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# Dental CT: imaging technique, anatomy, and pathologic conditions of the jaws

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**Abstract** In addition to conventional imaging methods, dental CT has become an established method for anatomic imaging of the jaws prior to dental implant placement. More recently, this high-resolution imaging technique has gained importance in diagnosing dental-associated diseases of the mandible and maxilla. Since most radiologists have had little experience in these areas, many of the CT findings remain undescribed. The objective of this review article is to present the technique of dental CT, to illustrate the typical appearance of jaw anatomy and dental-related diseases of the jaws with dental CT, and to show where it can serve as an addition to conventional imaging methods in dental radiology.

**Keywords** Computed tomography · Jaw · Teeth · Implant

## Introduction

Dental CT has become an established method for imaging of jaw anatomy prior to dental implant placement [1, 2, 3, 4, 5, 6]. The clinical use of these implants has rapidly increased over the past 20 years. It is estimated that 300,000 implants are placed each year with over 50 companies involved in the manufacture, marketing and distribution within the United States [7, 8].

The term "dental CT" does not represent a particular modality, but rather a specific investigation protocol. The main features of this protocol include the acquisition of axial scans of the jaw with the highest possible resolution together with curved and orthoradial multiplanar reconstructions (Fig. 1). Dentists commonly diagnose and work in the submillimeter scale; hence, a highly detailed image quality is required and challenges CT to its technical limits. This article reviews the specific technique of dental CT and illustrates the typical appearance of jaw anatomy and dental-related diseases of the jaw.

## Technique

### History

The technique of dental CT, also called Dentascan, was developed by Schwarz et al. in 1987, when these investigators first used curved multiplanar reconstructions of the jaw [9, 10]. At that time, the number of inserted implants in the jaw had steadily increased and there was a critical need for accurate imaging of the jaw anatomy, especially in the bucco-lingual plane. The major disadvantage of CT in the jaw region, the metal artifacts from tooth fillings, was overcome by using the axial plane for scanning instead of the coronal plane, which kept these artifacts in the occlusion plane and hence left the jaw

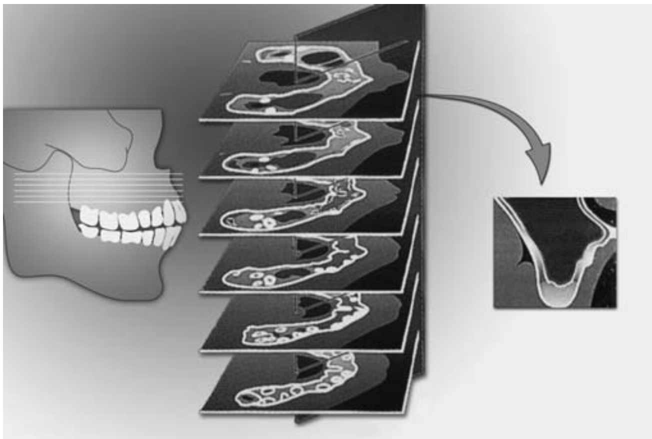

**Fig. 1** Dental CT of the maxilla. From axial slices (*center*) of a given investigation volume orthoradial reconstructions are calculated (*right*). As a single example this reconstruction demonstrates the alveolar crest and the left maxillary sinus

bone undistorted. This allowed for accurate display of the vertical as well as the important bucco-lingual dimensions of the jaw in actual size, which facilitated the work of the dentist [11].

Prior to this development, the first useful technique for pre-implant imaging of jaw anatomy was conventional orthoradial tomography, using a complex (circular, spiral, or hypocycloidal) blurring device, such as the Scanora or CommCat (Soredex, Marietta, Ga.; Imaging Sciences International, Roebling, N.J.) [12, 13]. Although this technique is still a valuable procedure, it is prone to errors, has the known disadvantages of conventional tomography, and does not allow imaging of the complete jaw within an acceptable time frame. Due to the higher cost and lesser availability of dental CT, conventional orthoradial tomography is still a standard investigation in many implanologic centers.

During the past years various studies have been published which have validated dental CT as an excellent tool for diagnosing dental-related pathologies [3, 14, 15, 16, 17, 18, 19, 20, 21]. Since occurring changes may be very subtle, an optimal image quality with the highest possible resolution is essential for establishing a correct diagnosis.

## Patient

Prior to imaging, the patient should be informed about the investigation and instructed not to move or swallow during the scan. The investigation is performed in the supine position with the cervical spine slightly overextended backward. The head should be strapped to the headrest and positioned as symmetrically as possible. This can be checked in the scoutview, where both rami and the angles of the mandible should be perfectly aligned. If movement of the mandible during the scan is likely to occur (e.g., edentulous jaws with lack of occlusion), it is possible to immobilize the jaw by having the patient bite on a cotton roll or on fast-hardening impression material.

## Scanner protocol

Dental CT investigations can be performed either on a conventional CT, spiral CT, or a multislice CT scanner. The device should be capable of performing high-resolution scans with a small focal spot and acquiring thin slices of 1.5 mm or less. A table feed of 1 mm is necessary to obtain high-quality images with optimal detail in the scan plane as well as in the multiplanar reconstruction. A spiral scan technique with 1 s per rotation is sufficient in most cases where imaging of jaw anatomy is performed prior to implant placement. If imaging of pathologic conditions is required, small details can be obtained by increasing the scan time to 2 s per rotation. The larger number of views due to the slower rotation speed of the tube provides the more detailed information necessary for imaging of frequently very subtle pathologic features. The field of view should be limited to 120 mm or less to avoid unnecessary imaging of the spine, neck, or posterior cranial fossa. A well-established universal protocol is provided as an example in Table 1.

Scan direction is caudocranial beginning with the mandible base and extends to include the alveolar crest for the mandible, whereas for the maxilla the scan plane starts with the alveolar crest and extends upward to include all root tips. If sinusitis is present, extensions of the scan are recommended to exclude possible dental-related causes, such as displaced root remnants or foreign bodies.

## Dose reduction

Dental CT images are displayed with a very low contrast setting (bone window) due to the excellent contrast between bone and soft tissue. Since no contrast medium is used and displaying soft tissue detail with digital enhanced contrast (soft tissue window) is usually not necessary, dental CT is ideally suited for applying dose-reduced investigation protocols [4, 22, 23]. This is primarily accomplished by reducing the tube current, which leads to increased quantum noise noted in the soft tissue compartment, whereas bone is only marginally affected. In addition, using 1.5-mm slice thickness instead of 1.0 and/or using a spiral technique with a pitch factor of more than 1.0 can further reduce dose delivery. The limiting factor here is that the important visualization of the mandibular canal is degraded when a high pitch factor is used, although orthoradial reconstructions are displayed

**Table 1** Example of standard investigation protocols for imaging of the anatomic situation (*Anatomy*) or pathologic conditions (*Pathology*) of the jaw with dental CT

| | Anatomy | Pathology |
|---|---|---|
| Scan type | Spiral | Incremental |
| Slice thickness (mm) | 1.0 | 1.5 |
| Table feed | 1.0 | 1.0 |
| Field of view (mm) | 120 (mandible)<br>100 (maxilla) | 120 (mandible)<br>100 (maxilla) |
| Scan time (s) | 1 | 2 |
| Matrix | 512 | 512 |
| Tube current (mA) | 25–100 | 25–100 |
| Tube voltage (kV) | 120 | 120 |
| Filter | High-resolution edge enhanced filter | High-resolution edge enhanced filter |
| Window setting | 2000 HU with, 400 HU center (bone window) | 2000 HU with, 400 HU center (bone window) |
| Scan plane | Hard palate (maxilla)<br>Mandible base (mandible) | Hard palate (maxilla)<br>Mandible base (mandible) |

in correct size. In addition, cystic lesions can be harder to detect since quantum noise can mimic mineralization.

Another possibility for dose reduction is to limit the scan range of the investigation. This is easily accomplished by excluding the occlusal region (crowns of the teeth), since this area is easily investigated by clinical means. Moreover, this region is frequently obscured by metal artifacts and hence provides limited additional information.

### Reconstructions

After the examination, the axial slices are transferred to a workstation to perform multiplanar reconstructions. This is usually done manually with the aid of a dental software package on the workstation, although some CTs have a dental software package included on the operating console. A planning line is drawn manually by the technician along the centerline of the jaw arch, which is the base for the subsequent orthoradial and panoramic multiplanar reconstructions. These multiple, computer-generated orthoradial reconstructions are calculated perpendicular to the planning line. Usually, the distance between each of the 40–60 orthoradial cuts is chosen to accommodate all reconstructions on a single sheet of film (usual distance, 1.5–3.0 mm; Fig. 2). Panoramic reconstructions are calculated along the planning line. Frequently, the dental software package allows calculation of two to four additional panoramic cuts parallel to the planning line, which are positioned just slightly closer to the buccal (outer) and lingual (inner) side from the planning line (usually approximately 2 mm). These cuts are seldom of major diagnostic importance but provide a very good overview of the general situation, since the panoramic cuts resemble conventional panoramic radiographs, which are familiar to dentists, oral surgeons, or maxillofacial surgeons.

### Hard copy

If a single jaw is scanned, all images can be displayed on three hard copies, of which the first two are the axial scans. This should be possible if an array of four columns by five rows of slices per hard copy is chosen. The remaining single hard copy accommodates all dental reconstructions, which should be precisely in 1:1 (lifesize) scale. This can be easily checked using a simple ruler next to the centimeter scale that usually is displayed with the images. This hard copy should consist of the axial planning slice, which includes the planning line and the orthoradial lines. Subsequent scans are numbered to allow correlation with the accordingly numbered orthoradial reconstructions. Panoramic reconstructions are included on the same hard copy and should allow correlation with the orthoradial reconstructions by indicating their position. The use of three hard copies offers the advantage of a good overview of the entire investigation for reporting purposes, as well as for ease of handling for the referring clinician.

## Jaw anatomy

### Normal anatomy

#### *Visible structures*

*Teeth.* The jaws contain 32 teeth (=16 per jaw, 8 per quadrant) which, based on their configuration and function, are grouped for each quadrant into molars (3), premolars (2), canine (1), and incisors (2). The tooth generally consists mainly of dentin which has a radiologic opacity similar to cortical bone. In the region of the crown, the dentin is surrounded by a thin layer of enamel, which has by far highest opacity of all natural tissues (similar density as contrast media or certain metals, e.g.,

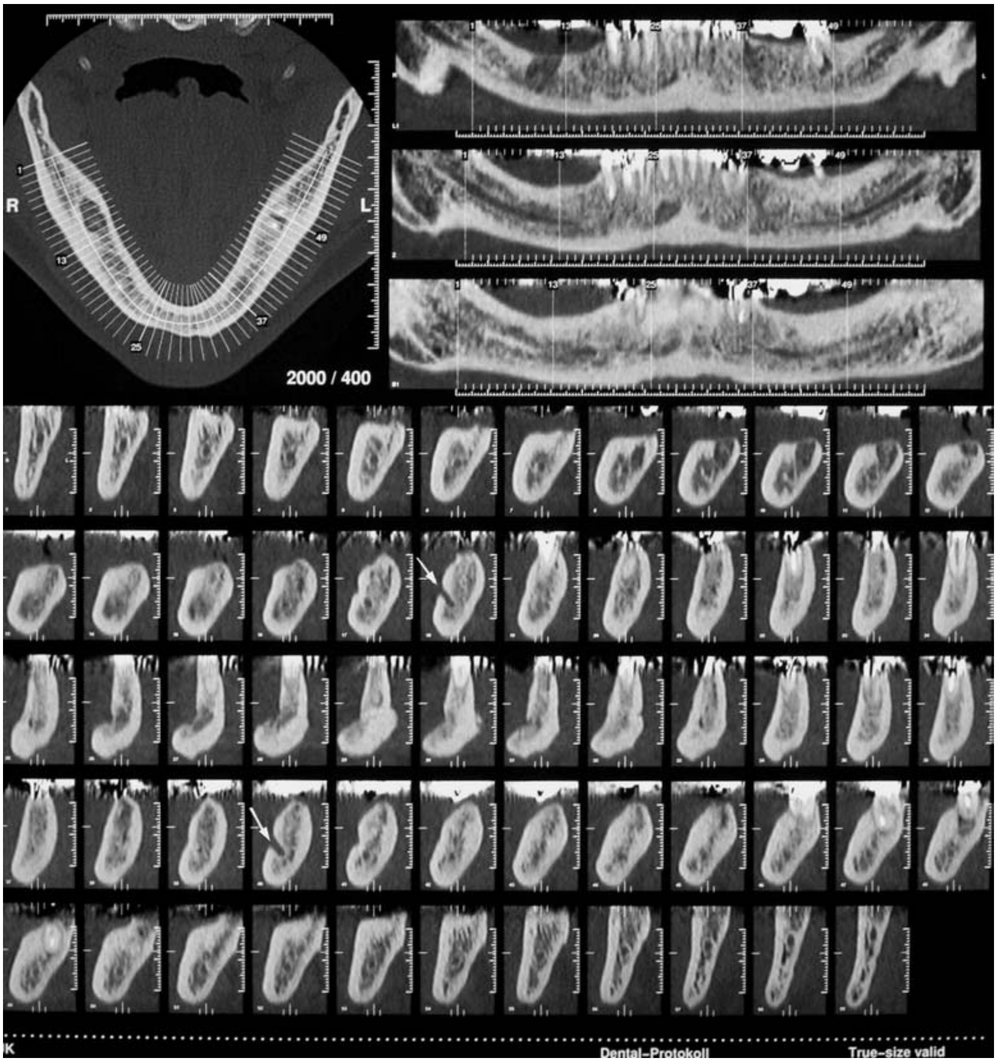


**Fig. 2** Complete hard copy with panoramic and orthoradial reconstructions of the mandible. *Upper left* axial slice of the mandible with planning line along the mandibular arch together with multiple numbered orthoradial lines. *Upper right* three panoramic slices reconstructed along the planning line. *Lower part* multiple orthoradial reconstructions corresponding to the orthoradial lines visible on the axial slice. Additionally, both mental foramina are indicated by two *small arrows* to facilitate the orientation between the interforaminal region and the two retroforaminal regions (*right* and *left*) The mandibular canal is visible as a small cortical ring in each retroforaminal region

titanium). The root canal is a centrally located, hypodense structure that is large in the crown region and decreases in size toward the direction of the root tip. The root dentin is surrounded by a thin layer of cementum, which cannot be differentiated radiographically. The tooth in the region of the root is surrounded by the narrow periodontal space, which is hardly visible on CT. A widened, clearly visible periodontal space is typically indicative of pathology. The molars in the mandible have two roots, whereas molars in the maxilla consist of three roots. The first premolar of the maxilla has two roots, whereas the remaining teeth have a single root (Fig. 3). Variations in the number of roots are primarily found in both maxillary premolars and the third molars.

*Alveolar crest.* The alveolar crest is the part of the jawbone that holds the tooth roots, periodontal space, and the lamina dura that envelops the periodontal space. The alveolar crest is the part of the jaw where most pathologic conditions occur.

*Mandible base.* The mandible base is located below the alveolar crest and contains the mandibular canal with the inferior alveolar nerve and vessels. The neurovascular bundle enters the canal at the mandibular foramen and exits through the mental foramen. The mandibular canal usually is well visualized on axial slices and orthoradial reconstructions, as long as it is surrounded by cortical bone. Frequently, in short segments, this cortical lamina is not present on some orthoradial reconstructions and hence the mandibular canal is obscured by the surrounding cancellous bone. Since this is hardly ever the case for the entire extent of the canal, the exact position of the mandibular canal can be located by means of interpolation between other orthoradial reconstructions where the canal is visible. Injury to the mandibular canal results in

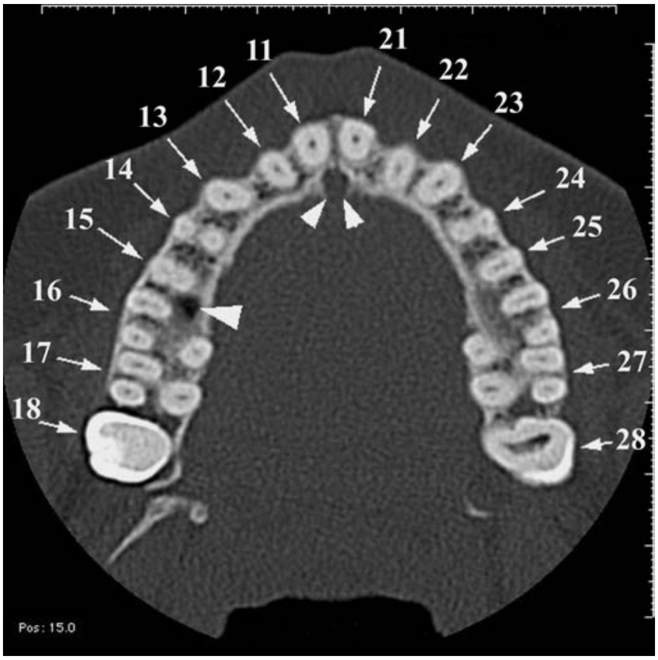


**Fig. 3** Axial slice through the alveolar crest of the maxilla. The numbers of each tooth are given according to international nomenclature (the first digit representing the quadrant and the second digit the tooth counted from the midline). In addition, the incisive canal (*double arrowhead*) and a small part of the maxillary sinus (*single arrowhead*) is visible

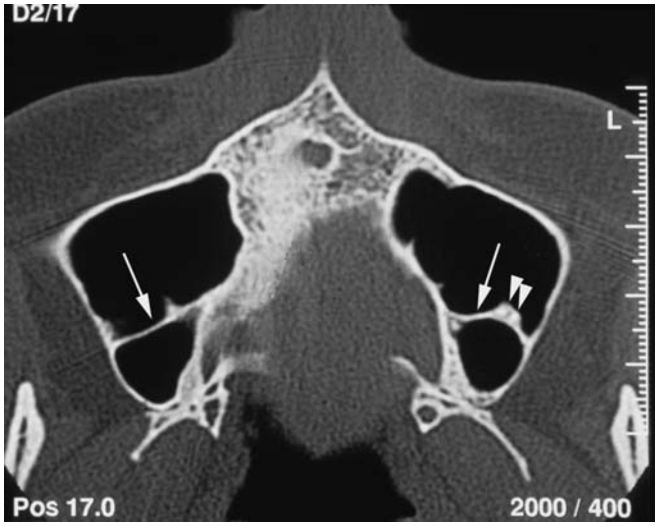


**Fig. 4** Axial slice through the maxillary sinus. Prominent Underwood septum within both sinuses (*arrows*). Two root tips of tooth 27 are visible within the left septum (*arrowheads*)

paralysis or numbness of the chin and edge of the mouth. Since the neurovascular bundle within the mandibular canal also supplies the teeth, sudden loss of tooth vitality within a whole quadrant can occur. Damage to the mandibular canal during placement of implants (or extraction of third molars) therefore represents one of the major issues for legal steps taken against dentists.

*Maxillary sinus.* The maxillary sinus can reach far mesially and between the roots of the molars and premolars. Due to the close relationship with these other structures, the maxillary sinus can be easily affected by inflammatory conditions and cystic lesions of the adjacent teeth. As a frequent variant, a bony septum may be visible in the sinus floor (Underwood septum), which can complicate pre-implant augmentative procedures such as the "sinus lift" (Fig. 4) [24].

## Bone volume/resorption/atrophy

After the loss of teeth, atrophy of the alveolar crest is a typical occurrence. This is due to the loss of chewing forces in the jaw and can lead to a complete loss of the alveolar crest in edentulous patients. Since the height of the alveolar crest in both jaws can be up to 4 cm, a third of the patient's face is lost and a typical surplus of soft tissue is present. Cawood and Howell have described and classified the bone volume loss in anatomic studies that can be applied to dental CT due to the perfect visualization of the alveolar crest in the orthoradial plane [25]. These six resorption classes represent typical appearances of jaw atrophy after tooth loss (Fig. 5). In general, after extraction of a tooth (class 2), a continuous reduction of bone occurs until the alveolar crest demonstrates a "knife-edge" appearance (class 4). If atrophy continues, further bone height is lost until only the jaw base remains as a thin bone layer (class 6). Although atrophy is a continuous process, single classes can be skipped. For example, class 2 can directly transform into class 4 by loss of the buccal cortical bone (juga alveolaria), which results in a knife-edge alveolar crest. The resorption classes are an important consideration when implantation is planned, and have an influence on the selection of implant dimensions and type as well as for the choice of a possible augmentation procedure such as sinus lift, onlay graft, or lateral augmentation. These operative procedures are used to artificially enhance the available bone volume by deposition of autologous bone or artificial bone replacement material.

## Bone quality

Bone quality, as described by Lekholm and Zarb, is of major importance for the success of an implant placement [26]. For preoperative planning bone quality has been categorized into four classes that basically describe the relation of cortical and cancellous bone in a specified region of the jaw (Fig. 6). The amount of cortical bone is

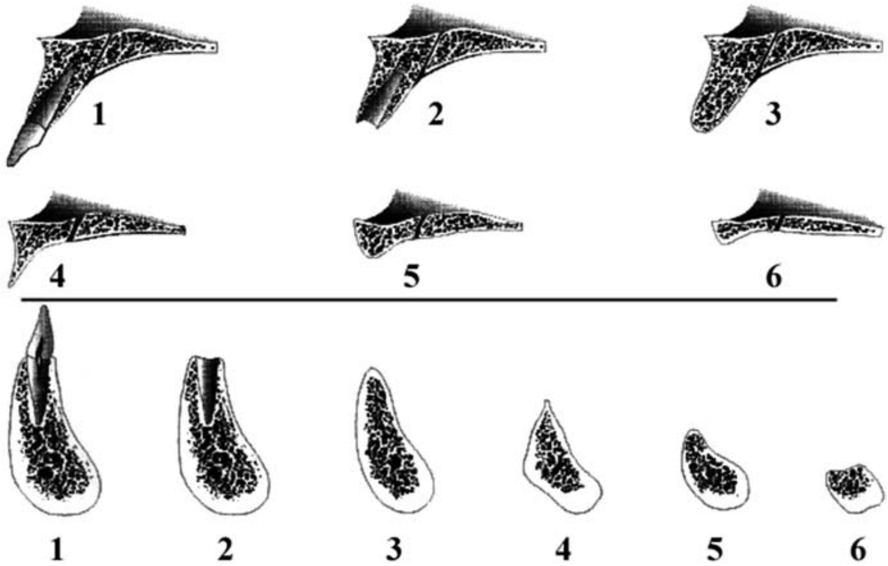


**Fig. 5** Classification of bone atrophy according to Cawood and Howell [25]. Schematic representation of atrophic changes in the anterior midline of the maxilla (*upper part*) and mandible (*lower part*)

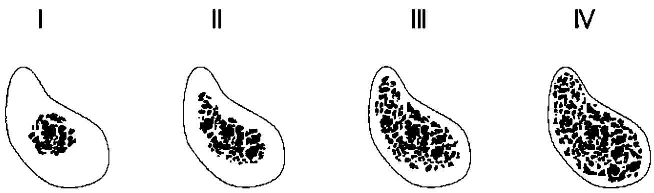


**Fig. 6** Classification of bone quality according to Lekholm and Zarb [26]

responsible for the primary stability of the implant, whereas cancellous bone is responsible for long-term stability. Although class 1 indicates optimum stability of the implant, studies have revealed classes 2 and 3 to have the best long-term results, with class 4 having the most frequent premature implant loss [5, 27].

### Measurements/implants

Evaluation of bone quantity is performed by measuring the height and width of the alveolar crest for a specified region. These values serve as an overview of the available bone quantity and do not serve as a suggested implant size. This is because the oral surgeon has multiple choices of implant sites and implantation directions using different angulations and different diameters. The choice is not solely based on the available amount of bone (bone-demanded implantation), but must take prosthodontic and cosmetic factors into account. Moreover, immediately prior to implant placement a canal is drilled, which usually is 1–2 mm longer than the final inserted implant. Thus, injury of anatomic structures can occur even if the final implant does not reach these structures; hence, the radiology report concerning measurements cannot serve as the sole factor for implant choice.

## Jaw pathology

In addition to imaging of jaw anatomy and its variants, dental CT has proved to be an excellent tool for diagnosing pathologic conditions of the jaw. Most lesions in this region are visible only in the millimeter or even submillimeter scale and therefore visualization of these alterations was not possible with typical CT protocols. This changed with the advent of dental CT where it was possible to visualize objects on the submillimeter scale. Still, conventional imaging (dental film, panoramic radiography) is the basic screening investigation for diagnosing pathologic conditions, but CT can aid in revealing additional features and in localization of a lesion or even help to exclude the presence of a pathologic condition more easily. In the following section, the most frequent pathologies found in the jaw are summarized.

### Chronic apical periodontitis

Chronic apical periodontitis (CAP) is a frequent finding in patients with pulpitis and in patients after dental treatment by root canal filling. It is characterized by an enlargement of the periodontal space at the periapical region of the tooth. Dental CT can demonstrate the root tip within a small osteolytic region (the enlarged periodontal space) [16]. If bacteria spreads into the surrounding cancellous bone in the chronic stage, a reactive enlargement of trabeculae occurs. This entity is described as "sclerosing ostitis," a form of chronic osteomyelitis. When the CAP reaches cortical bone, a periosteal reaction (Fig. 7)

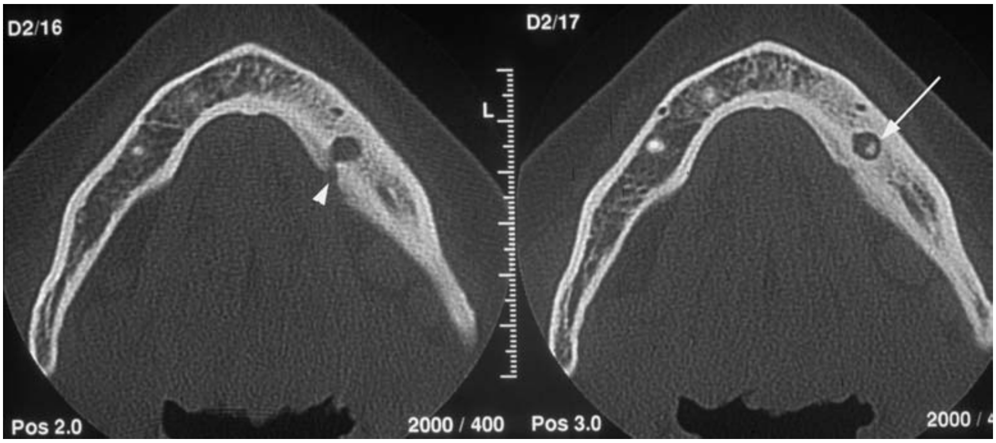


**Fig. 7** Axial slices demonstrating Chronic apical periodontitis (CAP) of tooth 35 (*arrow*) with surrounding sclerosing ostitis and lingual-sided perforation and periosteal reaction (*arrowheads*)

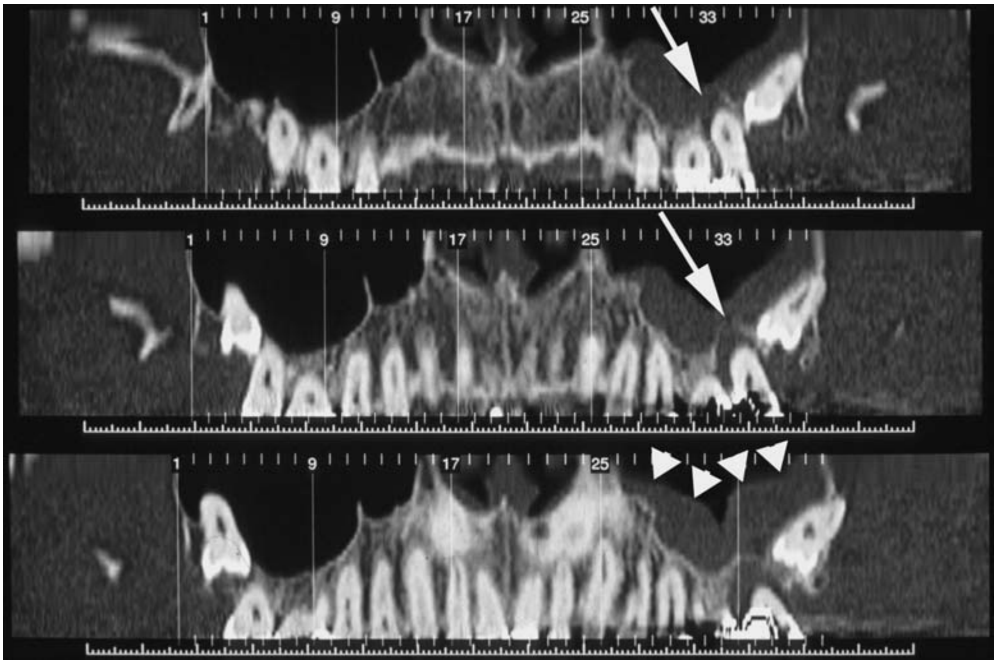


**Fig. 8** Panoramic slices of the maxilla. A CAP of tooth 27 with perforation into the left maxillary sinus (*arrows*) and reactive dentogen sinusitis (*arrowheads*)

or reactive sinusitis can be visible (Fig. 8). After perforation of the apical periodontitis through the cortical bone into the surrounding tissue, an infiltrate with soft tissue edema can be seen in this compartment.

## Radicular cysts

When a CAP remains untreated, it tends to grow until the granulation tissue around the root apex transforms and becomes a cystic, epithelial-lined lesion. These radicular cysts are the most common type of cyst in the jaw and can reach a substantial size with the risk of fracture [17, 28, 29]. They are characterized by a large, well-defined radiolucency (>1 cm) with the apex of a non-vital root in the epicenter of the lesion (Fig. 9). The size at which the transformation from CAP occurs is approximately 1 cm with a large overlap. Although a clear differentiation between CAP and radicular cyst based on criteria other than size is impossible, the choice of treatment is often different (operative vs endodontic treatment).

## Dentigerous cysts

The second most common cyst in the jaw, the dentigerous cyst, also called follicular cyst, is located around the crown of an impacted tooth and attaches to the cemento-enamel junction, which helps in the differentiation from radicular cysts [30, 31]. Dentigerous cysts are sharply delineated and frequently demonstrate a local


**Fig. 9** Radicular cyst within the left maxillary sinus arising from tooth 26. A root tip (*arrow*) is visible in the center of the lesion. Reactive mucosal swelling within the left sinus

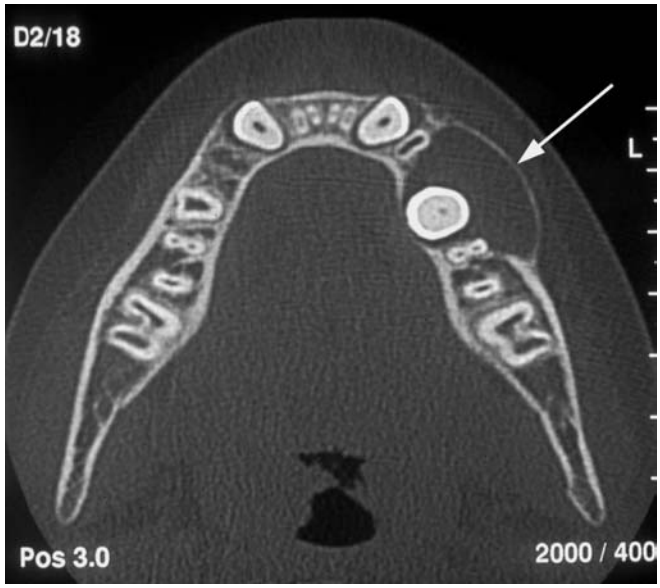


**Fig. 10** Dental CT of the mandible demonstrating a dentigerous cyst (*arrow*) arising from tooth 35. Adjacent roots are reached but not surrounded by the cyst

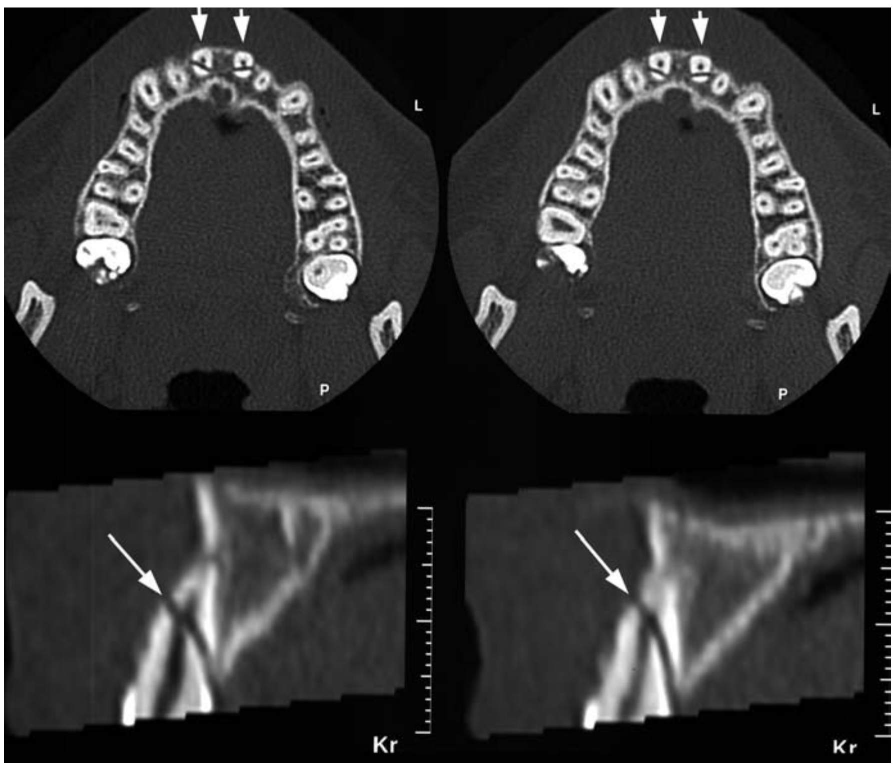


**Fig. 11** Dental CT of a fractured tooth 11 and 21 (*arrowhead*) after trauma, demonstrating a mesio-distal fracture line. Orthoradial reconstructions demonstrate oblique fracture of both teeth (*arrows*)

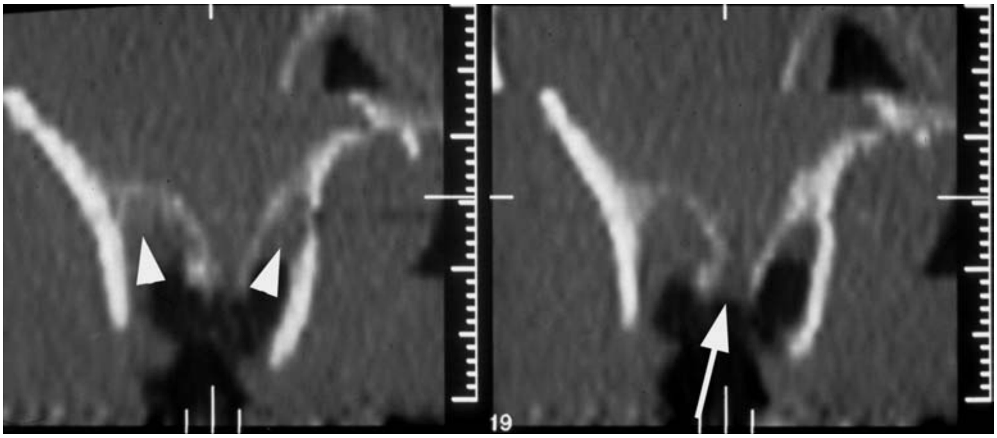


**Fig. 12** Orthoradial reconstruction of region 17: extraction socket (*arrowheads*) demonstrating an oro-antral fistula from the trifurcation (*arrow*) to the right maxillary sinus with reactive sinusitis

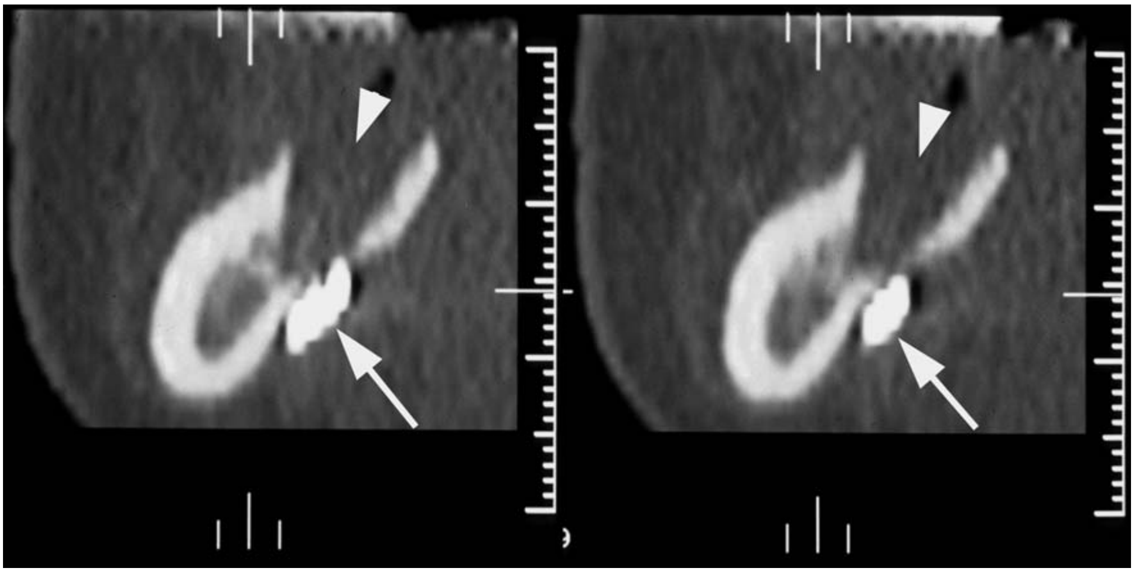

**Fig. 13** Foreign body in the lingual-sided soft tissue of the mandible (*arrows*). Panoramic radiography revealed the impression of the foreign body located within the visible extraction socket (*arrowheads*)

expansion of the buccal or lingual cortical plate. Adjacent roots of neighboring teeth can be easily reached, but usually are not surrounded by the cyst completely (Fig. 10).

## Root fractures

Horizontal root fractures, which usually occur after trauma, are easily diagnosed by clinical examination and conventional radiographic techniques, whereas vertical root fractures are visualized with dental film only when the fracture line is oriented at least partially within the direction of the X-ray beam. Studies have demonstrated that dental CT is superior to dental film in diagnosing vertical root fractures because CT is not sensitive to beam orientation [19]. These fractures usually occur as a result of conservative restorations of a tooth with a post or in endodontically treated teeth.

The limitations of dental CT in the diagnosis of dental fractures, resulting in false-negative readings, include small fissures below the resolution capability of CT and superimposed metal artifacts from root posts. In addition to obscuring a root, these artifacts can also mimic fracture lines, but these limitations can be overcome if the fracture extends below the root post and is visible there. Although horizontally oriented fractures lying in the scanning plane are difficult to visualize with CT, oblique fractures remain easily detectable (Fig. 11).

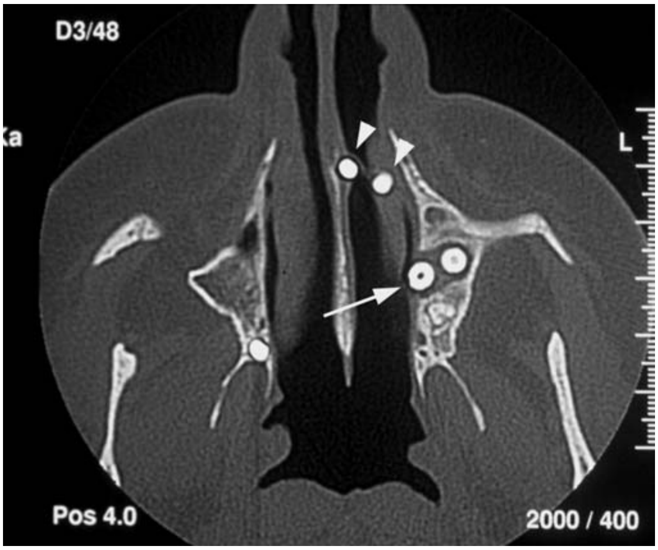


**Fig. 14** Axial slice demonstrating extensive "periimplantitis" in region 26 (*arrow*) and misplacement of implants in the anterior maxilla (*arrowheads*)

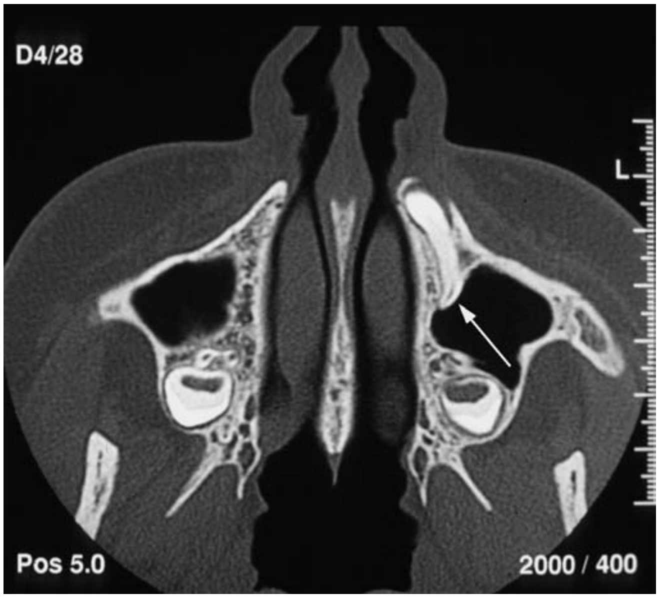


**Fig. 15** Axial slice of the maxilla. Horizontally positioned and impacted tooth 23 with a hook (*arrow*) at the apex within the left maxillary sinus complicating a planned extraction

Sinus fistula

Sinus fistula frequently occurs as a complication after tooth extraction or after root resection in the maxillary molar region and must be treated to prevent maxillary sinus inflammation. Dental CT can clearly localize the corresponding osseous defect in the alveolar ridge and frequently orthoradial reconstructions offer optimal visualization for preoperative planning (Fig. 12) [14].

Foreign bodies

Dental CT can help in localizing foreign bodies that can be found after or during dental treatment, which otherwise would be hard to detect with conventional radiologic methods. Most dental instruments and materials are radio-opaque, which helps in identifying the source and exact location. Materials usually found include root or crown fillings, gutta-percha, endodontic instruments, and root posts. These materials are typically located in the maxillary sinus, the alveolar ridge, or in the adjacent soft tissue and can be a source of chronic infection and pain (Fig. 13).

Implant placement "periimplantitis"

Correct implant placement is crucial to prevent early implant loss or clinical complications, which is especially important if implant perforation into the maxillary sinus or nasal cavity occurs [32, 33, 34, 35, 36]. Another major complication is perforation of the implant into the mandibular canal, which can lead to paresthesia of the mental region and loss of vitality of the more mesially located teeth. The term "periimplantitis" describes an osteolytic layer around implants due to chronic infection and/or malocclusion and it is the major radiologic indicator for imminent implant loss (Fig. 14).

Impacted teeth

Dental CT offers superb visualization of impacted teeth and can help the clinician to plan his treatment preoperatively or prior to orthodontic therapy [37, 38, 39]. The position of the tooth within the alveolar crest as well as the relation to surrounding structures is clearly disclosed. Resorption of adjacent roots and hooks, in particular, are easily detected and quantified by dental CT (Fig. 15).

## Conclusion

This review summarizes the capabilities of dental CT as an imaging method for dentistry. Anatomic features as well as the appearance of frequent dental pathologies are described with their typical findings, which the radiologist should communicate to the referring clinician.

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