4 Diagnostic Oral Pathology with Computed Tomography

Jerry E. Bouquot

INTRODUCTION

Among the most important aspects of patient care is the accurate diagnosis of the patient's disease. This task is made immeasurably more difficult by the fact that the clinical presentation of so many disease processes can be strikingly similar, despite potentially vast differences in etiology and pathogenesis. This is especially true for the many pathologic entities developing with the bones of the maxillofacial region.

Routine radiology has provided a reasonably effective means by which to distinguish one lesion or type of lesion from another, but the two-dimensional nature of radiographs imposes an obvious need for the interpretation of artifacts and superimpositions, making radiographic diagnosis more of an art than a true science. Nevertheless, the dental profession, or at least some among the profession, has been rather successful in formalizing an accurate system of radiographic features to aid in the development of a differential diagnosis of osseous lesions (Table 4.1).

The advent of the computed tomography (CT) scan greatly enhanced our ability to characterize pathologies of the maxillofacial bones, but the early images ("slices") were so thick and the distance between slices was so great, up to 7 mm, that much of the diagnostic detail was lacking and the clinician still had to extrapolate for an accurate interpretation. With more powerful computers and advanced programming allowing very small distances between slices and also allowing one to move smoothly through the slices for an almost three-dimensional view of a lesion, CT technology, including the cone beam CT (CBCT), has brought us to a level of unparalleled diagnostic capacity. In fact, these technologic advancements provide enough datapoints to actually allow the re-creation of the maxillofacial region in an undistorted three-dimensional image, including pathologic lesions (Figure 4.1).

This diagnostic advantage, however, is new enough that the dental profession has not yet had the time to establish a diagnostic classification system as useful as the one available for more routine dental

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Table 4.1 Broad categories of radiographic characteristics used for differential diagnosis

Primary characteristic	Subcategories
Well-demarcated, unilocular radiolucency	Location: periapical, pericoronal, between roots, below inferior alveolar canal, etc.
Well-demarcated, multilocular radiolucency	Location: pericoronal, ramus, etc.; age at diagnosis
Poorly defined/moth-eaten radiolucency	Character of lesion periphery: poorly demarcated, ragged, moth-eaten, partial/irregular sclerosis
Multifocal or generalized radiolucency	Cortical expansion, symptomatic
Well-demarcated radiopacity	Evenly diffuse lesion, irregular opacities, encapsulation, sclerotic rimming, tooth-like structures, etc.
Poorly demarcated radio-opacity	Evenly diffuse lesion (e.g., ground-glass), irregular opacities, symptoms, cortical expansion, etc.
Multifocal or generalized radio-opacities	Location
Mixed radiolucent/radio-opaque lesions	Multifocal, generalized, cotton-wool appearance, onion skinning, peripheral demarcation, sclerotic rimming, tooth-like structures, etc.

Source: Modified from Neville *et al.*, 2008.

Figure 4.1 Three-dimensional rendering of cone beam computed tomography imaging data for a dentigerous cyst of the right posterior maxilla. Notice the tooth crown protruding into the cyst lumen.

radiographs. Only time will tell whether a new system will emerge or the old system will simply be refined, but it seems much more likely that the latter will occur.

ASSESSING THE LESIONAL BORDER

One of the major advantages of CT and CBCT imaging is its ability to better assess the margins or borders of an intraosseous lesion. This is extremely useful in determining the aggressive or infective nature of a pathologic entity. With routine radiology, a simple periapical cyst, for example, may be poorly demarcated when, in fact, it is found at surgery to have very sharp margins. This long ago led to the conclusion that one cannot radiographically distinguish between periapical cysts and periapical granulomas. With spiral CT or CBCT, considerable additional information can be derived relative to:

- the abruptness, or lack thereof, of the lesional interface with surrounding bone;
- the thickness of the reactive bone layer around the lesion (Figure 4.2);
- the uniformity of the reactive bone layer around the lesion;
- the attachment of the lesional tissue to surrounding bone versus complete isolation from surrounding bone (e.g., to distinguish between an osseous and an odontogenic lesion; Figure 4.3);

Figure 4.2 Comparison of a pantographic radiograph (top left) and computed tomography scan of a dentigerous cyst of the posterior right maxilla. Note the rather uniform, imperforated cortical expansion of this well-demarcated lesion.

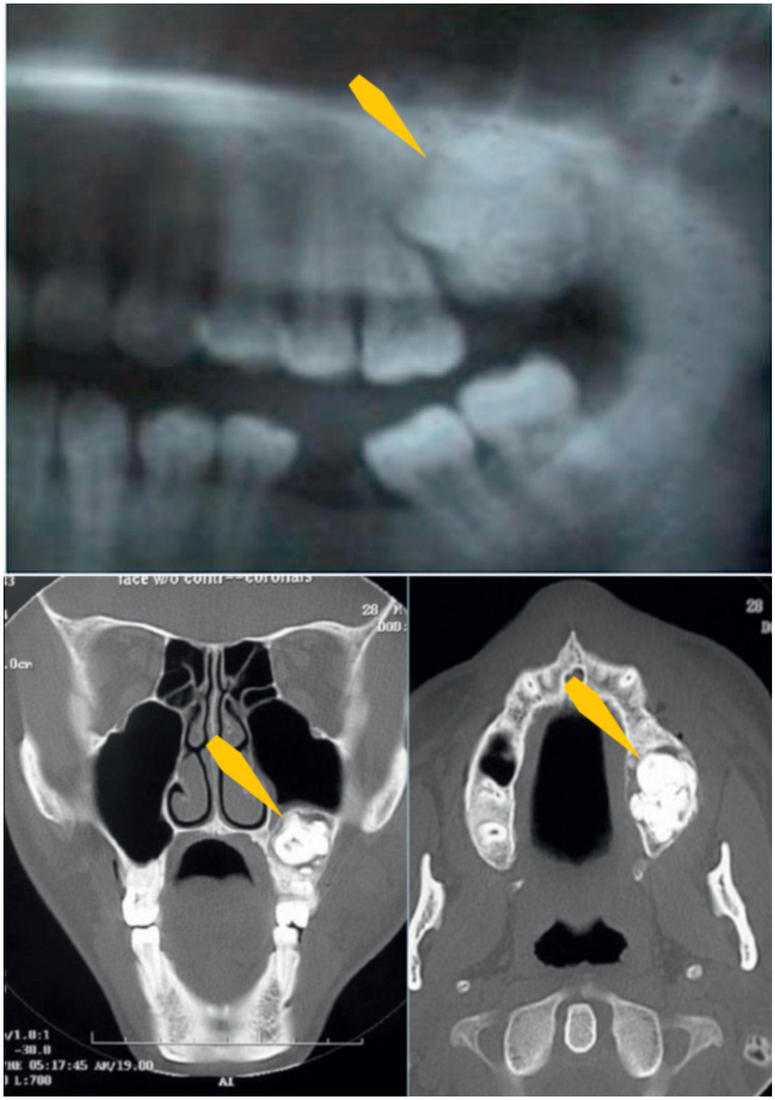

Figure 4.3 Comparison of pantographic radiograph (top) and computed tomography (bottom) images of a compound odontoma (arrows). Note the expansion into the sinus floor and the radiolucent fibrous capsule surrounding the lesion.

- areas of perforation of surrounding sclerotic rim or overlying cortex (Figure 4.4);
- erosion of adjacent osseous or dental structures;
- extension into the maxillary sinus (Figure 4.5).

Detailed assessment of the periphery is especially important because certain lesions will have a focus, perhaps only a small focus, of indistinct border or border perforation, possibly representing an area of infection, ischemic damage, or malignant transformation in an otherwise benign entity, which can

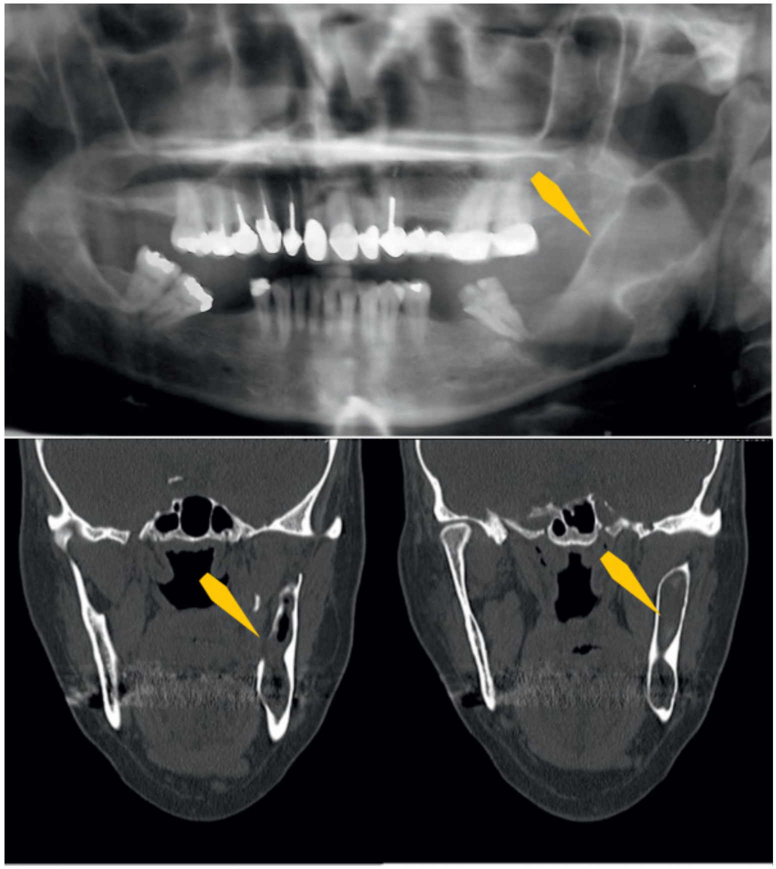

Figure 4.4 Comparison of pantographic radiograph (top) and computed tomography (bottom) images of an odontogenic keratocyst (arrows). Note the lack of cortical expansion and the lingual perforation.

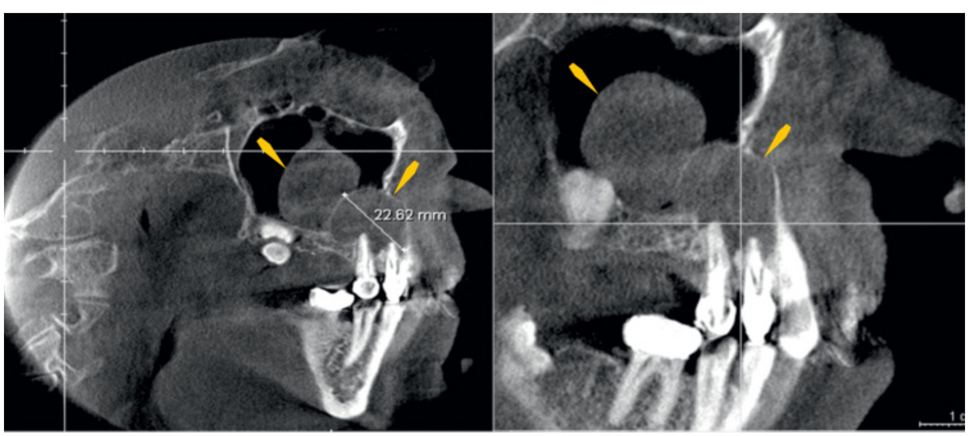

Figure 4.5 Cone beam computed tomography images of a periapical cyst expanded into the maxillary sinus (right arrows in each figure part), and a sinus "mucocele" or pseudocyst of the lateral wall of the maxillary sinus (left arrows in each figure part).

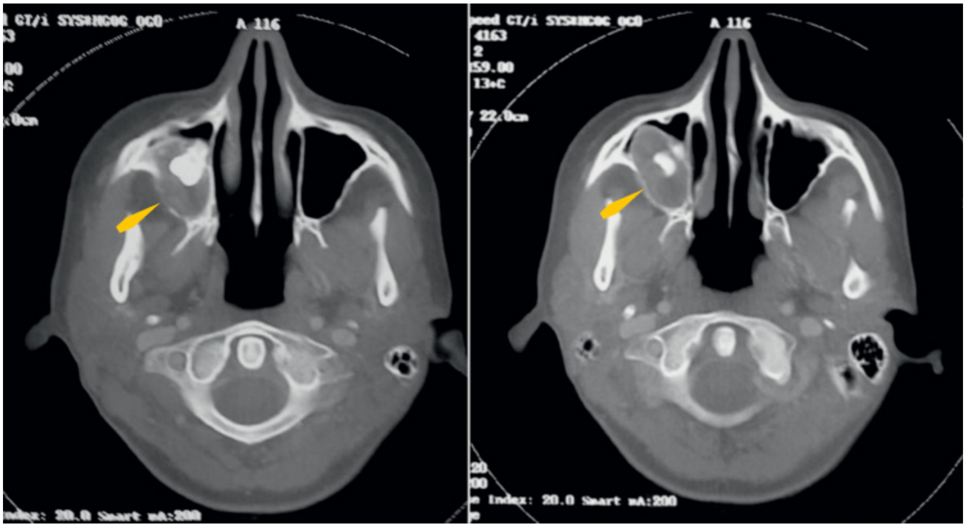

Figure 4.6 Computed tomography images of an impacted maxillary molar with an associated dentigerous cyst (biopsy showed it to be odontogenic keratocyst). Arrows point to posterior cyst wall with low bone density secondary to infection of the underlying cortical bone.

drastically change our understanding of the specific lesion. A cyst, for example, may develop infection and carcinoma (albeit a rare event), leading to a moth-eaten radiolucency, diminished bone density (Figure 4.6), or actual perforation (see Figure 4.4) of the thin bony wall surrounding it. Even a small area of inflammation or infection can explain a symptomatic cyst and may lead to an altered treatment plan or management, perhaps with preoperative antibiotics, or perhaps with extra attention paid to the area of interest during the surgery.

When the lesion is one that can perforate the overlying cortex and extend into surrounding soft tissues, such as an intraosseous malignancy, ameloblastoma (Figure 4.7), or odontogenic keratocyst (see Figure 4.4), the identification of a cortical defect becomes not only invaluable, but absolutely essential. Additionally, extension from the main body of an intraosseous lesion, such as is seen with a dental fistula, may be tracked with relative ease from the lesional origin to the end of the extension, for example a fistulous opening, with CT/CBCT imaging. These peripheral or border defects are seldom visualized with conventional dental radiology.

The well-demarcated border

A well-demarcated border, with a sharp, abrupt transition from lesion to surrounding bone, is, of course, a well-accepted sign of slow growth and a lesion, such as a cyst or benign neoplasm (see Figures 4.2, 4.4, and 4.7), that is pushing rather than invading into adjacent bone. The thin sclerotic rimming at the periphery of such lesions is the typical result of slow enlargement, representing the body's protective attempt to wall off the lesion, and this provides an additional assurance of the benign nature of the lesion. This concept was established via radiology, but modern CT and CBCT images allow an assessment of *all* margins, with no superimpositions, and especially allow an assessment of the uniformity of thickness of the reactive bony response (see Figure 4.2).

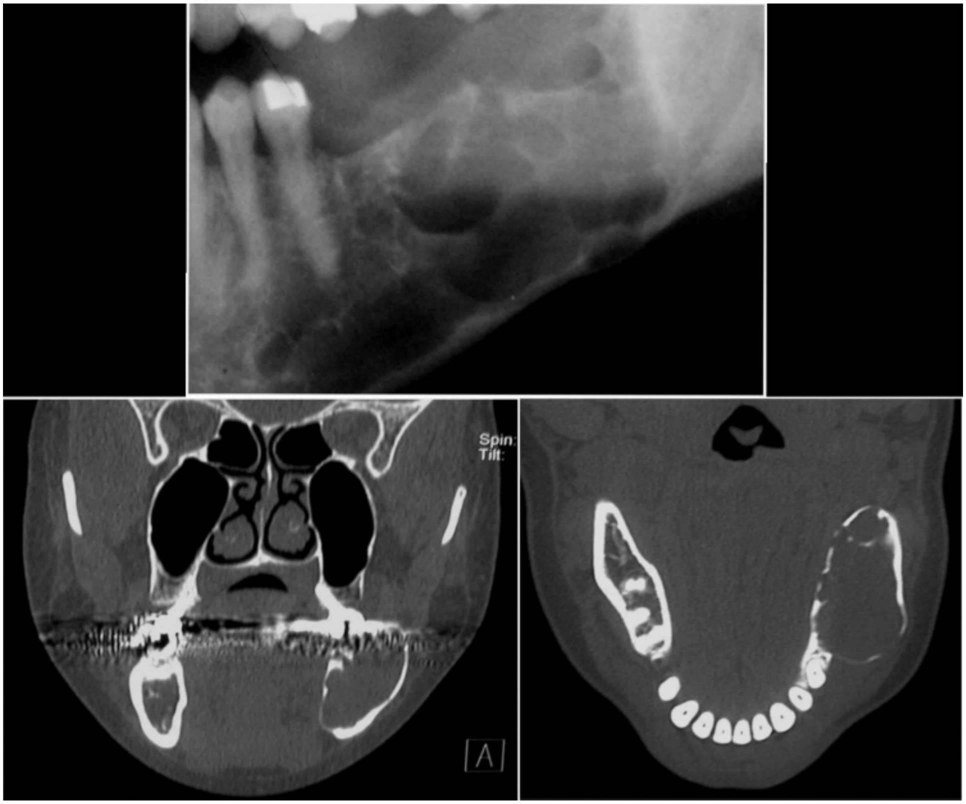

Figure 4.7 Comparison of pantographic radiograph (top) and cone beam computed tomography scan (bottom) of a large ameloblastoma of the left posterior mandible. Note the extensive cortical expansion with multiple small areas of cortical perforation on the computed tomography images.

Additionally, the complete *lack* of a bony reaction can provide good information. For example, a well-demarcated border without any bony reaction or sclerotic rimming should make one suspicious of:

- Langerhans cell histiocytosis (histiocytosis X);
- multiple myeloma;
- early Paget's disease of bone (osteoporosis circumscripta);
- a brown tumor in hyperparathyroidism.

The poorly demarcated border

When extensive or multiple radiolucencies have large regions with ill-defined or moth-eaten borders, the clinician's level of concern should be greatly increased: these are signs of infection or invasion. Since these changes are much more readily seen with CT/CBCT imaging, the new technology should naturally lead to an earlier detection of and intervention for aggressive entities, such as malignancy, with a subsequent improvement in prognosis; however, only time will tell whether or not this will become the case as more and more dentists use CBCT scanning. This also, of course, lays an additional obligation on a dentist to look more completely and critically at lesional borders.

Poorly demarcated borders suggest, among other disease processes:

- infection (acute osteomyelitis, chronic nonsuppurative osteomyelitis, periapical granuloma, infected cyst);
- ischemia (osteonecrosis, bone marrow edema, neuralgia-inducing cavitational osteonecrosis, traumatic bone cyst);
- osteopenia (focal osteoporotic marrow defect);
- malignancy (osteosarcoma, fibrosarcoma, Ewing's sarcoma, reticulum cell sarcoma, metastatic carcinoma, malignant odontogenic tumors, primary lymphoma of bone, leukemia);
- massive osteolysis (i.e., vanishing bone disease);
- desmoplastic fibroma and fibromatosis of bone;
- odontogenic myxoma or myxofibrosarcoma.

Extension or invasion of a lesion beyond its borders is also a key indicator of aggressiveness, and this is often impossible to see without CT technology.

The changed cortex

CT/CBCT imaging allows a much more concise assessment of cortical changes or responses to a lesion when an intraosseous process has enlarged to the point of contact with the overlying cortex. A uniformly thin cortex is to be expected with benign, slowly expanding lesions (see Figures 4.2 and 4.6). Very thin cortices, however, are often so thin that they cannot be visualized with routine radiology; this is not the case with CT and CBCT images. The CT technology gives enough detail, moreover, to often allow a determination of whether the cortex has been broken from outside pressures (remember the "eggshell crackling" sounds) or truly perforated by the lesional tissues. Such perforation is, of course, much more likely to be seen in severe infection, necrosis, or malignancy when there is no attempt at expansion of the cortex.

A lack of cortical expansion, even without perforation, can provide important information. For example, one of the benign cysts of the jaws, the odontogenic keratocyst, shows a remarkable inability to expand the cortices laterally, even when it is huge in an anteroposterior dimension (see Figure 4.4). This characteristic of little or no facial or lingual expansion, then, provides a key point of diagnostic information that can rule out many, many other multilocular radiolucencies, yet the characteristic cannot be seen with routine dental radiographs.

Two odd maxillofacial lesions are quite difficult to assess radiographically but are extremely easy to see with CT/CBCT imaging, and in fact the diagnosis can be made using the CT or CBCT images exclusively. The first of these, the Stafne bone cyst/defect, presents as a lingual concavity of the posterior mandibular cortex. The concavity is easily seen on CT images, providing a definitive diagnosis without biopsy or further testing, but presents as an intraosseous lesion on routine radiographs.

The second lesion, the "mucocele" or pseudocyst of the maxillary sinus, is a focal, sessile, edematous enlargement of the sinus lining, usually on the lateral wall of the maxillary sinus. This presents as a faint, diffuse, well-demarcated radio-opacity on pantographic radiographs and is extremely difficult to diagnose with just radiographs, yet a clinical diagnosis is important because no surgery or biopsy is required. With CT or CBCT imaging, the diffuse soft tissue enlargement and location become very easily identified

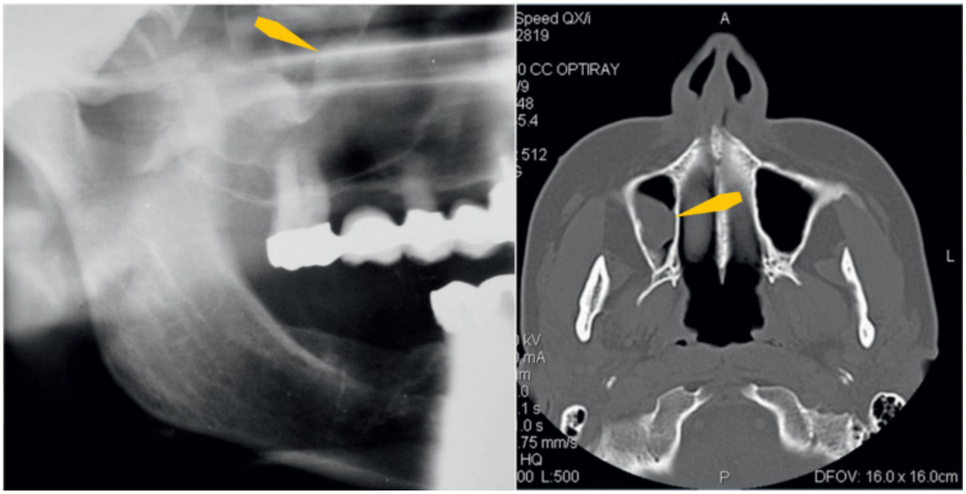

Figure 4.8 Comparison of pantographic radiograph (left) and cone beam computed tomography (right) images of a maxillary sinus "mucocele" or pseudocyst of the lateral wall (arrows). The radiograph demonstrates a barely visible oval radiopacity, but the sessile, soft tissue nature of the lesion is readily visualized with cone beam computed tomography.

(Figure 4.8). Along this same line, variations in anatomic development are much more readily assessed with CT/CBCT images, especially the three-dimensional re-creations.

The poorly demarcated mixed lesion

Not all lesions with poorly demarcated borders are severe or aggressive. One of the more valuable uses of CT or CBCT scans is the more precise clarification of the variety of mixed radiolucent/radio-opaque lesions found in the jaws. This improvement in imaging will most likely lead to a new classification of such lesions and will allow the clinician to rather easily separate those entities that blend into surrounding bone, that is, actual bony lesions (Figure 4.9), from those with capsules, such as are found around the odontogenic tumors. This is of considerable diagnostic importance. For example, when a mixed lesion blends slowly into surrounding bone with no attempt at encapsulation, the differential diagnosis or list of likely diagnoses includes:

- bone dysplasias (fibrous dysplasia, Paget's disease, early or mild osteopetrosis, focal osseous dysplasia, florid osseous dysplasia);
- benign bone neoplasms (osteoblastoma, enchondroma, internal osteoma, central ossifying fibroma);
- malignant bone neoplasm (osteosarcoma);
- reactive bone (condensing osteitis, idiopathic osteosclerosis, ischemic osteosclerosis, bone scar).

However, when a mixed lesion appears to be encapsulated, the following entities should be considered:

- odontogenic tumors (odontoma, Pindborg tumor, adenomatoid odontogenic tumor, ameloblastic fibro-odontoma, cementoblastoma);

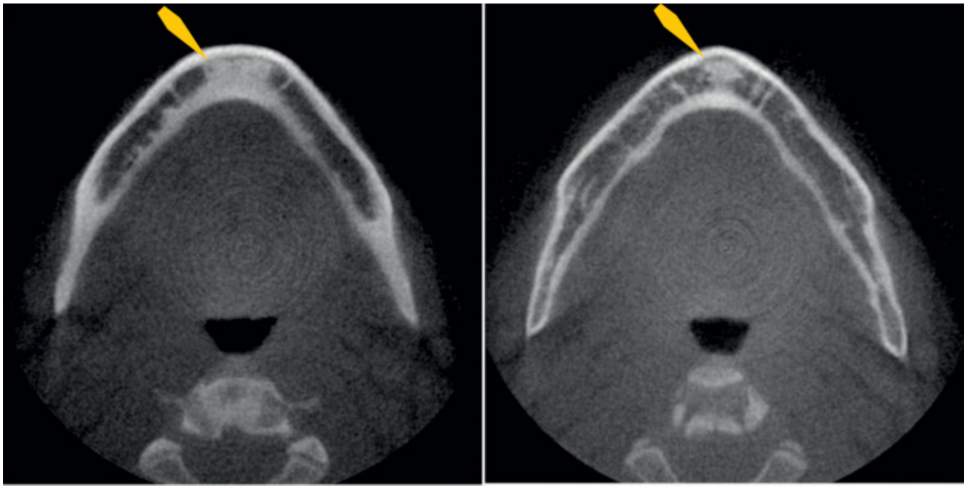

Figure 4.9 Computed tomography images of idiopathic osteosclerosis (arrows) show a lack of encapsulation and connection with overlying cortex.

- odontogenic cysts (Gorlin cyst);
- embedded root tip, partially resorbed impacted tooth, and supernumerary tooth.

CHARACTERIZING THE LESION

Without the superimpositions of two-dimensional radiographs, the characteristics of an intraosseous jaw lesion can be described much more accurately. The lack of sclerotic material in a radiolucency can be confidently confirmed, providing one differential diagnosis, or can be confidently *not* confirmed, that is, such material will be present, completely changing the differential diagnosis. These different lists were established with routine radiology, but the lack of superimpositions makes the assessment so much easier with CT or CBCT scans. Additionally, a scan can determine whether or not the radio-opacities are part of the lesion itself, that is, are scattered throughout the lesion, are centrally located within it (Figure 4.10), or are merely reactive bone at the periphery of the lesion, as is so commonly found in the central giant cell granuloma.

The CT or CBCT scan also makes the characterization of focal osteosclerotic regions more accurate. Without having to interpret superimposed calcified materials, it is much easier to say, for example, that a lesion has snowflake opacities (Pindborg tumor, Gorlin cyst, adenomatoid odontogenic tumor), cotton-wool opacities (Paget's disease, fibrous dysplasia, cemento-osseous dysplasias, ossifying fibroma, early osteopetrosis), globular opacities (cemento-osseous fibroma, complex odontoma), tooth-like shapes (odontoma, ameloblastic fibro-odontoma), or diffuse/ground-glass opacification (fibrous dysplasia, hyperparathyroidism). Also, the consistency of cortical masses, such as tori and exostoses, can be determined with accuracy. A torus composed entirely of marrow spaces, for example, might be at higher risk for bisphosphonate-associated osteonecrosis when a chronic surface ulcer is present.

Specific changes that are unique to certain rare diseases are also much more readily seen with CT/CBCT, such as:

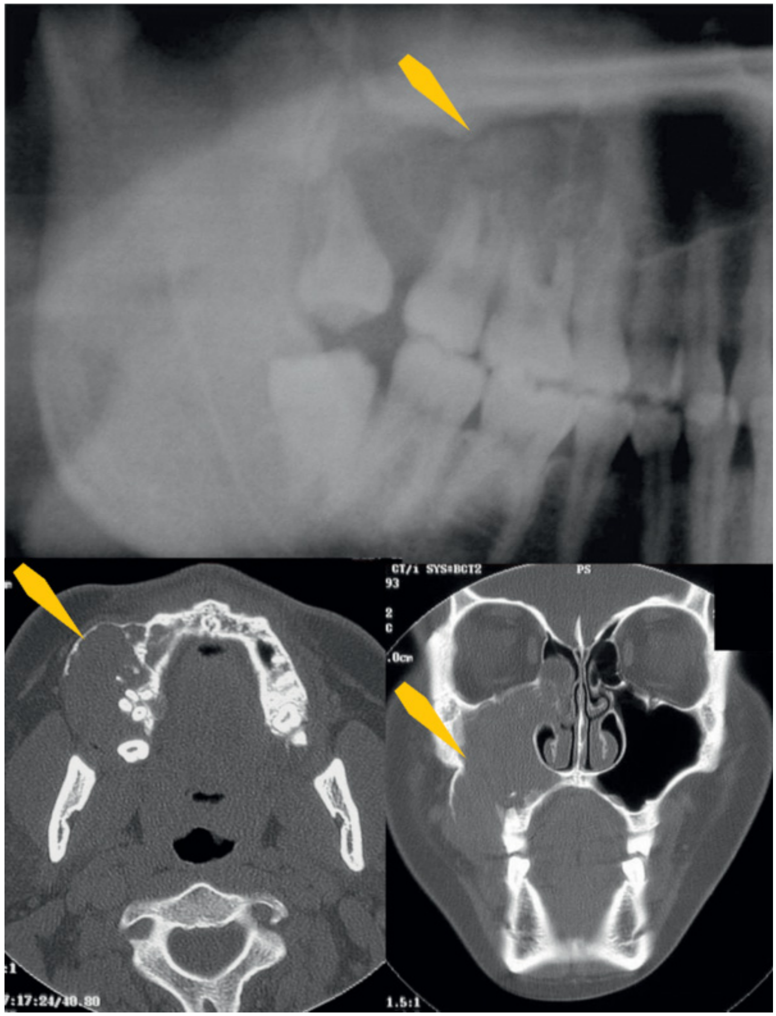

Figure 4.10 Comparison of pantographic radiograph (top) and computed tomography (bottom) images of a Pindborg tumor (arrows). Note the small radiopaque flecks on the left computed tomography image, indicative of calcification within the tumor itself. The cortex shows extensive destruction and expansion, with complete fill of the right maxillary sinus.

- an external sunburst pattern (osteosarcoma, fibrosarcoma, chondrosarcoma);
- an internal sunburst pattern (hemangioma);
- a peripheral onion-skin pattern (Garré's osteomyelitis, Ewing's sarcoma);
- loss of the lamina dura (hyperparathyroidism);
- fusion of bone with teeth (ankylosis);
- the honeycomb pattern of chronic ischemic bone disease;
- residual sockets (hormonal deficiency, hypocalcemia, chronic ischemia).

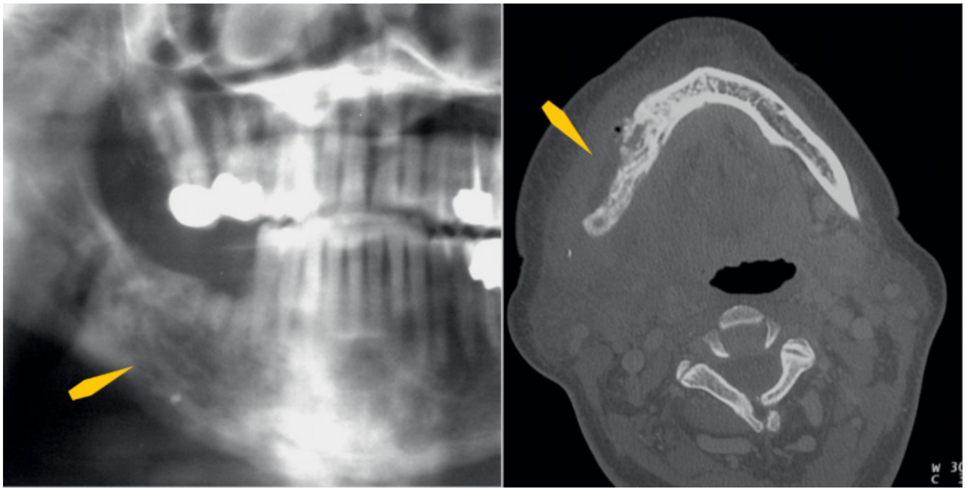

Figure 4.11 Comparison of pantographic radiograph (left) and computed tomography (right) images of chronic nonsuppurative osteomyelitis of the posterior right mandible, on the facial surface (arrows). Note the great destruction of the cortex overlying the area of involvement. The irregular, moth-eaten destruction hinted at on the radiograph is much more obvious on the scan.

DETERMINING THE LOCATION OF THE LESION

The CT/CBCT scan allows the clinician to exactly locate an oral pathologic lesion in relation to the teeth, the cortex, the alveolar nerves, and the maxillary sinus. This may greatly influence the surgical approach to such lesions. Although estimates of location can be determined with multiple views in routine radiology, the CT and CBCT technologies bring a completely new level of accuracy to this process. The clinician can now determine whether or not a mandibular molar's roots are wrapped around the inferior alveolar canal, an impacted tooth is very close to an erupted tooth, a tumor is very close to the mental foramen, a cyst of the anterior maxillary midline is within or outside the nasopalatine duct, and so on. This is such an important improvement that some consider the CT/CBCT scan to be *essential* to the proper workup of such lesions.

The localization of a lesion is especially important for moth-eaten or irregular radiolucencies, since malignancy or infection are almost always the underlying diagnosis. Radiographs are especially difficult to interpret for these entities, but CT or CBCT will show exactly where the disease is and how irregular the "invading" margin is (Figure 4.11). Scans are, moreover, excellent for determining the extent of bony destruction produced by an individual malignancy or necrosing process (Figures 4.12 and 4.13).

MARROW DISORDERS

The CT/CBCT technology has added an entirely new ability to evaluate stromal marrow and marrow disorders of the jaws. Low bone density, as seen in osteoporosis, chronic ischemic bone

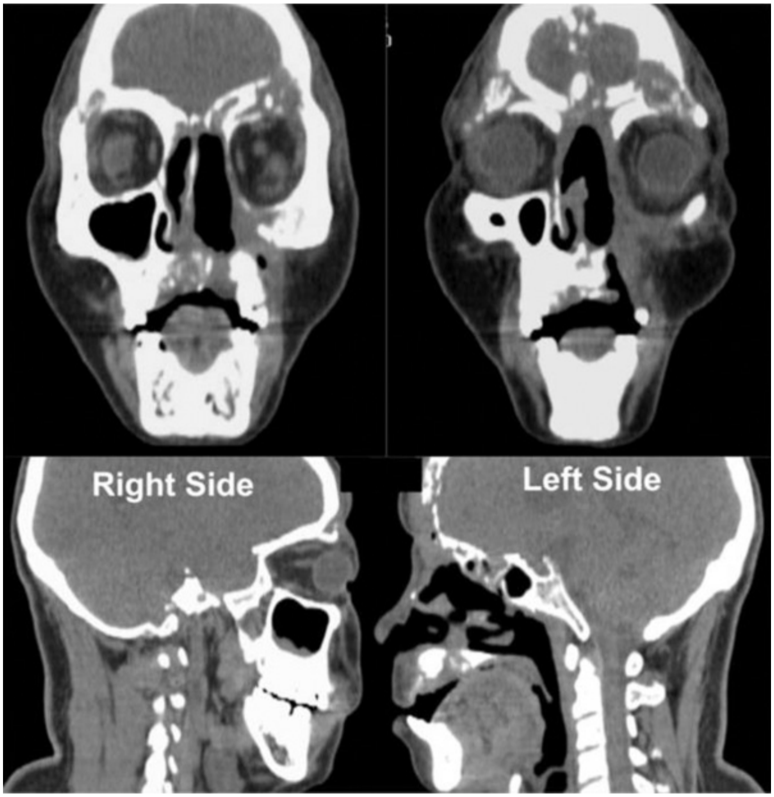

Figure 4.12 Two-dimensional computed tomography images of massive destruction of the bony structures of the left midface, extending into the frontal sinus region, in a patient with angiocentric B-cell lymphoma (midline lethal granuloma). (From Johnson *et al.*, 2007.)

disease, leukemic proliferation, and infiltrating disorders such as Gaucher's disease, is more readily assessed, as are pain-producing disorders, such as bone marrow edema and regional ischemic osteoporosis.

The intramedullary cavitations of traumatic bone cyst and chronic ischemic bone disease produce a very dark, black background, as opposed to the slightly hazy gray of the typical marrow-filled medullary spaces. This same intense darkness seen between thin but intact trabecula is characteristic of honeycomb bone, which appears at surgery to be similar to the dried jawbones used for student teaching and research, except that it is moist instead of dry. Both forms of bone have a complete lack of marrow within intramedullary spaces but radiographs cannot possibly identify this.

The broken, thin, misplaced trabecula and "calcific necrotic marrow detritus" of chronic ischemic bone disease can mimic a very faint variant of ground-glass bone, sometimes referred to as "ghost marrow" on radiographs; it is much more readily visualized with CT or CBCT imaging. The presence of a dense fibrous scar tissue over the top of a residual or intact socket years after the extraction is another feature of ischemic bone disorder that can be easily visualized by CT/CBCT but not by conventional radiographs.

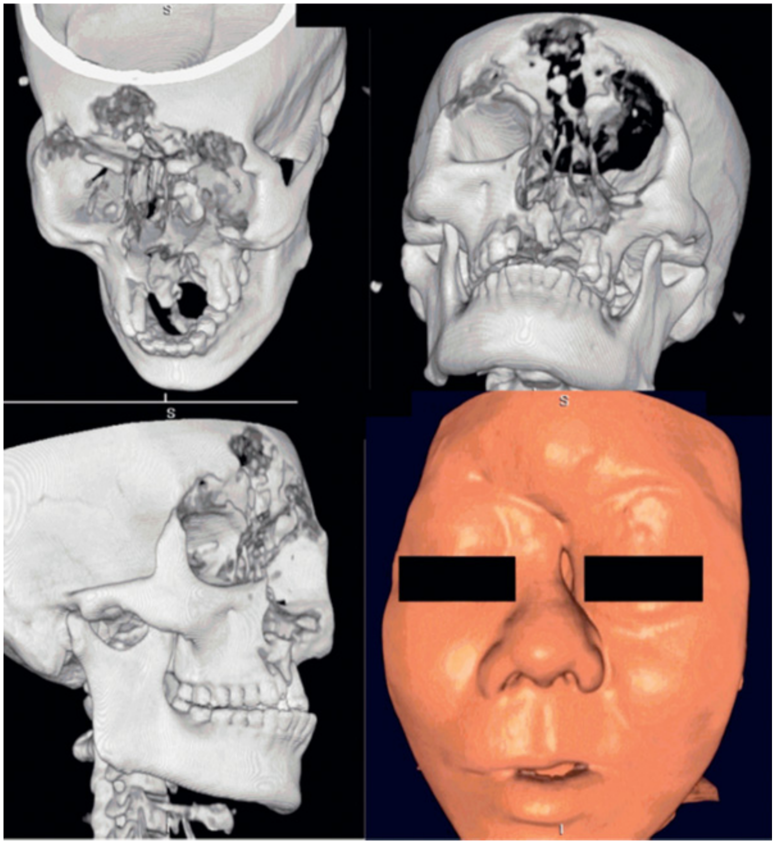

Figure 4.13 Three-dimensional computed tomography renderings of the same patient as in Figure 4.12 make the destruction of the maxillofacial and frontal regions more obvious. (From Johnson *et al.*, 2007.)

Maxillary sinus disease

The introduction of the pantograph more than 40 years ago gave dentistry a much better means by which to evaluate at least some of the disorders affecting the maxillary sinus. With CBCT imaging becoming more and more popular, and with so much more sinus data provided, the diagnosis of sinus lesions may soon enter into the realm of "routine" dentistry.

Areas of sinus membrane thickening, polypoid lesions, inflammatory and neoplastic masses, and cortical perforation or destruction (perhaps from dental infection) are routinely identified (see Figures 4.5, 4.8, and 4.10). The CBCT even allows the clinician to identify a central "ball" of aspergillosis, which has a tendency to develop in the sinus when zinc-containing endodontic material is extruded into the sinus. Also, the "mucocele" (pseudocyst) of the maxillary sinus can be diagnosed exclusively with CBCT (see Figure 4.8), when there is a broad, sessile base to a uniformly diffuse soft tissue bulge on the lateral wall of the sinus; this could only be suggested with conventional radiology.

The nearness of a root tip to the sinus can be easily determined using CT or CBCT imaging, and may alter the treatment plan for an extraction, or the fact that the root tip is *already* in the sinus prior to extraction will allow the clinician to warn the patient that a sinus perforation is unavoidable. Along this same line, the spatial association between a localized sinus membrane thickening and a tooth apex can suggest that a patient's chronic sinusitis might be related to dental infection rather than seasonal allergies. Additionally, a root tip that fractures off during extraction and falls into the sinus can be much more readily found and localized compared with conventional radiographic techniques.

FOLLOW-UP

One of the most valuable of all of the features of the CBCT scan is the ability to compare, without spatial distortion, bone changes before and after treatment. Complete removal of an intraosseous lesion, even an impacted tooth, is much more accurately assessed than with routine radiology. Lesions that have been deemed to be innocuous or "burned out," such as a central cementifying or ossifying fibroma in an older individual, and fibrous dysplasia or cherubism in an adult, can be accurately measured to see whether or not there is any change over time. Additionally, increased calcification, which is a common feature of mixed lesions even after they have finished expanding, can be much more accurately assessed, even measured. Recurrences of removed bony lesions can be found at a much smaller size than with conventional radiology, and the exact location can be determined, perhaps allowing for more conservative removal.

CONCLUSION

There is no doubt that, within a short time, the CBCT has become a diagnostic tool of choice for the workup of oral pathologic entities within the maxillofacial bones, more so than the routine CT scan, which has been available for many decades. Improved techniques and diagnostic expertise will surely lead to a refinement or re-creation of our present lists of differential diagnoses, upon which, in turn, our management or treatment plans are based. This can only be good for dentistry and dental patients alike.

FURTHER READING

Barragan-Adjemian C, Lausten L, Ang DB, Johnson M, Katz J, Bonewald LF. Bisphosphonate-related osteonecrosis of the jaw: Model and diagnosis with cone beam computerized tomography. Cells Tissues Organs 2009; 189(1–4): 284–8.

Beaman FD, Bancroft LW, Peterson JJ. Imaging characteristics of cherubism. AJR Am J Roentgenol 2004; 182: 1051–4.

Chan Y, Siewerdsen JH, Rafferty MA, Moseley DJ, Jaffray DA, Irish JC. Cone-beam computed tomography on a mobile C-arm: Novel intraoperative imaging technology for guidance of head and neck surgery. J Otolaryngol Head Neck Surg 2008; 37: 81–90.

Closmann JJ, Schmidt BL. The use of cone beam computed tomography as an aid in evaluating and treatment planning for mandibular cancer. J Oral Maxillofac Surg 2007; 65: 766–71.

DeLange J, van den Akker HP. Clinical and radiological features of central giant-cell lesions of the jaw. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005; 99: 464–70.

Hueman EM, Noujeim ME, Langlais RP, Prihoda TJ, Miller FR. Accuracy of cone beam computed tomography in determining the location of the genial tubercle. Otolaryngol Head Neck Surg 2007; 137: 115–18.

Johnson CD, Busaidy K, Bouquot J. Angiocentric T-cell lymphoma (midline lethal granuloma). Texas Dent J 2007; 764–5, 772–3.

MacDonald-Jankowski DS. Fibro-osseous lesions of the face and jaws. Clin Radiol 2004; 59: 11–25.

Miracle AC, Mukherji SK. Conebeam CT of the head and neck. Part 2: Clinical applications. AJNR Am J Neuroradiol 2009; 30: 1285–92.

Nakayama E, Sugiura K, Ishibashi H, Oobu K, Kobayashi I, Yoshiura K. The clinical and diagnostic imaging findings of osteosarcoma of the jaw. Dentomaxillofac Radiol 2005; 34: 182–8.

Neville B, Damm D, Allen C, Bouquot J. Oral and Maxillofacial Pathology, 3rd edn. Philadelphia: WB Saunders, 2008.

Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. Accuracy of three-dimensional measurements using cone-beam CT. Dentomaxillofac Radiol 2006; 35: 410–16.

Yonetsu K, Yuasa K, Kanda S. Idiopathic osteosclerosis of the jaws: Panoramic radiographic and computed tomographic findings. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997; 83: 517–21.

Zoumalan RA, Lebowitz RA, Wang E, Yung K, Babb JS, Jacobs JB. Flat panel cone beam computed tomography of the sinuses. Otolaryngol Head Neck Surg 2009; 140: 841–4.