2.1 Lateral Cephalometric Radiograph

Lateral cephalometric radiographs (Fig. 6.1) are taken with the X-ray beam perpendicular to the midsagittal plane of the patients' skull and the midsagittal plane in turn parallel to the radiographic film. Many different distances between the X-ray source, patients' head, and film cassette have been introduced for enlargement compensation, however, the most widely used distance between the X-ray source and the patient's midsagittal plane is around 150 cm, while the distance between the midsagittal plane and the film is 13–15 cm [18–20].

The lateral cephalometric radiograph is providing information of the craniofacial skeleton in the sagittal and vertical plane. In short, the application of lateral cephalometric analysis and cephalometric tracing can contribute to the following:

Fig. 6.1 Lateral cephalometric radiograph

1. Study of craniofacial growth in the sagittal and vertical dimension.
2. Study of the soft tissue in the sagittal and vertical dimension.
3. Study of upper airways, sinuses and tongue.
4. Establishment of lateral cephalometric norms specific for a group of people.
5. Study of the craniofacial differences between genders or between people of different racial/ethnic origin.
6. Study on the ageing of the craniofacial skeleton and the soft tissue in the sagittal and vertical dimension.
7. Diagnosis of malocclusions, craniofacial anomalies, and skeletal deformities in the sagittal and vertical dimension.
8. Orthodontic and orthognathic treatment planning of sagittal and vertical problems.
9. Evaluation of orthodontic treatment results on the hard and soft tissue.
10. Skeletal age assessment with the analysis of cervical vertebrae.
11. Detections of abnormalities of the skull or spine.

    By means of lateral radiographs many unilateral, midline or bilateral anatomic structures can be depicted. It is of great importance to understand that bilateral anatomic structures will be seen as one single projection of the two anatomic parts. In many cases, two lines can be seen, which represent the contour of the two bilateral elements, either due to inherent asymmetry between the two parts or due to head rotation in the cephalostat.

The position of the patient in a natural head position, with natural bite, natural lip seal, physiologic rest, and good head orientation can help visualize anatomy of the cranium, joint and soft tissue. Essentially two main components are necessary for description on lateral cephalometric radiographs, i.e., the hard tissue, where the bony elements and the denture are included, and the soft tissue together with the sinuses, airways, and nerve canals.

6.2.1.1 Hard Tissue Anatomic Elements

The most important hard tissue anatomic structures that can be identified on a lateral cephalometric radiograph can be divided in the following categories (Fig. 6.2a):

- Cranial and upper facial anatomic structures.

1. *Frontal bone*: a bone of the skull that forms the forehead and the superior part of the orbits. It has an inner (1a) and an outer (1b) cortical plate.
2. *Nasal bones*: The *nasal bones* are two small, symmetrical bones in the midline, which form the bridge of the nose. On the lateral cephalometric radiograph, only one of the two nasal bones can be depicted.
3. *Ethmoid bone*: The ethmoid bony complex is located between the two orbits and on the lateral cephalometric radiograph it is located superiorly to the nasal cavity, separating it from the brain.
4. *Cribriform plate*: It consists of a lot of small foramina located between the anterior cranial fossa and the nasal cavity.
5. *Anterior cranial base*: it extents anteriorly to the posterior wall of the frontal sinus and posteriorly to the planum sphenoidale and the anterior clinoid process. It forms the floor of anterior cranial fossa, the roof of the nasal cavity, the roof of the frontal sinus, the roof of the ethmoid and sphenoid sinus, and the roof of the orbits.
6. *Middle cranial base:* it extends from the anterior cranial base to the dorsum sellae.
7. *Posterior cranial base*: it extends from the dorsum sellae to the occipital bone.
8. *Planum sphenoidale*: it is the part of the anterior cranial base that forms the roof of the sphenoid sinus and lies anterior to the anterior clinoid process.
9. *Anterior clinoid process*: it is one of the two bony projections of the lesser wings of the

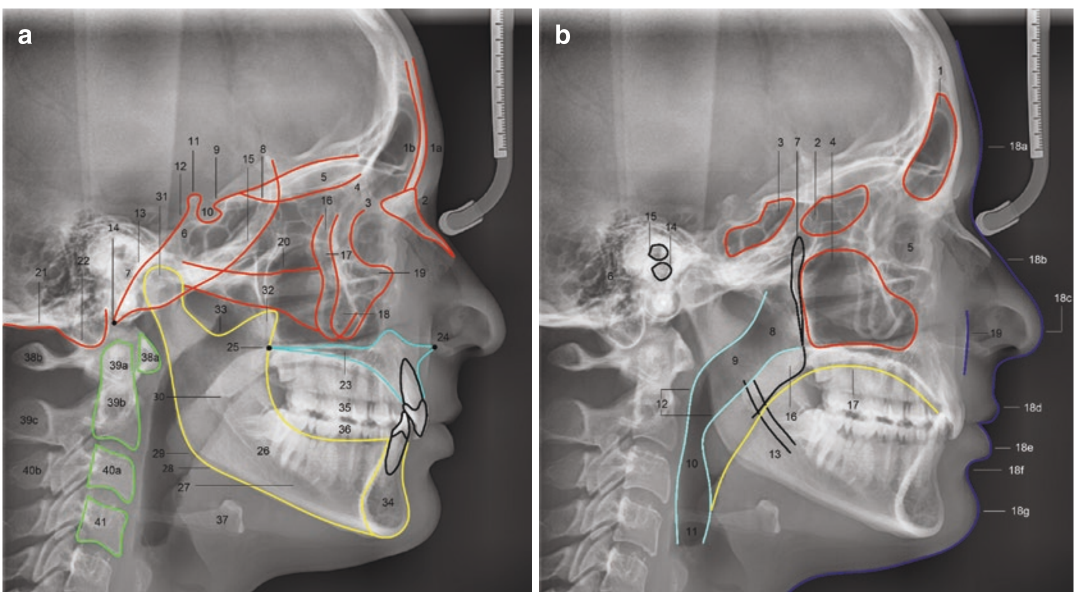

Fig. 6.2 (**a**) Identification of the most important skeletal and dental anatomic parts on the lateral cephalometric radiograph and (**b**) recognition of the main non-hard tissue elements of the craniofacial complex. Numbering corresponds to the text. (Images were created by Dr. Athina Chatzigianni with the use of Viewbox 4 Software (dHAL Software, Kifissia, Greece) [28])

sphenoid bone. It is the border between the anterior and middle cranial base and fossa.

10. *Sella Turcica*: it is the pituitary fossa, where the pituitary gland is located. It has a curved shape and its boarders are the anterior and posterior clinoid process.
11. *Posterior clinoid process*: together with the anterior clinoid process it surrounds the sella turcica. It is one of the two tubercles of the dorsum sellae.
12. *Dorsum sellae*: it is a part of the sphenoid bone and is located posterior to the sella turcica.
13. *Clivus*: it is a bony surface between the dorsum sellae and the foramen magnum and is seen as a straight line sloping downwards and backwards.
14. *Anterior border of foramen magnum*: it is the anterior border of the opening in the occipital bone of the *skull.*
15. *Greater wings of the sphenoid*: these are bony processes of the sphenoid bone.
16. *Zygomatic process of frontal bone:* it articulates inferiorly with the frontal process of the zygomatic bone through the zygomatico-frontal suture.
17. *Frontal process of zygomatic bone*: it articulates superiorly with the zygomatic process of the frontal bone through the zygomatico-frontal suture.
18. *Maxillary process of zygomatic bone*: it articulates inferiorly with the maxilla and forms the orbital surface of the maxilla.
19. *Orbital rim*: it is the cyclic bony margin surrounding the orbit.
20. *Zygomatic arch*: *it is a horizontal* bone at the side of the head around the maxilla and is figured posteriorly to the orbit and zygomatic bone.
21. *Occipital bone*: it is the bone posterior to the foramen magnum and the mastoid process.
22. *Mastoid process*: it is the lower bony projection of the occipital bone.

- Maxillary anatomic structures.

23. *Hard palate (floor of nasal cavity)*: it is the line that separates the oral cavity from the nasal cavities and the maxillary sinuses and extents from the anterior nasal spine to the posterior nasal spine.
24. *Anterior nasal spine*: it is the most anterior point of the hard palate in the midline.
25. *Posterior nasal spine*: it is the most posterior point of the hard palate in the midline.

- Mandibular anatomic structures.

26. *Mandible*: it is also referred as lower jaw and is the only mobile bone of the craniofacial complex, which articulates with the skull through the temporomandibular joint. It consists of a body, two rami, two condyles, two coronoid processes, two gonial angles, and one symphysis. In the lateral cephalometric radiograph only one projection of the bilateral structures is identified, except in cases of mandibular asymmetries or incorrect head position in the cephalostat, where two borders of each bilateral mandibular bone element could be present on the radiograph.
27. *Body of the mandible*: it is also called mandibular body and is the horizontal part of the bone extending to the mandibular angles bilaterally.
28. *Antegonial notch*: it is a concavity of the lower border of the mandible, anteriorly to the gonial angle.
29. *Gonial angle of the mandible*: it is also called mandibular angle and it describes the angle formed by the lower border of the mandibular body with the posterior border of the ramus.
30. *Ramus of the mandible*: the mandibular bone has two rami. Each of them includes the mandibular nerve canal and has two processes, the condylar and coronoid process.

31. *Condyle*: it is the part of the mandible that articulates with the skull in the temporomandibular junction.
32. *Coronoid process*: it is the process of the mandible, which is located mesially to the condyle.
33. *Sigmoid notch of mandible*: it is a deep concavity in the upper border of the mandible, which is surrounded by the condyle and the coronoid process.
34. *Symphysis*: it is the most mesial and lower part of the mandible and includes an external cortical plate and an internal cortical plate.

- Dental elements.

35. *Upper dentition*: it describes the teeth of the upper jaw (maxilla).
36. *Lower dentition*: it describes the teeth of the lower jaw.

- Neck skeleton.

37. *Hyoid bone*: it is located inferiorly and posteriorly to the mandibular bone at the height of the third and fourth cervical vertebra.
38. *first cervical vertebra (atlas)*: it is an atypical cervical vertebra located radiographically below the mastoid process and posteriorly to the mandibular ramus. The anterior arch (38a) and the posterior arch (38b) of atlas are seen on the radiograph.
39. *second cervical vertebra (axis)*: it is an atypical vertebra located below the atlas. Radiographically a vertical process (odontoid process) (39a), a body (39b), and a spinous process (39c) can be identified. The odontoid process of axis (dens) is a large vertical projection of the second cervical vertebra and is seen on the radiograph to intersect with the body of the first cervical vertebra.
40. *third cervical vertebra*: it is a typical vertebra, located between the second and fourth cervical vertebra. Radiographically the body (40a) and the spinous process (40b) can be identified.
41. *fourth cervical vertebra*: it is atypical vertebra like the third cervical vertebra.

6.2.1.2 Soft Tissue and Other Anatomic Elements

The soft tissue together with the sinuses, the air cavities, the tubes, and the nerve canals that can be identified on a lateral cephalometric radiograph are shown in Fig. 6.2b.

- Paranasal sinuses. There are four pairs of air spaces in the craniofacial complex. There are two frontal sinuses, two ethmoid sinuses, two sphenoid sinuses, and two maxillary sinuses:

1. *Frontal sinus*: There are two frontal sinuses in the frontal bone. In the lateral cephalometric radiograph, the projection of the two sinuses is seen as one air chamber located superiorly to the nasal bone.
2. *Ethmoid sinus*: There are two ethmoid sinuses, which can be better seen on the anteroposterior cephalometric radiograph around the nose. On the lateral cephalometric radiograph only one of the two ethmoid sinuses can be seen posteriorly to the orbit, superiorly to the zygomatic arch and inferiorly to the anterior cranial fossa.
3. *Sphenoid sinus*: There are two large sphenoid sinuses in the sphenoid bone. On the lateral cephalometric radiograph, the projection of the two sinuses can be seen as one sphenoid sinus, which lies inferior to the sella turcica and between the dorsum sellae and the greater wings of sphenoid bone.
4. *Maxillary sinus*: There are two maxillary sinuses in the maxillary bone, and these are the largest of the paranasal sinuses. On the lateral cephalometric radiograph, the projection of the two sinuses can be seen as one large air cavity, which is surrounded by the hard palate, the orbit, the floor of the ethmoid sinus, and the pterygomaxillary fissure.

- Cavities.

5. *Orbit:* it is a bony cavity (socket) of elliptical shape, where the eyeball is enclosed.
6. *Mastoid air cells*: these are tiny air cavities within the mastoid process of the cranium.

7. *Pterygomaxillary fissure*: it is a vertical opening on the lateral cephalometric radiograph, just above and posteriorly to the posterior nasal spine and the soft palate. It is a bilateral opening and the midline between the two shadows should be traced.

- Upper airways. They are the air passages, which start from the nasal cavity and end up to the larynx:

8. *Nasopharynx*: it is the nasopharyngeal airway area and is the most superior part of the pharynx, which starts radiographically posterior to the nasal cavity and maxillary sinus and ends to the height of the hard and soft palate.
9. *Velopharynx*: it extends from the posterior part of the hard palate to the posterior pharyngeal wall.
10. *Oropharynx*: it is the part of the airways that is located between the soft palate to the superior border of the epiglottis.
11. *Laryngopharynx:* it is in the inferior part of the pharynx and is extended to the sixth cervical vertebra.
12. *Pharynx wall*: Radiographically the anterior and posterior pharyngeal walls are seen.

- Nerve canals.

13. *Mandibular nerve canal*: there are two nerve canals, which are located within the mandibular bodies and include the inferior alveolar nerve, artery, and vein. Each nerve canal can be perceived on the radiograph as two distinguished lines running through the mandibular body.
14. *External auditory meatus*: it is a bony canal of sigmoid shape, which starts from the outer surface of the head. It has a cyclic shape and is located posteriorly and superiorly to the mandibular condyle on the cephalogram.
15. *Internal auditory meatus*: it is a canal starting from the internal acoustic porous. It has a cyclic shape and is located superiorly to the external auditory meatus on the cephalogram.

- Soft tissue and muscles.

16. *Soft palate*: it is comprised by muscles and connective tissue and lies posteriorly to the hard palate.
17. *Tongue dorsum*: it is the upper surface of the tongue and can be seen as a concave line inferior to the hard palate, starting from the front teeth and ending to the hyoid bone.
18. *Soft tissue profile*: This is the patient's profile marking of the soft tissue that surrounds the craniofacial complex. The soft tissue of the forehead, the nose bridge, the tip of nose, the upper and lower lip, the labiomental fold and the chin are shown (a to g respectively).
19. *Cheek*: it is the patient's fleshy part of the face below the eye.

6.2.2 Posteroanterior Cephalometric Radiography

Posteroanterior cephalometric radiographs (Fig. 6.3a) are taken with the X-ray beam perpendicular to the coronal plane of the patient's skull. The source of the X-ray beam is behind the patient's head, and the film in front of the patient's face, with the forehead and nose against the cassette [21, 22]. The patient's canthomeatal line forms a 10-degree angle with the horizontal plane and the Frankfurt plane is perpendicular to the image receptor [23].

The posteroanterior cephalogram (PAC) analysis and tracing may provide information on bilateral anatomic structures in the transverse and vertical plane and could be used in the following applications:

1. Study of craniofacial growth in the transverse and vertical dimension.
2. Study of skeletal asymmetries.
3. Study of the sinuses bilaterally.
4. Establishment of posteroanterior cephalometric norms specific for a group of people.
5. Study of the craniofacial differences between genders or between people of different racial/ethnic origin.
6. Study on the ageing of the craniofacial skeleton.

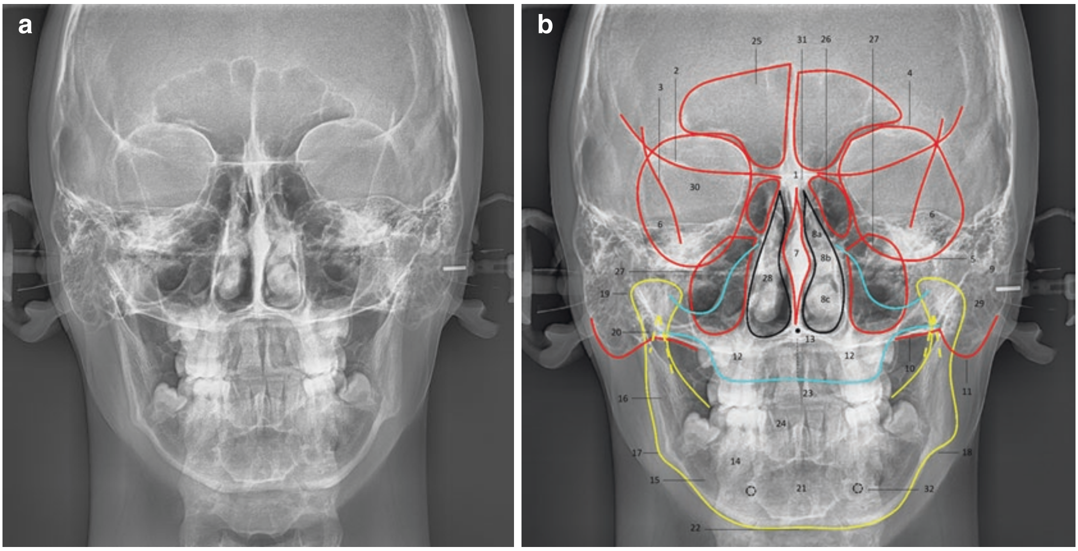

Fig. 6.3 (**a**) Posteroanterior cephalometric radiograph and (**b**) identification of the most important skeletal, dental and non-hard tissue anatomic parts. Numbering corresponds to the text. (Images were created by Dr. Athina Chatzigianni with the use of Viewbox 4 Software (dHAL Software, Kifissia, Greece) [28])

7. Diagnosis of malocclusions, craniofacial anomalies, and skeletal deformities in the transverse and vertical dimension.
8. Orthodontic and orthognathic treatment planning of transverse and vertical problems.
9. Evaluation of orthodontic treatment results on the transverse and vertical plane.

   Like in the lateral cephalograms, two main components are necessary for description on posteroanterior cephalometric radiographs, i.e., the hard tissue (bone and teeth) and the non-hard tissue parts, like the sinuses and the cavities.

6.2.2.1 Hard Tissue Anatomic Elements

The hard tissue anatomic structures that can be identified on a posteroanterior cephalometric radiograph (Fig. 6.3b) can be divided in the following categories:

- Cranial and upper facial anatomic structures.

1. *Crista galli*: it is a triangular process in the midline above the ethmoid bone.
2. *Lesser wing of sphenoid:* these are two bony projections of the upper part of the sphenoid bone.
3. *Greater wings of sphenoid*: these are bony processes of the lower part of the sphenoid bone.
4. *Orbital roof*: it is the superior border of the orbit.
5. *Inferior orbital rim*: it is the inferior border of the orbit.
6. *Petrous ridge*: it is a part of the temporal bone separating the anterior from the middle cranial fossa.
7. *Nasal septum*: it is a vertical line dividing the two nasal cavities.
8. *Nasal conchae*: these are three bony projections of the lateral wall of the nasal cavity. They are divided in superior (a), middle (b), and inferior (c) nasal conche.
9. *Zygomatic arch*: *it is the horizontal* bone at the side of the head and is figured bilaterally around the maxilla.
10. *Occipital bone*: it forms the base of skull and can be seen radiographically at the level of the maxillary bone.
11. *Mastoid process*: the same as in lateral cephalogram, it is the lower bony projection of the occipital bone.

- Maxillary anatomic structures.

12. *Maxilla*: it is the upper jaw formed by the two maxillary bones, which are fused together through the intermaxillary suture.
13. *Anterior nasal spine*: it is the most anterior point in the midline where the two maxillary bones are fused.

- Mandibular anatomic structures.

14. *Mandible*: it is the lower jaw and in this radiographic image a mandibular body, two rami, two condyles, two coronoid processes, two gonial angles, and one symphysis can be detected.
15. *Body of the mandible*: it is also called mandibular body and is the horizontal part of the bone extending from the midline to the mandibular angles bilaterally.
16. *Ramus of the mandible*: two mandibular rami are present in this radiograph. Each of them includes the mandibular nerve canal and has two processes, the condylar and coronoid process.
17. *Gonial angle of the mandible*: it is also called mandibular angle and it describes the angle formed by the lower border of the mandibular body with the posterior border of the ramus.
18. *Antegonial notch*: it is a concavity of the lower border of the mandible, anteriorly to the gonial angle.
19. *Condyle*: it is the part of the mandible that articulates with the skull in the temporomandibular junction. Two condyles can be seen on the posteroanterior radiograph.
20. *Coronoid process*: it is the process of the mandible, which is located mesially to the condyle. On the posteroanterior radiograph two coronoid processes can be identified adjacent to the condyles, however, it is difficult to discern them.
21. *Symphysis*: it is radiographically located in the midline of the mandible.
22. *Mandibular midpoint*: it is the midline of the mandible.

- Dental anatomic structures.

23. *Upper dentition*: it describes the teeth of the upper jaw.
24. *Lower dentition*: it describes the teeth of the lower jaw.

6.2.2.2 Sinuses, Cavities, and Foramina

The non-hard tissue elements figured on a posteroanterior cephalogram (Fig. 6.3b) include mainly sinuses, cavities, and foramina and are described below:

- Paranasal sinuses.

25. *Frontal sinuses*: there are two frontal sinuses within the frontal bone, which are separated by a vertical line called septum.
26. *Ethmoid sinuses*: there are two ethmoid sinuses external to the nasal bone bilaterally and between the two orbits.
27. *Maxillary sinuses*: They are located laterally and slightly inferiorly to the nasal cavities.

- Cavities.

28. *Nasal cavity*: it is an air chamber in the middle of the face, which is divided in two cavities by the nasal septum.
29. *Mastoid air cells*: these are tiny air cavities within the mastoid process of the cranium.
30. *Orbit*: it is a bony cavity (socket) of elliptical shape, where the eyeball is enclosed.

- Foramina.

31. *Cribriform plate*: it is a structure pierced with small foramina between the cranial base and the nasal cavity.
32. *Mental foramen*: it is a foramen in the body of the mandible in proximity to the second premolar and is the terminal of the mandibular nerve canal.

6.2.3 Other Cephalometric Radiographic Views

Apart from the above standard cephalometric radiographs, which are being used for many years in the orthodontic and orthognathic field, various other cephalometric images have been used to examine the bones of the head from different views. Example of such views are the submentovertex and the occipitomental views of the skull, which are applied on specific occasions and mostly when fractures of craniofacial bones are suspected. Ideal head positioning for submentovertex cephalometric radiographs (SMV) involves the central X-ray starting from below the chin and being perpendicular to the midsagittal and coronal planes, while the head angulation is aimed upwards and backwards at 10-degrees angle [23]. For the occipitomental view a 30-degree angle is applied.

The main applications of submentovertex and occipitomental view in orthodontics include:

1. The determination of the long axis of the condyle. This facilitates the corrected tomography of the temporomandibular joint.
2. The measurement of mandibular length.
3. The assessment of skeletal asymmetry.
4. The evaluation of the imaged paranasal sinuses.
5. The evaluation of fractures of the imaged bones.

As seen in Fig. 6.4a, b, depending on head orientation, the following anatomic parts, most of which have been already analyzed above, can be identified on these radiographs:

1. *Frontal sinuses.*
2. *Sphenoid sinuses.*
3. *Maxillary sinuses.*
4. *Nasal cavity.*
5. *Nasal septum.*
6. *Lower orbital rim (6a) and lateral orbital wall (6b).*
7. *Zygomatic arches.*
8. *Upper dentition.*
9. *Mandible.*
10. *Body of the mandible.*
11. *Gonial angle.*
12. *Ramus of the mandible.*
13. *Condyle.*

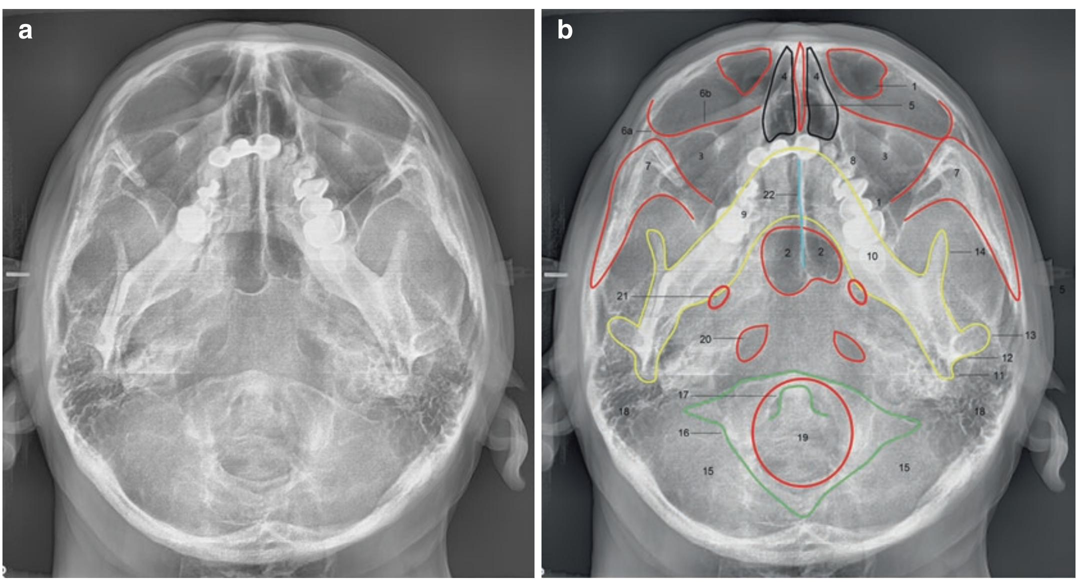

Fig. 6.4 (**a**) Example of submentovertex/occipitomental cephalometric view and (**b**) depiction of the most important anatomic elements. Numbering corresponds to the text. (Images were created by Dr. Athina Chatzigianni with the use of Viewbox 4 Software (dHAL Software, Kifissia, Greece) [28])

14. *Coronoid process.*
15. *Base of skull.*
16. *first cervical vertebra (atlas).*
17. *Odontoid process (dens) of second cervical vertebra.*
18. *Mastoid air cells.*
19. *Foramen magnum.*
20. *Foramen lacerum.*
21. *Foramen oval.*
22. *Intermaxillary suture*: it is the suture in the midline between the two maxillary bones. In this view it is superimposed with the projection of the nasal septum.

6.2.4 Three-Dimensional Cephalometric Imaging

To overcome the limitations of 2D cephalometric radiographic methods, the use of 2D cephalometric radiographs is being gradually replaced by three-dimensional (3D) radiographic images of the craniofacial bones in an attempt to describe craniofacial discrepancies in a 3D manner.

For this purpose, the medical CT, which was introduced in 1972 by G. Hounsfield, who received a Nobel prize in 1979 [24], quickly gained popularity for dental and orthodontic imaging, diagnosis, and treatment planning. However, due to its major drawbacks, such as high cost and high patient radiation dose, the alternative of CBCT was introduced in dentistry and has been since then the method of choice for a 3D hard tissue reconstruction and imaging [25]. Recently, high-resolution 3D magnetic resonance imaging (MRI) has been examined as an even more favorable alternative for 3D imaging of the head and neck region and as a tool for 3D treatment planning in orthodontics and orthognathic surgery with favorable results [26].

In the field of orthodontics, the 3D rendering of the craniofacial structures and the 3D anatomic landmarks acquisition and identification gave rise to the 3D cephalometric analysis of the craniofacial complex and face and new software for 3D orthodontic assessment have been developed. Despite the fact that the reliability of 3D cephalometric landmarks is still questionable and further research is required in the field [27], the 3D image modality of the craniofacial region is a new path on cephalometric analysis and treatment planning.

In general, the main clinical uses of 3D cephalometric imaging are described below:

1. Study of the 3D craniofacial shape and growth.
2. Study of the 3D skeletal asymmetries.
3. Study of the 3D soft tissue.
4. Study of the 3D upper airways.
5. Establishment of 3D cephalometric norms specific for a group of people.
6. Study of the 3D craniofacial differences between genders or between people of different racial/ethnic origin.
7. Study on the ageing of the 3D craniofacial skeleton and the 3D soft tissue.
8. Diagnosis of malocclusions, craniofacial anomalies, and skeletal deformities in a three-dimensional manner.
9. Orthodontic treatment planning.
10. 3D virtual orthognathic-surgical treatment planning.
11. Evaluation of orthodontic treatment results on the 3D hard and soft tissue.
12. Detections of abnormalities of the 3D skull and3D spine.

The hard tissue anatomic parts that can be recognized on a rendered 3D cephalometric image are listed below (Fig. 6.5a, b):

- 3D cranial and upper facial anatomic structures.

1. *Frontal bone.*
2. *Nasal bones.*
3. *Nasal cavity.*
4. *Nasal septum.*
5. *Sphenoid bone.*
6. *Ethmoid bone.*
7. *Orbital roof.*
8. *Lateral wall of orbit.*
9. *Inferior orbital rim.*

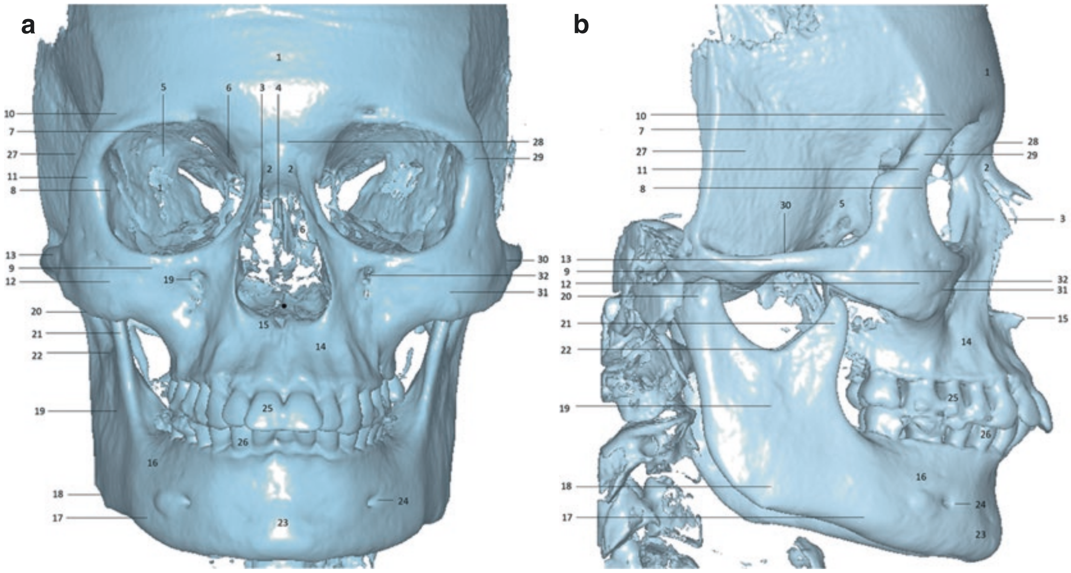

Fig. 6.5 Three-dimensional cephalometric image created by CBCT together with the numbering of the most important anatomic parts: (**a**) frontal view and (**b**) lateral view. Numbering corresponds to the text. (Images were created by Dr. Athina Chatzigianni with the use of Viewbox 4 Software (dHAL Software, Kifissia, Greece) [28])

10. *Zygomatic process of frontal bone.*
11. *Frontal process of zygomatic bone.*
12. *Maxillary process of zygomatic bone.*
13. *Zygomatic arch.*

- 3D Maxillary anatomic structures.

14. *Maxilla.*
15. *Anterior nasal spine.*

- 3D Mandibular anatomic structures

16. *Mandible.*
17. *Body of the mandible.*
18. *Gonial angle of the mandible.*
19. *Ramus of the mandible.*
20. *Condyle.*
21. *Coronoid process.*
22. *Antegonial notch.*
23. *Symphysis.*
24. *Mental foramen.*

- 3D Dental anatomic structures

25. *Upper dentition.*
26. *Lower dentition.*

- Additional anatomic parts identified on a 3D craniofacial image, which were not clearly discerned in the previous 2D images:

27. *Temporal bone*: it is situated at the side of the cranium and base of the skull. It articulates with the zygomatic bone, the mandible, the sphenoid bone, the parietal bone, and the occipital bone.
28. *Frontonasal suture*: it is the suture between the frontal bone and the two nasal bones.
29. *Frontozygomatic suture*: it is the suture connecting the frontal bone and the zygomatic bone.
30. *Zygomaticotemporal suture*: it is the suture connecting the temporal bone and the zygomatic bone.

31. *Zygomaticomaxillary suture*: it is the suture connecting the zygomatic process of the maxillary bone and the maxillary process of zygomatic bone.
32. *Infraorbital foramen*: it is situated in the maxillary bone, below the infraorbital margin. The infraorbital nerve, artery, and vein are transmitted through this foramen.

6.3 Summary

In conclusion, the aim of this chapter was neither to delve into technical aspects of cephalometric radiographic examination nor to present cephalometric landmarks or cephalometric analysis. The purpose was to feature the main cephalometric views, which can be utilized to image the bones, the sinuses, the nerve canals, and other important anatomic parts of the craniofacial skeleton. The deep knowledge of the cephalometric radiographic anatomy is essential for the correct identification of all the anatomic elements of the craniofacial region. The proper recognition of these anatomic structures is required for infallible cephalometric analysis in orthodontics and orthognathic surgery. The cephalometric analysis is based on the identification and use of anatomic landmarks of different craniofacial structures and possible errors on landmark placement may lead to measurement errors and diagnostics mistakes. Despite the inevitable limitations of 2D cephalometric radiographic images, they remain a valuable imaging tool for the clinicians. The transition to 3D cephalometric radiography not only has started, but has already shown great progress, nevertheless more research and technological advances are needed to fully adopt this imaging method in everyday clinical practice.

References

1. Pacini AJ, Carrera. First X-ray picture of skull: roentgen ray anthropometry of the skull. J Radiol. 1922;3:230–8.
2. Broadbent BH. A new X ray technique and its application to orthodontia. Angle Orthod. 1931;1:45–66.
3. Hofrath H. Bedeuting der rontgenfern und abstands aufnahme fur die diagnostic der kieferanomalien. Fortschr Orthod. 1931;1:232–58.
4. Bjork A. Prediction of mandibular growth rotation. Am J Orthod. 1969;55:585–99.
5. Moyers RE, Bookstein FL, Hunter WS. Analysis of the craniofacial skeleton: cephalometrics. In: Moyers RE, editor. Handbook of orthodontics. Chicago: Year Book Medical; 1988. p. 247–309.
6. Ingerslev CH, Solow B. Sex differences in craniofacial morphology. Acta Odontol Scand. 1975;33:85–94.
7. Broadbent BH Sr, Broadbent BH Jr, Golden WH. Bolton standards of dentofacial developmental growth. St. Louis, MO: CV Mosby; 1975.
8. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod. 1983;83:382–90.
9. Baumrind S, Frantz RC. The reliability of head film measurements. I: landmark identification. Am J Orthod. 1971;60:111–27.
10. Na KC, Yoon YJ, Kim KW. A study on the errors in the cephalometric measurements. Korean J Orthod. 1998;28:75–84.
11. Malkoc S, Sari Z, Usumez S, Koyuturk AE. The effect of head rotation on cephalometric radiographs. Eur J Orthod. 2005;27:315–21.
12. Athanasiou AE, Miethke RR, Van De Meij AJW. Random errors in localization of landmarks in postero-anterior cephalograms. Br J Orthod. 1999;26:273–84.
13. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin N Am. 2008;52:707–30.
14. Durão AR, Pittayapat, Rockenbach MIB, Olszewski R, Ng S, Ferreira AP, Jacobs R. Validity of 2D lateral cephalometry in orthodontics: a systematic review. Prog Orthod. 2013;14:31.
15. Grayson B, Cutting C, Bookstein FL, Kim H, McCarthy JG. The three-dimensional cephalograms: theory, technique, and clinical application. Am J Orthod Dentofacial Orthop. 1988;94:327–37.
16. Zhu M, Cai Z, Zhang LY, et al. Establishment of 3D analysis system of craniomaxillofacial skeleton. Chin J Oral Maxillofac Surg. 1998;8:15.
17. Athanasiou AE. Orthodontic cephalometry. London: Mosby-Wolf; 1995.
18. Proffit WR, Fields HW Jr, Sarver DM. Contemporary orthodontics. 4th ed. St. Louis, MO: Mosby Elsevier; 2007.
19. Bergensen EO. Enlargement and distortion in cephalometric radiography: compensation tables for linear measurements. Angle Orthod. 1980;50:230–44.
20. Weems RA. Radiographic cephalometric technique. In: Jacobson A, editor. Radiographic cephalometry from basics to video imaging. Carol Stream: Quintessence; 1995. p. 39–52.
21. Richardson ME. Reproducibility of depressed posterioranterior cephalometric radiographs. Angle Orthod. 1967;37:48–51.
22. Ricketts RM. Perspectives in the clinical application of cephalometrics: the first fifty years. Angle Orthod. 1981;51:115–50.

23. Tetradis S, Kantor ML. Extraoral radiographic examinations. In: White SC, Fharoah MJ, editors. Oral radiology: principles and interpretation. 6th ed. St. Louis, MO: Mosby, Elsevier; 2009. p. 191–206.
24. Hounsfield GN. Computed medical imaging. Nobel lecture, 1979. J Comput Assist Tomogr. 1980;4:665–74.
25. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8:1558–64.
26. Juerchott A, Saleem MA, Hilgenfeld T, Freudlsperger C, Zingler S, Lux CJ, Bendszus M, Heiland S. 3D cephalometric analysis using magnetic resonance imaging: validation of accuracy and reproducibility. Sci Rep. 2018;8:13029.
27. Sam A, Currie K, Oh H, Flores-Mir C, Lagravere-Vich M. Reliability of different three-dimensional cephalometric landmarks in cone-beam computed tomography: a systematic review. Angle Orthod. 2019;89:317–32.
28. Halazonetis DJ. Computer-assisted cephalometric analysis. Am J Orthod Dentofacial Orthop. 1994;105:517–21.