# Essentials of Oral and Maxillofacial Surgery

Edited by **M. Anthony Pogrel** Karl-Erik Kahnberg Lars Andersson



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# **Essentials of Oral and Maxillofacial Surgery**

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Edited by

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## Preface

Shortly after the successful launch of our international reference textbook *Oral and Maxillofacial Surgery* in 2010, we had the idea of abstracting and distilling the essential elements of the textbook and adding new sections to produce a textbook suitable for dental students and trainees worldwide. This textbook is the result of those efforts. It is designed to fulfill the curricular needs in oral and maxillofacial surgery for all dental students and it will also fulfill most of the needs of trainees in oral and maxillofacial surgery and allied disciplines. We have maintained the same team of international authors as in the larger textbook. We hope this textbook portrays the excitement we feel in the development of our specialty over the past 20 years and gives a flavor of some of the anticipated achievements of the next few years.

This book is dedicated to our teachers and mentors (we stand on the shoulders of giants) as well as the dedication and sacrifices of our wives Ann, Ingrid, and Karin.

M. Anthony (Tony) Pogrel

Karl-Erik Kahnberg

Lars Andersson



Editors at editorial board meeting, Gothenburg, Sweden, March 2013

# About the companion website

This book is accompanied by a companion website:

www.wiley.com/go/pogrel/oms

The website includes:

- 89 interactive multiple-choice questions
- Powerpoints of all figures from the book for downloading

## Part 1: Basic Principles

(Section Editor: Tony Pogrel)

### Chapter 1

### Patient Evaluation

The goal of preoperative evaluation is to reduce patient risk and the morbidity of surgery, and is based on the premise that it will modify patient care and improve outcome.

The Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) requires that all patients receive a preoperative anesthetic evaluation and the American Society of Anesthesiologists (ASA) has approved Basic Standards for Preoperative Care which outline the minimum requirements for a preoperative evaluation. Preoperative patient assessment is important in order to develop a safe and appropriate surgical and anesthetic plan.

#### **Obtaining a patient history**

The importance of an accurate, detailed history cannot be overemphasized because it provides the framework on which the clinician builds an accurate diagnosis and treatment plan. An inaccurate or incomplete evaluation may lead to a delay in treatment, unnecessary testing, or misdiagnosis.

It is often helpful to review previous medical records. This can provide important information and save time during the interview process. The patient should be asked to describe the history of the present illness (HPI). Information should be gathered regarding onset, intensity, quality, location, duration, radiation, and any exacerbating or relieving factors. Constitutional symptoms that relate to the present illness should also be noted. Examples of pertinent positives and negatives with regard to the chief complaint may include fever, chills, loss of weight, weakness, etc.

The past medical history (PMH) alerts the clinician to any coexisting illnesses that may have an impact on any planned surgeries. A family history (FH) may

reveal risk factors for patients as well as the possibility of inherited illnesses such as hemophilia or malignant hyperthermia.

The social history (SH) of a patient should include information regarding their social support system and also any habits such as tobacco, alcohol, or illicit drug use. These habits may adversely affect healing and also increase a patient's risk for undergoing a planned surgical procedure.

A review of systems (ROS) is a comprehensive method of inquiring about a patient's symptoms on an organ system basis. The review of systems may reveal undiagnosed medical conditions unknown to the patient.

#### **Physical examination**

During the physical exam the clinician further reinforces or disproves impressions gained during the history-taking portion. Vital signs are recorded at the beginning of the physical exam. These include blood pressure, pulse rate, respiratory rate, and temperature. The patient's general appearance should be noted.

For a complete description of examination techniques the reader is advised to consult textbooks on physical diagnosis.

#### **Comorbidities/systemic diseases**

The clinician needs to assess potential risk factors and understand their effect on treatment. Changes in heart rate, rhythm, blood pressure, preload, afterload, and inotropy may occur during surgery and these can have deleterious effects, especially in patients with comorbidities. The risks for complications are greatest when caring for patients who are

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already medically compromised. Many significant untoward events can be prevented by careful preoperative assessment along with attentive intraoperative monitoring and support.

#### Cardiovascular system

#### Cardiac disease

Cardiac complications following non-cardiac surgery constitute an enormous burden of perioperative morbidity and mortality. More than one million operations annually are complicated by adverse cardiovascular events, such as perioperative myocardial infarction or death from cardiac causes. Common cardiac risk factors include diabetes, hypertension, family history of heart disease, hypercholesterolemia, and obesity. Certain populations of patients, such as the elderly, diabetics, or women, may present with more atypical features.

Methods for evaluating a patient's cardiac risk preoperatively include a careful history, including exercise tolerance, physical examination, and electrocardiogram (EKG). Based on this information, various risk indices, guidelines, and algorithms can assist the clinician in deciding which patients can undergo surgery without further testing and which patients may benefit from further cardiac evaluation or medical therapy prior to surgery. Risk assessment involves evaluating patients' comorbidities and exercise tolerance, as well as the type of procedure to be performed to determine the overall risk of perioperative cardiac complications. Exercise tolerance is a major determinant of cardiac risk and need for further testing. Beta blockade has shown clear benefits in risk reduction whereas revascularization procedures, such as coronary artery bypass grafting, have not been shown to be useful in reducing non-cardiac surgical risk.

#### Hypertension

Hypertension is a common disease which can increase perioperative cardiac risk. Hypertension has been associated with an increase in the incidence of silent myocardial ischemia and infarction. The Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure recently revised their definition. Hypertensive patients with left ventricular hypertrophy are at a higher perioperative cardiac risk than non-hypertensive patients.

Controversy exists regarding whether to delay a surgical procedure in a patient with untreated or poorly controlled hypertension. Aggressive treatment of high blood pressure does diminish long-term risk. A study often quoted as the basis for delaying surgery for patients with a diastolic blood pressure greater than 110mmHg actually demonstrated no major morbidity in that group of patients. Other authors have found little association between blood pressures less than 180mmHg systolic or 110mmHg diastolic and postoperative outcomes. Patients with severe hypertension are more prone to perioperative myocardial ischemia, ventricular dysrhythmias, and lability in blood pressure. For patients with blood pressures greater than 180/110 mmHg there is no absolute evidence that postponing surgery will decrease the cardiac risk. For patients without endorgan changes, such as renal insufficiency or left ventricular hypertrophy, it may be appropriate to proceed with surgery. However, patients with a markedly elevated blood pressure and new onset of a headache should have surgery delayed for further medical treatment. Patients with hypertension may have a contracted intravascular volume and therefore have an increased susceptibility to vasodilator effects of commonly used sedative and anesthetic agents. For elective surgery it is best to have the patient's blood pressure optimized prior to surgery.

Risk factors for hypertension include smoking, hypercholesterolemia, increasing age, family history of cardiovascular disease, and diabetes. Untreated hypertension commonly causes coronary heart disease, cardiomegaly, congestive heart failure, and end-organ damage. When evaluating a patient with hypertension, it is important to determine the presence of end-organ damage (heart, lung, and cerebrovascular systems). An elevated systolic blood pressure may be a better predictor of postoperative myocardial ischemia than elevated diastolic blood pressure.

#### Pulmonary system

Pulmonary complications are a major cause of morbidity for patients undergoing a surgical procedure. They occur more frequently than cardiac complications with an incidence of 5–10% in those having major non-cardiac surgeries. Perioperative pulmonary complications include atelectasis, pneumonia, bronchitis, bronchospasm, hypoxemia, and respiratory complications. For patients with an upper respiratory illness, surgery should be delayed if possible for at least 2 weeks after resolution of the illness. Studies have indicated a 10% incidence of severe complications, respiratory as well as cardiac arrest, pneumonia, and prolonged intubation due to increased sputum, when surgery is performed on patients with an active upper respiratory tract infection.

During the presurgical evaluation, the clinician should obtain information about exercise tolerance, chronic cough, or unexplained dyspnea. On physical exam, findings of rhonchi, wheezing, decreased breath sounds, dullness to percussion, and a prolonged expiratory phase are important. Preoperative pulmonary function tests are usually reserved for patients undergoing lung resection or those undergoing major surgery who have unexplained pulmonary signs and symptoms after a history and physical examination.

#### Obesity

A patient is considered obese when their body weight is 20% or more above ideal weight. Obesity can be measured by the body mass index (BMI) which is derived by dividing the weight in kilograms by the height in meters squared (BMI =  $Wt/ht^2$ ).

A BMI greater than 30 suggests increased morbidity due to stroke, heart disease and diabetes. At a minimum, these conditions indicate the need for close evaluation of the patient's airway and cardiac and pulmonary status. Even with an adequate airway, ventilation may be difficult because of the patient's size and a tendency toward hypoxemia. There may also be significant cardiovascular changes.

On the other hand, the clinician should not dismiss a low BMI, especially with evidence suggesting an eating disorder. Nutritional deficiency may be present along with significant cardiac changes, fluid and electrolyte imbalances, delayed gastric emptying, and severe endocrine abnormalities.

#### Imaging

A patient's presentation will dictate which films are required. Radiographs such as plain films, cone beam or fan beam computed tomography (CT), nuclear scans, and arteriography are helpful in various circumstances. The risks associated with these studies should be weighed against the added benefit from them.

#### Laboratory studies

Some institutions have preadmission screening test algorithms based on factors such as age of the patient (Table 1.1). Preoperative laboratory tests should be ordered based on defined indications such as positive findings on a history and physical exam. A thorough history and physical examination can be used to identify those medical conditions that might affect perioperative management and direct further laboratory testing. A study by Golub et al. reviewed the records of 325 patients who had undergone preadmission testing prior to surgery. Of these 272 (84%) had at least one abnormal screening test, while only 28 surgeries were canceled or delayed. Only three patients potentially benefited from preadmission testing, including a new diagnosis of diabetes in one and non-specific EKG changes in two. Another study

**Table 1.1** Sample preadmission screening test algorithm. (EBL, estimated blood loss; HTN, hypertension; IVDA, intravenous drug abuse; LMP, last menstrual period; ABG, arterial blood gases; CBC, complete blood count; PT, prothrombin time; PTT, partial thromboplastin time; LFTs, liver function tests; CXR, chest X-ray; EKG, electrocardiogram; HCG, human chorionic gonadotropin; UA, urinalysis; PFTs, pulmonary function tests; T/S, type and screen.)

| CIRCLE APPROPRIATE LABS TO ORDER            |      |        |            |       |               |                                   |     |     |        |                    |      |     |
|---|------|--------|------------|-------|---------------|-----------------------------------|-----|-----|--------|--------------------|------|-----|
| Preoperative condition                      | ABGs | CBC    | PT/<br>PTT | Lytes | BUN/<br>Creat | Blood/<br>Glucose or<br>Accucheck | LFT | CXR | EKG    | Hcg<br>preg/<br>UA | PFTs | T/S |
| Possible EBL >500 ml                        |      | Х      |            |       |               |                                   |     |     |        |                    |      | Х   |
| Neonates                                    |      | Х      |            |       |               |                                   |     |     |        |                    |      |     |
| Age: >40 yr                                 |      |        |            |       |               |                                   |     |     | Х      |                    |      |     |
| Age: >75 yr                                 |      | Х      |            |       |               | Х                                 |     |     | Х      |                    |      |     |
| Cardiovascular disease/chronic HTN          |      | Х      |            |       | Х             |                                   |     | Х   | Х      |                    |      |     |
| Use of diuretics, digoxin                   |      |        |            | X*    | Х             |                                   |     |     | Х      |                    |      |     |
| Severe pulmonary disease/<br>prethoracotomy | Х    | Х      |            |       |               |                                   |     | Х   | Х      |                    | Х    |     |
| Malignancy/radiation/chemotherapy           |      | X, plt |            | Х     | Х             |                                   |     |     |        |                    |      |     |
| Hepatic disease                             |      | X, plt |            |       |               |                                   | Х   |     |        |                    |      |     |
| Chronic alcoholism                          |      | X, plt |            | Х     | Х             |                                   | Х   |     | Х      |                    |      |     |
| Renal disease (dialysis)                    |      | Х      |            | Х*    | X*            |                                   |     | _/+ | _/+    |                    |      |     |
| Bleeding disorder/anticoagulant therapy     |      | X,plt* | Х*         |       |               |                                   |     |     |        |                    |      |     |
| Diabetes                                    |      |        |            | _/+   | Х             | X*                                |     |     | >30 yr |                    |      |     |
| Possible pregnancy/gyn surgery              |      |        |            |       |               |                                   |     |     |        | Х*                 |      |     |

Note: Not all diseases are included. Therefore, the physician should use own judgment regarding patients having diseases that are not listed.

In patients with stable medical conditions, labs and EKGs within the last 3 months, and CXR within the last year, will be acceptable. X Items should be done within 72 hours of surgery.

\*Urine pregnancy test if LMP >21 days with possibility of pregnancy or menstruating females <18 years of age, all women undergoing tubal ligation and all women having a hysterectomy who are in their reproductive years or who are experiencing the first year of menopause.

Table 1.2American Society of Anesthesiologists physicalstatus classification.

| Status                     | Disease state  |
|----------------------------|--|
| ASA class 1                | No organic, physiologic, biochemical, or psychiatric disturbance   |
| ASA class 2                | Mild to moderate systemic disturbance that may not be related to the reason for surgery                                      |
| ASA class 3                | Severe systemic disturbance that may or may not be related to the reason for surgery   |
| ASA class 4                | Severe systemic disturbance that is life threatening with or without surgery   |
| ASA class 5                | Moribund patient who has little chance of<br>survival but is submitted to surgery as a last<br>resort (resuscitative effort) |
| Emergency<br>operation (E) | Any patient in whom an emergency operation is required   |

by Narr *et al.* demonstrated minimal benefits from routine testing and proposed that routine laboratory screening tests were not required in healthy patients.

#### Assessing anesthetic/surgical risk

Once the clinician has gathered information by interviewing and examining the patient, they can classify them according to the American Society of Anesthesiologists (ASA) Classification of Physical Status (Table 1.2). Patients with a lower ASA classification represent a lower surgical risk than do patients with severe systemic disease. This system is commonly used and is helpful in identifying risk factors so that modifications in the treatment plan can be undertaken. The surgical procedure influences the scope of preoperative evaluation required by determining the potential range of physiologic flux during the perioperative period.

#### **Office vs inpatient**

Once the clinician has gathered pertinent information during the preoperative work-up, they must decide where best to perform the surgical procedure.

Safety continues to be the guiding factor in deciding where various types of procedures should be performed. Options available include office surgery, ambulatory surgery centers, and traditional hospitalbased locations. Many variables are considered when deciding on whether to perform a surgery in the office or perform the surgery elsewhere, including the size and severity of the surgery.

Patient factors should also be an important part of the decision on where to perform the procedure. Patients with poorly controlled medical conditions such as morbid obesity or poorly controlled hypertension should be carefully evaluated, and appropriate preoperative testing should be performed to determine their surgical risk. Patient factors such as increased age, an operating time longer than 120 minutes, cardiac diagnoses, peripheral vascular disease, cerebrovascular disease, malignancy, and immunodeficiency can place patients at higher risk for immediate hospital admission.

Advantages of performing surgery in a hospital setting include the addition of another health care provider to administer anesthetic during the surgical procedure. Imaging techniques such as ultrasonography, CT, and chest radiographs are readily available, as are blood chemistries to rapidly diagnose and treat complications. Also, procedures such as interventional radiology, for such things as embolization, are available. Ultimately the decision on where to perform a surgery depends on both the surgeon and informed patient considering the type and length of the procedure, patient health factors, and safety.

#### Summary

The process of preoperative evaluation is essential in assessing the medical condition of patients, evaluating their overall health status, determining risk factors, and educating them. The goal of preoperative evaluation is to reduce patient risk and the morbidity of surgery.

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### **Chapter 2**

# Radiographic Imaging in Oral and Maxillofacial Surgery

#### Introduction

The most common radiographic examinations of oral and maxillofacial surgery patients are intraoral and panoramic radiographs. However, today computed tomography (CT) and magnetic resonance imaging (MRI) are common examinations in imaging of many different conditions. A useful investigation is one in which the result – positive or negative – will alter management or add confidence to the clinician's diagnosis. It is important to try to minimize the radiation dose to the patient (particularly children). CT can potentially give significant absorbed doses to the patient. The trend today is to use a low-dose technique for CT, but this can be at the expense of the image quality and its use depends on the clinical problem.

#### Computed tomography (CT)

CT is a digital technique providing images of thin slices of the patient with a variable thickness. The slice thickness can be less than 1mm by use of very small X-ray detectors and a fan-shaped X-ray beam transmitted through the patient. By simultaneously scanning several slices of the body (multislice CT), the scan time can be reduced significantly and the smallest details can be imaged within short scan times. Multislice CT enables a wide range of clinical applications and, through the use of computer software, three-dimensional (3D) images can be produced. Images can be viewed in the axial, coronal, or sagittal planes depending on the diagnostic task. This is referred to as multiplanar reformatted (MPR) imaging. Images can also be viewed in any other plane decided by the operator. CT has the advantage over other radiographic techniques that it eliminates superimposition of images of structures outside the area of interest. It has an inherent high-contrast resolution and differences between tissues that differ in physical density by less than 1% can be distinguished. For image display, each pixel is assigned a CT number (Hounsfield units - HU) representing density. The density of air is defined as -1000HU, water as 0HU and bone tissue has more than  $+400\,\mathrm{HU}$ . To allow the observer to interpret the image, only a limited number of HU are displayed. A clinically useful gray scale is achieved by setting the window level and window width on the computer console to a suitable range of HU, depending on the tissue being studied. The term "window level" represents the central HU of all the numbers within the window width. The window width covers the HU of all the tissues of interest and these are displayed as various shades of gray.

### Cone-beam computed tomography (cone-beam CT)

This technique has been commercially available since the early years of the present century. Cone-beam CT is based on volumetric tomography, in contrast to conventional fan-beam CT where slices are scanned. From this, volume slices can be reconstructed in various planes. One advantage with cone-beam CT compared to conventional CT is the lower radiation dose. The radiation dose is reduced by up to 98% compared with conventional CT and is comparable to 2-28 average panoramic radiographs. The dose varies substantially, however, depending on the device, imaging field and selected technique factors. The scan time is relatively short (around 10s) and the resolution is high (i.e. around 0.125mm) and approaches that of fan-beam CT. The software is usually adapted to maxillofacial imaging and is realtime interactive, for example for implant planning.

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#### 8 Basic Principles

In both cone-beam CT and conventional CT, artifacts are produced by metal objects and it is important to try to avoid exposing metal fillings and crowns.

#### Magnetic resonance imaging (MRI)

MRI does not use ionizing radiation, but rather uses magnetic fields to align protons in the body, which can then be recorded electronically as they revert to their baseline orientation, and reformatted to build up an image. There are, however, some contraindications since the presence of ferromagnetic metals is a potential hazard. Patients with magnetic or paramagnetic metallic foreign objects, pacemakers, and metal clips must not be examined. Pregnancy is a relative contraindication.

The advantage of MRI is that it offers the best resolution of tissues of low inherent contrast and it has an excellent soft tissue contrast resolution. Disadvantages are relatively long imaging times and patients who suffer from claustrophobia cannot be examined. Open MRI scanners are sometimes used for claustrophobic patients but the images are of low resolution and are usually unsuitable for head and neck imaging.

MRI physics is complex and an understanding of the basic concepts is important in order to manipulate the scan parameters to improve the quality of the images.

#### **Impacted teeth**

A preoperative examination of an impacted tooth usually consists of two intraoral radiographs exposed at different angles (Fig. 2.1 a and b) or a panoramic radiograph. Using intraoral films in three different projections gives an insight into the true anatomy of third molars when the radiographic appearance was compared to the clinical observation. Intraoral and panoramic radiographs are usually sufficient to show



Fig. 2.1 Impacted lower third molar in a mesioangular position. (a) Periapical radiograph taken with  $+10^{\circ}$  vertical angulation of the X-ray tube. Two mesial roots (one straight and one curved) and one distal root are seen. (b) Periapical radiograph taken with  $-10^{\circ}$  vertical angulation of the X-ray tube. The mandibular canal seems to be buccal to the curved root. (c) Cone-beam CT with 1mm thick sections. Upper left image is a cross-section of the mandible through the roots. The mandibular canal is seen below the mesial roots, lingual to the buccal root and buccal to the lingual root. Upper right image is a sagittal view of the buccal part of the tooth and the straight mesio-buccal root is shown. Lower section shows an axial view of the tooth, which is situated close to the lingual compact bone. (d) Same as (c), but the section is lingually placed. The curved mesio-lingual root is shown in the sagittal view.



**Fig. 2.2** Cone-beam CT examination of a non-erupted maxillary canine causing resorption of the root of the lateral incisor. The crown of the canine is situated palatal to the root of the incisor. (a) Upper left, sagittal view. Upper right, cross-section of the jaw. Lower, axial view. (b) Same as (a), but the 1 mm thick section is placed more palatal in the sagittal section. The root tip of the canine is curved mesially.

the relationship between the roots of the third molar and the mandibular canal. However, narrowing of the canal, increased radiolucency ("dark band") and interruption of the radiopaque border of the mandibular canal can justify a CT examination. Conebeam CT has been shown to have a high diagnostic accuracy in predicting neurovascular bundle exposure during extraction of impacted mandibular third molars. Figure 2.1 c and d show an example of an impacted mandibular third molar with a complicated root anatomy examined with cone-beam CT.

CT is also valuable when examining impacted teeth in other regions. Cone-beam CT has been shown to be indicated for localization of impacted maxillary canines and has demonstrated root resorption better on the adjacent incisors compared to conventional radiography. Figure 2.2 shows a cone-beam CT examination of a non-erupted maxillary canine causing resorption of the root of the lateral incisor.

#### Pathological conditions – inflammatory lesions, cysts, benign and malignant tumors

The aims of the radiographic examination are to give information that leads to the most probable diagnosis and to the optimal treatment. The examination must cover the whole pathological area in at least two dimensions. A combination of different radiographic techniques can lead to a more certain diagnosis, but it should always be kept in mind that the treatment also must be affected positively by the extended examinations in order to be justified. There are some radiological signs that always must be looked for when interpreting radiographs of pathological conditions, such as:

- location and size;
- periphery and shape;
- internal structures;
- effects on surrounding structures.

#### Inflammatory lesions

There are several lesions that present as a radiolucent area in the jaws. Inflammatory lesions located in the periapical area are by far the most common changes. It is not possible to differentiate radiologically between a radicular cyst and apical periodontitis. Radicular cysts tend to be larger than periapical granulomas, but a large variation in size has been shown for both types of lesions. This is not a diagnostic problem for small periapical radiolucencies as endodontic treatment has a high success rate and the prevalence of true cystic lesions is low. At follow-up after endodontic treatment and periapical surgery it is important to standardize the radiographic examination regarding projection and density/contrast of the image to be able to compare different examinations. An example is given in Figure 2.3 where the projection was changed between the two radiographs taken on the same occasion and it appears that the size of the periapical bone destruction has changed.

Cone-beam CT should be considered when no detectable pathology is found in periapical radiographs and clinical tests indicate pathology, as more periapical lesions are found with cone-beam CT. This is especially important in patients with chronic



**Fig. 2.3** Evaluation of healing after apical surgery of the upper left canine. Radiographs in (a) and (b) are taken at the same occasion, but with different projections. The apical bone destruction has a different appearance depending on the change of projection.

maxillary sinusitis, as a dental cause may be found in up to 40% of patients with chronic maxillary sinusitis.

Radiographs of the paranasal sinuses are not indicated routinely when sinusitis is suspected. Panoramic radiography should not be used for the detection of small osteolytic lesions in the maxillary sinus and soft tissue changes can be difficult to detect in panoramic radiographs depending on whether the surrounding structures are projected into the maxillary sinuses. CT is more rewarding than conventional radiography in the examination of the paranasal sinuses. Low-dose, high-resolution CT is recommended when medical treatment has failed, when complications arise, or if malignancy is suspected. Figure 2.4 shows a case of chronic maxillary sinusitis examined with panoramic radiography and lowdose CT.

#### Cysts and benign tumors

Radicular cysts are the most common cysts found in the jaws, followed by dentigerous cysts and keratocystic odontogenic tumors (KCOT). Large cysts in the region of the maxillary sinus may be difficult to image with conventional radiographs and CT is usually indicated to see the extension of the cyst (Fig. 2.5). Dentigerous cysts and KCOTs are usually incidental findings in panoramic radiographs, with KCOT predominantly found in the mandible (Fig. 2.6).

#### **Malignant tumors**

Primary malignant bone tumors are uncommon in the jaws. Squamous cell carcinoma is the most common head and neck cancer and it may invade the underlying bone. The typical appearance on a panoramic radiograph of a malignant lesion involving the jaw bone is bone destruction with a border that is ill defined. Figure 2.7 shows an example of a carcinoma



**Fig. 2.4** A patient with chronic maxillary sinusitis. Panoramic radiography (a) and low-dose CT (b, c) were performed. (a) Panoramic radiograph showing root fragments of the upper left third molar with periapical bone destruction. The maxillary sinuses are difficult to evaluate. (b) Axial CT showing complete radiopacification of the left maxillary sinus. The bony walls are slightly sclerotic. (c) Coronal reconstruction showing the same picture as (b).

of the maxillary sinus involving the upper jaw detected on a panoramic radiograph. Rapidly growing malignant lesions destroy the alveolar bone but usually no root resorption is present. A typical sign is that the teeth may appear to be floating in space: "floating teeth".

The radiographic examination of malignant tumors often comprises CT and MRI to determine the extent of the tumor and to evaluate cervical lymphadenopathy. Post-treatment examinations are usually performed to evaluate the effect of treatment. A combination of CT and positron emission tomography (PET) has been introduced and PET/CT is now widely used as an advanced clinical tool for the diagnosis, staging, and restaging of cancer, and for the assessment of tumor therapy. A combination of MRI and PET is also becoming available. PET is a functional study where a radiolabelled isotope of glucose is given intravenously and areas of high metabolic activity can be recorded. The uptake is recorded by a nuclear imaging system and is normally merged with CT or MRI imaging for improved localization.

#### Temporomandibular joint (TMJ)

Imaging of TMD patients plays a minor role in the management of these patients as it has been shown that the treatment outcome is not affected by the radiological findings. Despite the success of conservative care, however, some patients do not improve and TMJ surgery may be indicated. In these cases

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**Fig. 2.5** Patient with a fistula in the maxillary right canine region. Buccal swelling and symptoms of sinusitis. He mentions that a tooth was extracted in the region about 10 years ago when he had similar symptoms. The final diagnosis was proved to be residual cyst. (a) Panoramic radiograph which is difficult to interpret. (b) CT with an axial section showing well-defined bone destruction in the right maxillary canine region. (c) Coronal section showing the cystic lesion with thickened bone around the cyst. Soft tissue swellings are seen in the maxillary sinus. (d) Axial CT taken 10 years earlier, when the patient had symptoms of sinusitis. A cystic lesion is seen around the root tip of the right maxillary canine. The tooth was later extracted.



Fig. 2.6 Panoramic radiograph showing a multilocular bone destruction in the right mandibular ramus area. The patient had no symptoms and the cyst was detected in bitewing radiographs taken by his dentist. The tentative radiological diagnoses were ameloblastoma or keratocystic odontogenic tumor (KCOT). The diagnosis from the pathologist's report was KCOT.

radiography is indicated, as well as in patients with trauma, tumors, ankylosis and developmental anomalies. Further, radiographic examination of patients with polyarthritic conditions, such as rheumatoid arthritis, can be recommended to evaluate the degree of joint destruction. Bone scanning with <sup>99m</sup>technetium phosphate isotopes might be indicated to determine the level of growth activity in condylar hyperplasia.

There are different techniques for imaging the TMJ: panoramic radiography, plain radiography, conventional and computed tomography, arthrography, and MRI. Panoramic radiography is not a reliable method for accurately showing the shape of the mandibular condyle and the temporal component is poorly visualized. Plain radiography of the TMJ





**Fig. 2.7** The patient complains of pain in the upper left jaw. A swelling of the left cheek is noticed. (a) Panoramic radiography shows an ill defined bone destruction in the area of the left maxillary sinus and the edentulous jaw seems to be involved in the bone destruction. (b, c) Contrast-enhanced axial CT sections showing bone destruction of the anterior and medial walls of the maxillary sinus and of the alveolar bone. The tumor is expanding buccally into the cheek. (d) Coronal section showing complete destruction of the jaw. The superior bony wall to the orbit seems intact.

depicts the mineralized part of the joint, but superimposition of adjacent anatomic structures can make interpretation difficult. Conventional tomography improves the depiction of the bone structures. However, minor bony changes will not be shown in conventional tomography. CT imaging provides exquisite detail for bony abnormalities, such as ankylosis, fractures (Fig. 2.8), osseous tumors and arthrosis and 3D images can be produced; 3D reconstructions of a patient with condylar aplasia are shown in Figure 2.9.

MRI has replaced arthrography and can provide information about disk position, joint fluid, bone marrow changes, and bone structure at multiple levels of the joint. MRI is the prime diagnostic imaging technique in TMD patients. The technique, however, is expensive and there are no studies showing when the results of the MRI examination will result in a better treatment outcome for the typical TMD patient. Imaging of the TMJ is definitely indicated prior to TMJ surgery and the preferred method is MRI if the soft tissue should be shown and CT if the hard tissue is of prime interest. In cases of tumors the methods often are combined.

#### Implant treatment

Panoramic radiography is the first choice for the radiological appraisal before implant treatment. The technique is, however, dependent on proper positioning of the patient during exposure and objects located outside the center of the sharply depicted plane are reproduced with distortions. Reliable measurements have been found for digital panoramic radiography, but both over and underestimation of vertical linear measurements have been found in other studies of panoramic radiography. The inherent errors in panoramic radiography should always be kept in mind whenever an exact assessment of a distance is required. Panoramic radiography is inferior to CT in visualization of the mandibular canal and in measurements related to the mandibular canal. Today, CT has almost totally replaced conventional tomography. There is equal accuracy so cone-beam CT should be preferred as this technique gives lower radiation dose compared to multislice CT and has a superior array of software for dental implant and related plan-



Fig. 2.8 Cone-beam CT of a fracture of the condylar neck after a bicycle accident. Upper left, sagittal view; upper right, coronal view; lower right, axial view. The condylar fragment has been dislocated medially and inferiorly. The images are taken with 3D Accuitomo (Morita Corp.)

ning procedures. However, when a completely edentulous patient is examined several exposures with cone-beam CT with a narrow field size are necessary (Fig. 2.10). CT is indicated whenever the bone volume





**Fig. 2.10** Multislice CT examination for planning of implant treatment of an edentulous maxilla. (a) Panoramic radiograph. The bucco-palatal bone width of the maxilla was judged to be questionable. (b) 3 mm thick paraxial reconstructions made perpendicular to the alveolar bone (cross-sections) of the left side from the incisor to the premolar region. The images are produced in scale 1:1. B = buccal, L = lingual. (c) 3 mm thick panoramic reconstructions. The number of the vertical lines can be identified in the paraxial sections in order to locate the section.



Fig. 2.9 CT 3D reconstructions of a patient with hemifacial microsomia and aplasia of the right condyle. The patient is missing the ear and a defective zygomatic arch is seen on the right side. The left side has developed normally.



**Fig. 2.11** Cone-beam CT of the mandible to visualize the mandibular canal. Images are produced in scale 1:1. (a) Anterior section showing the mental foramen (coronal section, lower right). (b) Posterior section in the molar region showing the mandibular canal (coronal section, lower right).

must be evaluated accurately and when localizing the mandibular canal. Figure 2.11 shows cone-beam CT of the mandibular canal. Another indication for CT is when evaluating bone grafting procedures in relation to implants, as two-dimensional radiographs underestimate bone resorption. Postoperative follow-up examinations after implant treatment are usually performed with intraoral radiographs taken in a standardized way.

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