RADIOGRAPH X-RAY IN ORTHODONTICS

When considering interceptive or active orthodontic treatment, a radiograph may provide additional information on:

a) Presence or absence of teeth
b) Stage of development of permanent dentition
c) Root morphology of teeth, including root length and any existing root resorption
d) Presence of ectopic or supernumerary teeth
e) Presence of dental disease
f) Relationship of the teeth to the skeletal dental bases, and their relationship to the cranial base.

Several radiographic views are routinely used by the orthodontist and they are important diagnostic tools in assessing an orthodontic condition and in determining suitable treatment plans.

1) PERIAPICAL RADIOGRAPHS

A full set of ten periapical X-rays was recommended before the advent of the orthopantomogram (OPG). They covered all the present teeth and the adjacent teeth. They are still ideal for the detection of anomalies related to changes in the size, shape and content of the tooth structure and/or the lamina dura and/or the periapical region.

The advantages of periapical radiographs are:

1-Low radiation dose.

2-Excellent clarity of teeth and their supporting structure.

3-Possibility of obtaining localized view of area of interest.

The main disadvantages of the Periapical x-ray include the increased radiation that a person has to undergo to cover the full complement of his/her teeth. Also at times the patient is not cooperative, and may not allow the repeated placement of films in the desired manner in his/her mouth. With the increased use of OPGs, the use of periapical x-ray has reduced considerably. Yet, they are ideal for localized views in relatively small areas of interest because of the excellent clarity that they allow.

2)BITEWING RADIOGRAPHS

They are seldom used but are ideal for the detection of proximal caries, assessment of existing restorations and the study of interdental bone height in these areas.

3)OCCLUSAL RADIOGRAPH

Occlusal radiographs are used in patients who are unable to open their mouth wide enough for perapical radiographs and are selected in special cases. lntraoral occlusal radiographs are of special interest to an orthodontist when dealing with impacted teeth or for the study of the labio-lingual position of the root apices in the anterior segments of the maxillary and the mandibular dentition. They are particularly useful in the maxillary arch, for assessing root form of the incisors, the presence of midline supernumerary teeth and canine position, either alone or in combination with additional views using parallax. In cases of cleft palate or other congenital anomalies of the maxilla, occlusal radiographs can provide valuable information for treatment planning.

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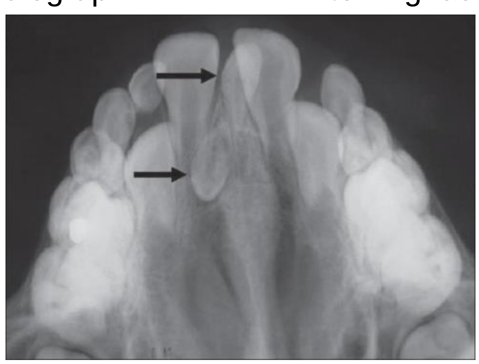
Periapical radiograph

Bitewing radiograph



Occlusal radiograph (showing supernumerary teeth (arrowed)

4) Hand-Wrist and cephalometric Radiographs for skeletal maturity:

The level of maturity attained and the amount of growth potential remaining is an important consideration while treating malocclusions. The maturational status of the patient has a strong bearing on orthodontic diagnosis, treatment planning, outcome of the treatment and post-treatment stability. The prepubertal growth spurt is considered to be an advantageous period for certain types of orthodontic treatment, such as growth modification procedures using orthopedic and functional appliances; while orthognathic surgeries are best carried out after the cessation of growth.

Chronological age is an unreliable guide for the assessment of children's maturational status due to the wide individual variation observed in terms of timing,

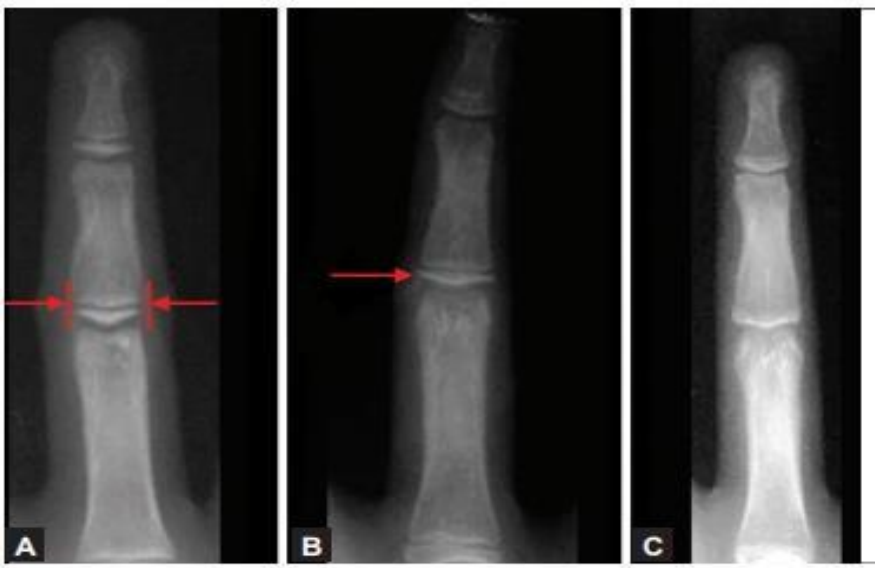
duration and velocity of growth. Children of same age may vary in their maturity status a great deal; therefore, maturity indicators have been developed using other parameters, such as height gained, secondary sex changes, dental development and skeletal ossification.

Since orthodontist works primarily with teeth and bone, the skeletal age or bone age can provide reliable information while helping in accurate growth prediction. Hand- wrist radiographs have been widely used to assess skeletal maturity. However, evaluation of cervical vertebrae on lateral cephalograms is gaining popularity in the recent years.

A) Hand-Wrist radiograph

The basis of using hand-wrist radiographs for assessing skeletal age is that the skeleton in the hand-wrist region is made of numerous small bones (27 small bones + distal ends of long bones radius and ulna); these numerous bones in the hand-wrist region are derived from a total of 51 separate growth centers. The development of these bones from the appearance of calcification centers to epiphyseal plate closure occurs throughout the entire postnatal growth period and therefore provides a useful means of assessing skeletal maturity. Different ossification centers in hand and wrist appear and mature at different times. The appearance and progression of ossification in various ossification centers follows a predictable and scheduled pattern which can be standardized. To do this, a hand–wrist radiograph of the patient is simply compared with standard radiographic images in an atlas of the development of the hand and wrist. It has been shown that stages of hand–wrist development correlate reasonably well with the adolescent spurt in growth of the mandible.

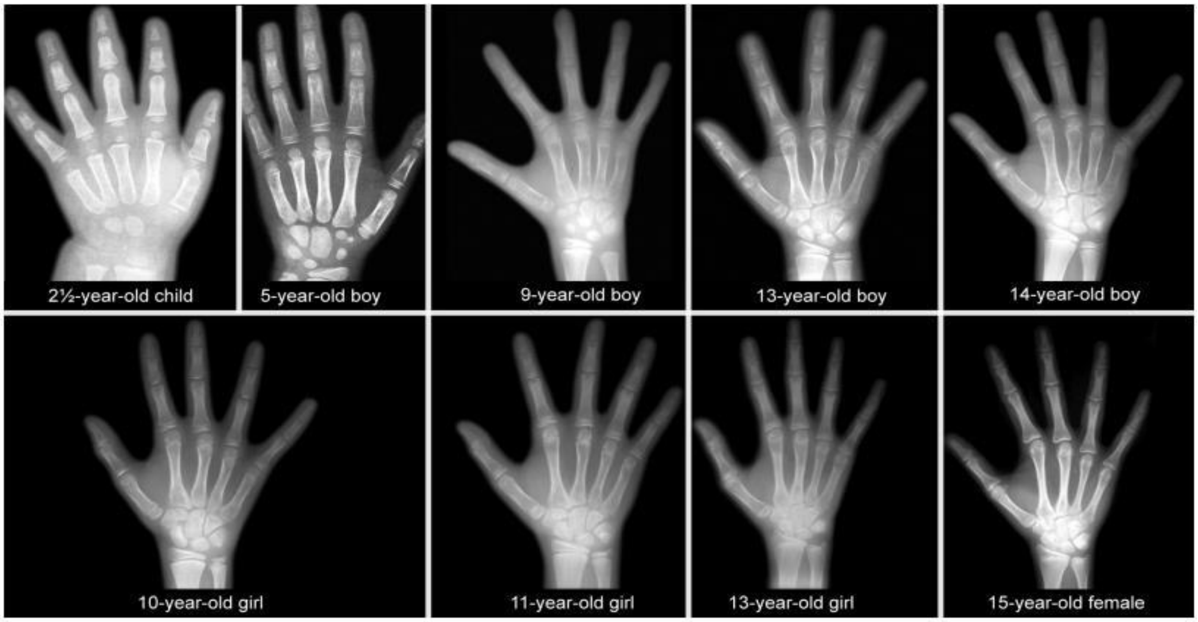
For example the phalanges are ossified from a primary center for the shaft and a proximal epiphyseal center. Ossification in the shaft (primary center) begins prenatally. The epiphyseal centers (secondary centers) appear postnatally around two to four years of age. Ossification in the epiphyses continues progressively and the fusion of the epiphyses with their respective diaphyses is completed during puberty at about 15th– 16th year in females and 17th–18th year in males. The phalanges appear to ossify in three stages (Figure 1). Stage 1: The epiphysis and the diaphysis are equal. Stage 2: The epiphysis caps the diaphysis by covering it like a cap. Stage 3: Fusion occurs between the epiphysis and the diaphysis.



Stages in ossification of phalanges; (A) Stage 1: The epiphysis and the diaphysis are equal; (B) Stage 2: The epiphysis caps the diaphysis by connecting it like a cap; (C) Stage 3: Fusion occurs between the epiphysis and the diaphysis.

Correlation: Hand-wrist radiographs have been correlated to:

- ✓ Dental development.
- ✓ Peak height velocity.
- ✓ Cervical vertebrae.
- ✓ Cranial base outline.
- ✓ Spheno–occipital synchondrosis.



Development of numerous small bones of the hand-wrist region occurs throughout the entire postnatal growth period and thus provides a useful means of assessing skeletal maturity

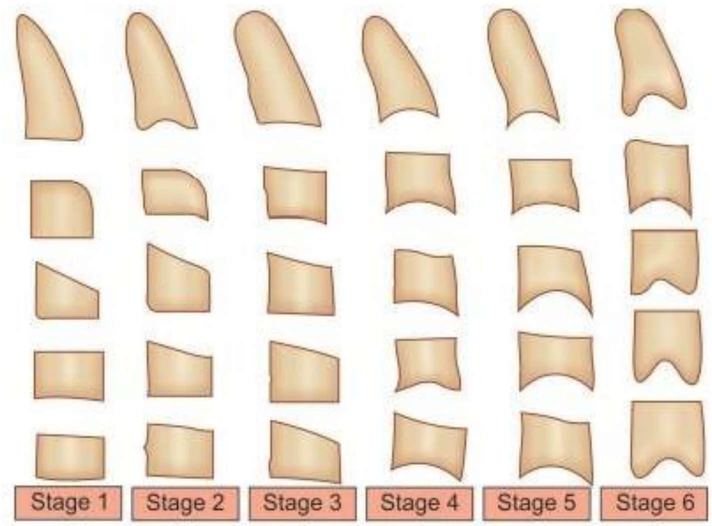
B) Cervical vertebrae skeletal maturity indicator.

Hand-wrist radiographs have been used conventionally as the standard method of evaluating skeletal maturity. Although accurate, this method necessitates additional radiation exposure to patients. Furthermore, the handwrist site is far removed from the jaw, which is the site of orthodontic correction. In recent years, evaluation of cervical vertebrae has been increasingly used to determine skeletal maturation. A new system of skeletal maturation assessment using the cervical vertebrae was first developed by Hassel and Farman. Several subsequent studies have shown a significant correlation between developmental or maturational changes occurring in the cervical vertebrae than that of the hand-wrist region. Cervical vertebrae maturity indicator (CMVI) method is increasingly being used in the recent years instead of the conventional hand-wrist radiograph method. One of the main reasons for the rising popularity of the method is that cervical vertebral maturation can be assessed on lateral cephalograms, which is used regularly in orthodontic diagnosis, thus, precluding the need for an additional radiograph.

Most methods of cervical vertebral maturation are based on morphologic changes that occur in cervical vertebral bodies as growth progresses. Hassel and Farman developed a method of skeletal maturation assessment using cervical vertebrae in which there are six stages of development.

They take into account the morphologic characteristics of the cervical (C2, C3 and C4) vertebrae, such as: Shape of the vertebral bodies, Height of the vertebral bodies and the concavity of the lower border of the cervical bodies. The changes in the shape of cervical vertebral bodies of C3 and C4 at each level of skeletal development are assessed.

Cephalometric radiograph



Assessment of skeletal maturity using cervical vertebrae

- Stage 1: 80–95% of pubertal growth is remaining.
- Stage 2: 65–85% of pubertal growth remains.
- Stage 3: 25–65% pubertal growth is remaining.
- Stage 4: 10–25% of pubertal growth is remaining
- Stage 5: 5–10% pubertal growth remaining.
- Stage 6: Pubertal growth is complete with no more growth potential remaining.

The advantages of using this method of assessment include the following:

1) **Ease of Use:** The assessment of CVMI is relatively straightforward. Orthodontists can quickly evaluate the patient's skeletal maturity by analyzing the shape and developmental stage of the cervical vertebrae on cephalometric radiographs.

2) **No Need for Additional Imaging:** Since cephalometric radiographs are routinely used in orthodontic diagnosis and treatment planning, there is no need for additional imaging procedures, reducing the patient's exposure to radiation.

3) **Patient Engagement:** CVMI results can be used to educate patients and their families about the expected timing and duration of orthodontic or orthopedic treatment. This can improve patient engagement and compliance with treatment recommendations.

5) ORTHOPANTOMOGRAM: (OPG) panoramic radiograph.

It is a panoramic, two-dimensional (2-D) x-ray that captures the entire mouth in a single image, including the teeth, upper and lower jaws, surrounding structures. It is often encountered in dental practice and occasionally in the emergency department; providing a convenient, inexpensive and rapid way to evaluate the gross anatomy of the jaws and related pathology.

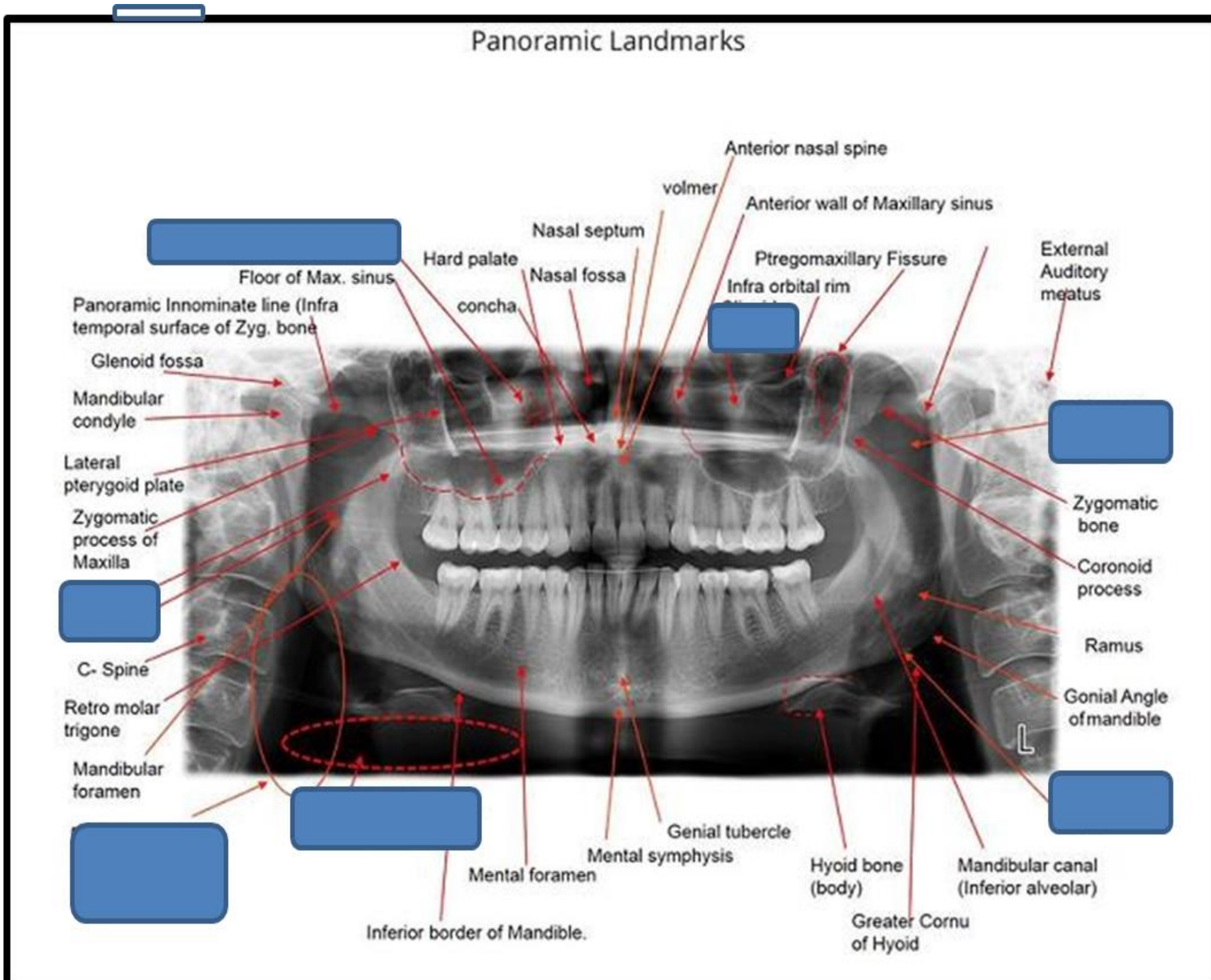
The orthopantomogram is considered an essential diagnostic aid and should be examined prior to undertaking any orthodontic treatment. OPG was is not always available routinely in dental clinics and the patient may require to be referred to special X-ray centers (in the past), nowadays, it become more available and may be present in most of dental clinics.

Advantages of an orthopantomogram

i. A large anatomic area is visualized in a single image
ii. These are probably the most frequently preserved records of any orthodontic case in areas where this facility is available
iii. The radiation exposure is low, less than that for four IOPAs
iv. Patient cooperation is rarely a problem
v. Inter-operator variation is minimal

Disadvantages of an orthopantomogram

i. Specialized equipment is required, needs extra space, so it is rather expensive than periapical x-ray
ii. Distortions, magnifications and overlapping of structures are a problem
iii. lOPAs may still be required
iv. It provides less sharp images and less accurate information about dental and oral diseases than regular intraoral periapical or bite-wing radiographs.



For any student of orthodontics, it is essential to be able to correctly read and interpret an orthopantomogram. It is advised that while reading an orthopantomogram a correct protocol must be followed so as not miss out any important diagnostic details. The most convenient and simple method is presented below.

Step 1

Orient the radiograph as when looking at the patient, i.e. with the patient's left side positioned on the clinician's right. The radiograph is then placed on a view box. It is preferred to dim the remaining lights in the room.

Start examining from the right condylar head and follow the outline along the neck and the posterior border of the ramus. Continue following the outline of the mandibular body to the symphyseal region anteriorly along the lower border of the mandible to the left condyle. Compare the outline for discontinueties, radiopacities or radiolucencies and most importantly from an orthodontic perspective for symmetry. Asymmetry may result from faulty positioning of the patient or that of the cassette in its holder. Note the thickness and density of the mandibular cortex and the other structures including the mandibular canals, mental foramina, and the coronoid process.

Step 2

Examine the medullary bone of the mandible for the usual anatomic landmarks and note anything suggestive of pathology, especially in the periapical regions of the teeth. The third molar development and position should definitely be noted as it may play an important role in determining the type of retention planned and/or their enucleation if required.

Step 3

Next, examine the cortical outline of the maxilla starting on the right side. Trace the pterygo-maxillary fissure, hard palate with the anterior nasal spine. Examine the nasal cavities and the nasal septum followed by the maxillary sinuses. It is advisable to compare the right and left sides especially of the nasal cavities and the maxillary sinuses. Radiopacities in these regions could be suggestive of pathology or sometimes the presence of foreign body. These might reflect upon the breathing pattern of the patient.

Step 4

Margins of a number of soft tissue structures may be seen on the orthopantomogram. These include the--- tongue, soft palate, nose and earlobes the lip lines and the nasolabial folds.

Step 5

Radiopaque shadows, which superimpose on normal anatomic structures are called "ghosts" and are actually artifacts. These can sometimes pose a problem in radiographic interpretation. These are created when the X-ray beam projects through a dense object, e.g. the spinal cord and the opaque shadow of the object projects onto the opposite side of the radiograph.

Step 6

Finally evaluate the teeth for-presence, stage of development, state of eruption unerupted or impacted teeth, placement, root morphology and position, cavities, fractures, contacts, and/or any pathology.

Teeth may appear to be magnified or minimized in the horizontal dimension depending on their position. The maxillary and mandibular cusp tips should be generally separate (unless there is a change in the cant of occlusion and there should be gentle curve to the occlusal plane.

The orthopantomograrm may not be sufficient by itself. If any doubt arises it is recommended that an lOP A of the concerned region be taken

6) Cone-beam Computed Tomography (CBCT)

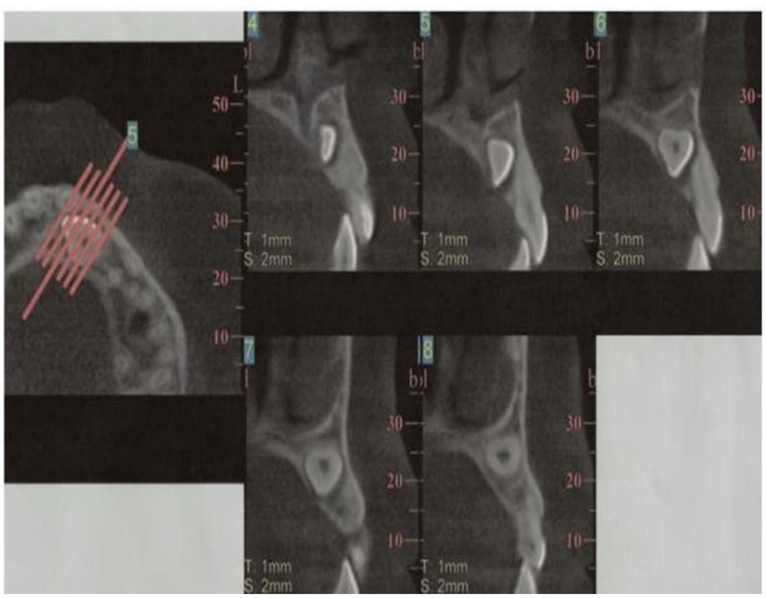
Plain film and cephalometric radiography are invaluable for accurate diagnosis and treatment planning, but they only provide a two dimensional image of a three-dimensional structure, with all the associated errors of projection, anatomical superimposition, landmark identification, measurement and interpretation.

Imaging of the hard tissues composing the jaws and dentition using conventional computed tomography (CT) is largely impractical, due to the high radiation dosage, lack of resolution and significant cost. The introduction of cone- beam computed tomography (CBCT) for views of the face and jaws in the early 21st century has resulted in the dosage being reduced and the resolution significantly improved, with its adaption and refinement for imaging of the teeth and jaws now providing a useful three-dimensional diagnostic tool. There is little doubt that the images that can be obtained from CBCT are impressive, allowing accurate visualization and analysis of the teeth and jaws in three-dimensions. CBCT can also be very useful for airway analysis, assessment of alveolar bone height and volume prior to implant placement and imaging of temporo-mandibular joint morphology.

Orthodontic Applications of Cone Beam Computed Tomography:

Conventional computed tomography (CT) imaging involves the use of rotating X-ray equipment, combined with a digital computer, to obtain images of the body. Using CT imaging, cross-sectional images of body organs and tissues can be produced. CBCT is a faster, more compact version of traditional CT with a lower dose of radiation. Through the use of a cone-shaped X-ray beam, the size of the scanner, radiation dosage, and time needed for scanning are all dramatically reduced. The three dimensional (3D) views produced may be useful in certain orthodontic cases:

- Accurate location of impacted teeth and a more accurate assessment of any associated pathology, particularly resorption of adjacent teeth.
- Assessment of alveolar bone coverage, height and volume.
- Severe facial asymmetry, especially asymmetries involving roll and yaw.
- Syndromes, congenital deformities, and sequelae of facial trauma.
- Planning of some complex combined orthodontics and orthognathic surgery cases



Cone-beam computed tomography (CBCT) of the patient with the impacted canine, confirmed that there is a small amount of root resorption occurring on the palatal aspect of the upper left lateral incisor, close to the apex of the tooth.

There is a consensus that it provides new information that could improve the treatment plan in certain situations, and enough enthusiasm to lead some orthodontists to advocate use of CBCT on all orthodontic patients, replacing panoramic, cephalometric, and occlusal radiographs, as well as tomograms of the TMJ. There is a significant radiation dose increase in doing this. However, it should not be forgotten that the radiation dose from traditional intraoral and extraoral radiography is significantly less than that from CBCT imaging of the same area (see Table below)

Table 6.1 Radiographs used in orthodontics and dose equivalence

Radiographic examination	Effective radiation dose (µSv)	Equivalent background radiation (days)	Risk of fatal cancer (per million)
DPT	3–38	0.5–5	0.2–1.9
Cephalometric lateral skull	2–5.6	0.3–0.45	0.34
Upper standard occlusal	8	1.2	0.4
Bitewing/periapical	0.3–2.2	0.15–0.27	0.02–0.6
Conventional CT scan (maxilla)	100–3000	15–455	8–242
Conventional CT scan (mandible)	350–1200	53–182	18–88
Chest	14	3	2
CBCT (small volume)[a]	10–67	4–10	
CBCT (large volume)[a]	30–1100	10–42	

Figures are based upon Radiation Protection 136, (2004). European Guidelines on Radiation Protection in Dental Radiology. The Safe Use of Radiographs in Dental Practice. European Commission. It should be emphasized that these only represent a guide and are regularly updated as new recommendations are made, particularly with regard to tissue weighting factors in the calculation of effective doses.
CBCT, cone-beam CT; CT, computerized tomography; DPT, dental panoramic tomograph.
[a]Cone-beam CT data is based upon Pauwels et al (2012) and the 2011 SEDENTEXCT publication.

Cone beam computed tomography (CBCT) now allows the acquisition of detailed 3D images of the face in high resolution. Using this 'virtual' 3D information, software is being developed that could revolutionize the way that orthognathic planning and surgery is undertaken.

Tooth Morphology and Relative Position within the Alveolar Bone

High-resolution images that include an arch quadrant or both upper and lower arches are needed to evaluate buccal and lingual plates of the alveolar bone, bone loss or formation, bone depth and height, presence or absence of unerupted teeth, tooth development, tooth morphology and position, amount of bone covering the tooth, and proximity or resorption of adjacent teeth. CBCT findings may lead to modifications in the treatment planning (e.g., avoid extraction, help decision of which tooth to extract, evaluate dilacerated roots or placement of bone plates and miniscrews), reduced treatment duration, and additional root resorption control and in the orthosurgical planning. Before placing temporary anchorage device (TADs), CBCT is being used as a clinical tool to identify optimal position and to avoid damage to roots. The use of surgical guides based on CBCT data has also been suggested.

Temporomandibular Joint Health and Disease

High-resolution images that include one joint at separate right and left acquisitions yield the best quality of images for TMJ assessments. The spectrum of the clinical and pathologic presentation of TMJ osteoarthritis ranges from structural and functional failure of the joint with disc displacement and degeneration to subchondral bone alterations and sclerosis and bone erosions.

Dentofacial Deformities and Craniofacial Anomalies

CBCT images offer the ability to analyze facial asymmetry and anteroposterior, vertical, and transverse discrepancies associated with complex craniofacial problems. The virtual treatment simulations using 3D virtual or printed surface models constructed from CBCT or CT images can be used for treatment planning in orthopedic corrections and orthognathic surgery and for printing surgical splints after performing virtually simulated surgery.