Clinics Review Articles

VETERINARY CLINICS OF NORTH AMERICA:
EXOTIC ANIMAL PRACTICE

Disorders of the Oral Cavity

EDITOR
Vittorio Capello

CONSULTING EDITOR
Jörg Mayer

SEPTEMBER 2016

Contributors

CONSULTING EDITOR

JÖRG MAYER, Dr.med.vet, MSc
Diplomate American Board of Veterinary Practitioners (Exotic Companion Mammals); Diplomate European College of Zoological Medicine (Small Mammals); Diplomate American College of Zoological Medicine; Associate Professor of Zoological Medicine, Department of Small Animal Medicine and Surgery, College of Veterinary Medicine, University of Georgia, Athens, Georgia

EDITOR

VITTORIO CAPELLO, DVM
Diplomate, European College of Zoological Medicine (Small Mammal); Diplomate, American Board of Veterinary Practitioners-Exotic Companion Mammals; European Veterinary Specialist in Zoological Medicine (Small Mammal), Clinica Veterinaria S. Siro; Clinica Veterinaria Gran Sasso, Milano, Italy

AUTHORS

VITTORIO CAPELLO, DVM
Diplomate, European College of Zoological Medicine (Small Mammal); Diplomate, American Board of Veterinary Practitioners-Exotic Companion Mammals; European Veterinary Specialist in Zoological Medicine (Small Mammal), Clinica Veterinaria S. Siro; Clinica Veterinaria Gran Sasso, Milano, Italy

THOMAS M. DONNELLY, BVSc
Diploma in Veterinary Pharmacy; Diplomate of the American College of Laboratory Animal Medicine; Diplomate of the American Board of Veterinary Practitioners-Exotic Companion Mammals; Diplomate of the European College of Zoological Medicine - Small Mammal; Exotic Animal Service, Centre Hospitalier Universitaire Vétérinaire d'Alfort, École Nationale Vétérinaire d'Alfort, Maisons-Alfort, France

JOANNA HEDLEY, BVM&S
Diploma in Zoological Medicine (Reptilian); Diplomat of the European College of Zoological Medicine (Herpetology); Member of the Royal College of Veterinary Surgeons; Head, RVC Exotics Service, Royal Veterinary College, London, United Kingdom

VLADIMIR JEKL, MVDr, PhD
Diplomate of the European College of Zoological Medicine (Small Mammal); Associate Professor, Avian and Exotic Animal Clinic, Faculty of Veterinary Medicine, University of Veterinary and Pharmaceutical Sciences Brno, Brno, Czech Republic

CATHY A. JOHNSON-DELANEY, DVM
Board of Directors, Washington Ferret Rescue & Shelter, Kirkland, Washington

LOIC LEGENDRE, DVM, FAVD
Diplomate AVDC; DEVDC; West Coast Veterinary Dental Services Ltd, Vancouver, British Columbia, Canada

ANGELA M. LENNOX, DVM
Diplomate of the European College of Zoological Medicine (Small Mammal); Diplomate of the American Board of Veterinary Practitioners-Avian; Exotic Companion Mammal; Avian and Exotic Animal Clinic, Indianapolis, Indiana

ELISABETTA MANCINELLI, DVM, CertZooMed
Diplomate of the European College of Zoological Medicine (Small Mammal); Bath Referrals, Rosemary Lodge Veterinary Hospital, Bath, Somerset, United Kingdom

CHRISTOPH MANS, Dr med vet
Diplomate of the American College of Zoological Medicine; School of Veterinary Medicine, University of Wisconsin-Madison, Madison, Wisconsin

YASUTSUGU MIWA, DVM, PhD
Veterinary Medical Center, School of Veterinary Medicine, The University of Tokyo; Miwa Exotic Animal Hospital, Tokyo, Japan

LAUREN VIRGINIA POWERS, DVM
Diplomate of the American Board of Veterinary Practitioners (Avian Practice); Diplomate of the American Board of Veterinary Practitioners (Exotic Companion Mammal Practice); Avian and Exotic Pet Service, Carolina Veterinary Specialists, Huntersville, North Carolina

HELEN E. ROBERTS-SWEENEY, DVM
Elma Animal Hospital, Williamsville, New York

BRIAN SPEER, DVM
Diplomate of the American Board of Veterinary Practitioners (Avian Practice); Diplomate of the European College of Zoological Medicine (Avian); The Medical Center for Birds, Oakley, California

DAVID VELLA, BSc, BVSc (Hons)
Diplomate of the American Board of Veterinary Practitioners-Exotic Companion Mammals; Sydney Exotics and Rabbit Vets, Crows Nest, New South Wales, Australia

Contents

Diagnostic Imaging of Dental Disease in Pet Rabbits and Rodents

Vittorio Capello, DVM, DECZM (Small Mammal), DABVP-Exotic Companion Mammal[a,b,*]

KEYWORDS

• Dental disease • Rabbit • Computed radiography • Computed tomography
• Magnetic resonance • Stomatoscopy

KEY POINTS

- Before additional diagnostic imaging, a thorough clinical examination must be performed, including inspection of the oral cavity in the conscious patient.
- Complete radiographic study should include at least 4 projections of good diagnostic quality; additional views are recommended for complete evaluation of dental and bony structures.
- Computed tomography overcomes superimposition of anatomic structures over a single plane, allowing multiple 2-dimensional views in the 3 spatial axes and 3-dimensional surface and volume reconstructions.
- Stomatoscopy is essential for inspection of the oral cavity; it prevents the risk of missing lesions, allows early diagnosis, and facilitates treatment of cheek teeth and other intraoral procedures.
- MRI provides excellent visualization of odontogenic abscesses and their relationship with adjacent anatomic structures, in particular for challenging complications such as retromasseteric and retrobulbar abscesses.

INTRODUCTION

The oral examination and the diagnosis of oral disorders in most exotic companion mammal species are intrinsically difficult (especially in common species such as rabbits and rodents) because of their size and oral anatomy. For these reasons, diagnostic imaging modalities assume particular importance in the evaluation of teeth and surrounding structures.

Aside from traditional radiographs, advanced diagnostic imaging has become popular in exotic mammal medicine. Increased owner education and therefore demand

The author has nothing to disclose.
[a] Clinica Veterinaria S. Siro, Via Lampugnano, 99, Milano 20151, Italy; [b] Clinica Veterinaria Gran Sasso, Via Donatello, 26, Milano 20134, Italy
* Clinica Veterinaria S.Siro, Via Lampugnano, 99, Milano 20151, Italy.
E-mail address: capellov@tin.it

Vet Clin Exot Anim 19 (2016) 757–782
http://dx.doi.org/10.1016/j.cvex.2016.05.001 **vetexotic.theclinics.com**
1094-9194/16/$ – see front matter

coupled with the availability of referral centers for diagnostic imaging like computed tomography (CT) and MRI, make it both feasible and affordable. In the case of dental disease and other oral disorders (in particular of pet rabbits and selected rodent species), it is of paramount importance for both diagnosis and diagnostic accuracy, for detailed prognosis, and for treatment choice. In the case of extraoral surgical treatment, it is critical to plan the most effective surgical technique or approach.

BEFORE DIAGNOSTIC IMAGING: THE CLINICAL EXAMINATION

Dental disease is a syndrome (in most cases acquired and progressive) and can produce a wide range of clinical signs and symptoms.[1,2] These symptoms may be related specifically to the primary dental problem (reduced food intake, dysphagia, anorexia, changes in fecal quantity and size, weight loss) or to complications associated with dental disease (excessive grooming, excessive salivation and drooling, facial abscesses, epiphora, exophthalmos, nasal discharge, dyspnea). Other signs and symptoms are indicative of diseases or conditions secondary to dental disease (poor general condition, gastrointestinal problems, poor coat and skin diseases, ocular diseases, death).[1–4]

Before the physical examination, a thorough history should be obtained and the diet and feeding habits should be reviewed with the owner. Considering the predisposition of prey species to mask or hide symptoms, the absence of a clear clinical history does not rule out the possibility of dental disease. Reluctance to eat hay, reduced food intake, and abnormal feces in rabbits and rodents are common early symptoms frequently missed by owners. A thick hair coat can hide evident signs such as weight loss or the presence of facial swellings.

After overall inspection, palpation of the external maxillary and mandibular profiles (including the ventral aspect of the mandible and the temporomandibular joint) is performed to detect bony irregularities or swellings consistent with apical elongation of cheek teeth, periapical deformities, or abscesses. The incisor teeth are inspected from both the frontal and lateral aspects. The lateral mobility of the mandible is evaluated to assess the clinical crowns of cheek teeth. With careful and proper restraint, the oral cavity can be inspected with an otoscope in nonsedated rabbits and some large rodents. Even though a complete assessment of the oral cavity using inspection alone is not possible, it is helpful to detect spurs, elongated crowns, and buccal or lingual ulcerations, and to make a preliminary diagnosis. The examination of the eye and periocular structures, including patency of the nasolacrimal duct, should be part of the dental examination in rabbits. When dental disease is a presumptive or a differential diagnosis, the oral examination must be completed with the animal under general anesthesia.[1]

RADIOLOGY

The 2 radiologic imaging techniques used in exotic veterinary practice are radiography and CT.[5] The basic principles of physics are the same for both techniques, as images are generated by x-rays produced by a large diode (the x-ray tube). The most important and practical difference is that CT overcomes the superimposition of imaging that is intrinsic to conventional radiography.[5,6] Although radiography generates images where all tissues in the area of interest are superimposed over a single plane (therefore, multiple, complementary views are necessary to partially bypass this physical limitation), CT generates multiple, parallel cross-sectional images of the tissues of the patient that are elaborated and rendered by computer software.

Radiography

Radiography provides critical information to complement the clinical examination, and represents one of the most important diagnostic tools in veterinary dentistry.[1,2,7] It is also important to consider that the clinical crown, visible above the gingival margin, represents a small portion of the tooth, and that most of the dental structure (the reserve crown of hypsodont/elodont teeth and the root of brachyodont/anelodont teeth) is invisible on clinical inspection. Supporting bone and periapical structures, as well as other parts of the skull, should always be evaluated for diagnosis of dental disease.[1,5]

Digital modalities

Over the past few years, digital radiography (DR) has almost completely replaced conventional film radiography. The basics of radiography on standard films and high resolution films have been reported elsewhere.[5]

Conceptually, digital radiology (DR) is not an advanced technique, and does not necessarily produce higher quality radiographs than good-quality conventional radiographs. Most of the basic principles of traditional radiography on films apply to digital as well. The most important of them is patient positioning to obtain proper diagnostic views. However, some technical features should be considered.

Two digital imaging systems are available: computed radiography (CR) and direct digital radiography (DDR).[5] In the case of CR, detectors are placed in a cassette, which does not include films and intensifying screens. The image plate is processed by a specific scanner, which is a stand alone unit similar to an x-ray film processor, but is faster and does not require a dark room. Data are converted in a digital format image and processed by a computer, with specific software. The greatest advantage of CR is its ability to be coupled with standard radiographic equipment. Ideally, both systems (CR and traditional radiography) can be used with the same x-ray machine, and this is particularly important for the practitioner during the transition between the older system and CR.

DDR sends digital information directly to the computer without the intermediate scanning step. Advantages of DR include no need for x-ray films, dark room, or film storage; an immediate feedback (in case of DDR) and fewer retakes; immediate adjustment of the grayscale; and flexibility of the digital format for storage, recording, and distribution. Nevertheless, some potential advantages may not be so obvious when DR is applied to exotic patients.

The most important concern for use of any digital system in small exotic species is resolution. The area corresponding to the “film” has a fixed number of pixels (usually corresponding with standard resolution of approximately 250 pixels per inch [ppi] with CR, and about 180 ppi with DDR). Higher resolutions plates (commonly named “mammography plates”) and scanners able to take and process at double resolution (500 ppi) are available, but they are more expensive and not needed for a standard small animal practice dealing mostly with dog and cat patients.

Reduced time and increased efficiency are well-recognized benefits of DR. However, the exotic patient requires more time for anesthesia, monitoring, and positioning. Therefore, the advantage of reduced time may be less significant with exotic companion mammals.

Teleradiology and increased interactivity with referral clinicians and colleagues is certainly easier with DR. Digitalization of films with a camera results in loss of visual information and altered grayscale. High-quality digital images can be obtained by scanning good quality films, although a scanner for transparencies is required.

Intraoral radiography

The intraoral technique is usually preferred in veterinary medicine over the extraoral technique, because it produces images of optimal resolution and diagnostic quality.[8] Intraoral films or digital plates are nonscreen films that can be placed directly inside the patient's mouth, reducing the object-to-film distance, and therefore minimizing the image size distortion. The use of intraoral film is reported in rabbits and selected rodent species,[9,10] but in the author's experience the correct placement of films within the oral cavity of rabbits and rodents is difficult to suboptimal owing to patient size (and impossible in smaller rodent species). In most patients, intraoral techniques can therefore be used primarily for the evaluation of anatomic structures such as maxillary and mandibular incisor teeth, rostral cheek teeth, and the rostral portion of the maxilla. A dental radiographic unit is preferable to a standard radiographic unit to expose intraoral films, because it can be moved easily, facilitating the positioning of the patient and the use of proper angles to obtain dedicated oblique views.[8]

Intraoral films and plates used extraorally

Larger intraoral films or digital plates and the advantages of mobile dental radiographic units may be coupled to obtain extraoral views using them outside of the oral cavity.[1,8] However, the resulting image is usually not enough to include the entire head of a rabbit or a guinea pig, requiring additional views to obtain the complete picture of the skull. In the author's opinion, this is the most important drawback when using intraoral equipment in an extraoral fashion.

Extraoral radiography

Because of difficulties obtaining good quality intraoral images, in particular of cheek teeth and surrounding structures, the extraoral technique is used most commonly in the evaluation of dental structures in rabbits and rodents by most exotic companion mammal veterinarians.[1,5] Considering the complex dental disease syndrome in rabbits and related complications, such as osteomyelitis of the mandible and other empyemas of the preformed cavities of the skull (nasal cavities, tympanic bullae), radiographic examination of the entire skull is of paramount importance and strongly recommended by this author.

Radiographic projections and normal radiographic anatomy of the head

A complete radiographic study of the head in rabbits and rodents should include 1 or 2 latero-lateral (LL), right-to-left and left-to-right latero-oblique (LO), dorso-ventral (DV; or ventro-dorsal [VD]) and rostro-caudal projections.[1,5,8] Additional views such as LO with a different degree of obliquity, slight LO in the rostro-caudal direction rather than the standard DV, slight obliques from the VD position, VD with the mandible shifted laterally, and intraoral projections may be useful or required for the radiographic study of a specific patient.[5] Also, contrast studies of the nasolacrimal duct may be performed if clinical indications are present. Most authors agree that LL is the most useful view.[1,8] When evaluating a patient for dental disease, the author considers LL, right-to-left and left-to-right LO, and DV views as essential, and recommends additional oblique and rostrocaudal views for assessment of specific areas. With the exception of preliminary test radiographs to obtain an overall evaluation, and in cases of extreme anesthetic risk, general anesthesia is mandatory for accurate patient positioning and to avoid motion artifacts.

Radiographic anatomy of the head of the rabbit, guinea pig, and chinchilla, as well as proper positioning to obtain the 5 standard projections with the extraoral technique, have been described in detail in the literature.[1,5,11,12] The reader is referred to those references on this subject for further details.

Interpretation of radiographs of the skull

Correct positioning and diagnostic quality of the LL view is confirmed by perfect superimposition of bilateral anatomic structures, such as the rostral margin of the right and left orbit, optic foramen, tympanic bullae, mandibular processes, and temporomandibular joints.[1,8,13] The ventral margin of right and left mandibles should appear superimposed. This view should be obtained with the mouth closed and is used to evaluate both the incisor and cheek teeth.

In the rabbit, the mandibular incisor teeth should occlude between the maxillary first and second (accessory) set of incisor teeth. Rodent species are *simplicidentata*, having a single pair of maxillary incisor teeth, and show a functional brachygnathism of the mandible. For these reasons, the mandibular incisor tooth occludes just palatal (caudal) to the maxillary incisor tooth.

In rabbits and chinchillas, the LL projection assesses the occlusal plane of the cheek teeth, but not in the guinea pig because in this species the occlusal plane is angled. Also, the LL projection is critical to evaluate coronal and apical elongation of the cheek teeth, and changes in tooth curvature. To determine abnormalities on one particular side requires oblique views.

The cheek teeth of rabbits form a regular palisade, and their occlusal plane has a zig-zag pattern, owing to the interdigitation of mandibular and maxillary teeth and presence of enamel ridges on their occlusal surface. The dental interproximal spaces of the occlusal surface are virtual, because these teeth are packed together tightly. Mandibular cheek tooth 2 is straight and with the long axis almost perpendicular to the ventral cortex of the mandible. The remaining mandibular cheek teeth show a degree of curvature. Maxillary cheek tooth 1 is curved slightly and the remaining maxillary cheek teeth are almost straight, with slight divergence of the apices. The reserve crowns of maxillary cheek tooth 3 to cheek tooth 6 are located inside a peculiar bony structure of the rabbit skull called the alveolar bulla, which lies cranial, ventral, and medial to the orbital fossa. This anatomic feature plays an important role in formation of retrobulbar and parabulbar abscesses after periapical infection of those maxillary cheek teeth. The apex of maxillary cheek tooth 3 is radiographically slightly dorsal to the apices of the other cheek teeth, following the dome of the alveolar bulla. All mandibular cheek teeth should be at some distance from the ventral cortex of the mandible, which should be visible as a smooth, thick, radiopaque line.

In guinea pigs, the occlusal plane of cheek teeth slopes approximately 30° dorsal to ventral from buccal to lingual side. Because of this angle, the occlusal plane of the cheek teeth cannot be evaluated on an LL view. The mandibular cheek teeth reach close to the ventral mandibular cortex, which should appear smooth.

Clinical crowns of the cheek teeth of chinchillas are short. The occlusal plane is nearly horizontal, so it is easily evaluated on an LL view. The apices of the mandibular cheek teeth are close to the smooth and thin ventral cortex of the mandible, except for the last cheek tooth, which is shorter than the other 3 cheek teeth. The interproximal spaces between cheek teeth are minimal. The ventral cortex of the mandible should be smooth with no deformity.

The LO views are obtained with the animal in lateral recumbency and the head (or the tube head of the x-ray machine) slightly rotated to avoid superimposition between the tooth apices of right and left sides. The rotation should not be excessive to minimize image distortion. Normally a 10° to 20° rotation is sufficient, unless specific oblique views are necessary, in particular to display part of the masseteric fossa. Right-to-left and left-to-right views should always be obtained for comparison, even if dental disease is suspected only on 1 side. Right and left reference structures (tympanic bullae, mandibular processes, and temporomandibular joints) should appear

just dorsal and ventral to each other. If the head is incorrectly tilted in rostrocaudal direction as well (eg, lifting the nose too much), these structures will seem to be out of line. A slight oblique projection in the craniocaudal direction may be desired in selected cases. The LO view allows the evaluation of the reserve crowns and apices of the mandibular cheek teeth of one side (usually the side next to the digital plate) and the maxillary cheek teeth of the opposite side. Also, the apex of each incisor tooth can be better visualized than on LL projection.

Symmetry between the right and left sides is critical for proper evaluation of VD or DV projections. These views allow the evaluation of the relationship between the mandible and the skull, and the integrity of the margins of mandibular and maxillary bones. Severe cheek teeth elongation and deformation, bone deformation, and perforation may be visualized. In chinchillas, apical elongation and bone perforation typically occur laterally on the maxilla and the mandible, and are visualized with this projection. In all species, evaluation of the incisor teeth is difficult with this view. A slight oblique projection may be desired in selected cases. Also, the VD projection with the mandible shifted laterally prevents superimposition with part of the maxilla on the contralateral side. This view is useful to evaluate part of the nasal cavity and the maxillary recess.

An adequate rostrocaudal projection is the most difficult to obtain. However, it may give information on cheek teeth before intraoral inspection, including the occlusal plane angle, presence of spikes and spurs, coronal and apical elongation, and cortical perforation by dental apices. This is the only radiographic projection allowing evaluation of the occlusal plane of cheek teeth in guinea pigs. Anisognathism, which is characterized by a narrow mandible and wider maxilla in the rabbit and the opposite in the guinea pig and chinchilla, is easily appreciated with this view.

Common radiographic abnormalities of the skull and teeth of the rabbit (**Figs. 1–7**), rodents, and other exotic mammals have been reported extensively.[1,5,12–14] The reader is referred to those references for further details. Objective interpretation of dental disease in rabbits, guinea pigs, and chinchillas with the use of anatomic reference lines has been described.[10,15] The use of lines may facilitate diagnosis in many cases; however, they should only be applied to optimal projections to be reliable. In rabbits, frequent exceptions do exist depending on morphology of the skull in different breeds.

Computed Tomography

Basic principles

CT is a radiologic technique to obtain multiple, parallel cross-sectional image slices of the tissues of the patient.[1,6,12,16,17] Multiple exposures are made as an x-ray tube within a gantry rotates around the patient as it moves along the gantry on a couch. The final image is generated by a computer. The concept of “slice” imaging originated from the need to overcome superimposition of anatomic structures that is intrinsic to conventional radiography. Actually, the main advantage of CT over radiography is that in the first, all tissues in the area of interest are not superimposed over a single plane. The tissue slice is digitally divided into 3 dimensional tiny blocks named *voxels*. Voxels have length, width, and depth; depth corresponds with the tissue slice and can be less than 1 mm. The computer analyzes the mean attenuation of radiographs of each voxel, producing various shades of grey on the final image. CT scans elaborate images via the standardized, internationally recognized Digital Imaging and Communication in Medicine (DICOM) format.

Imaging exotic patients is a challenge because of their small size. The consequence of smaller patient size is production of a small image that will be of lower resolution

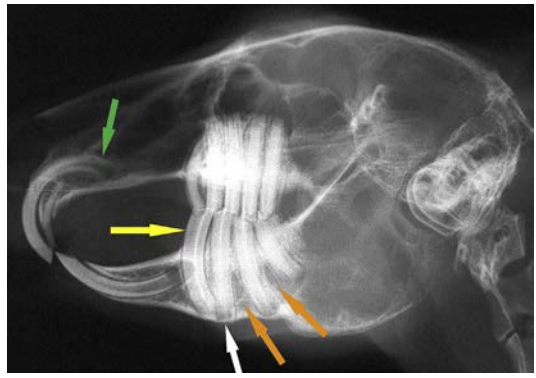

Fig. 1. Radiography of the head of a rabbit, latero-lateral view, demonstrating early stage of acquired dental disease. Overall coronal elongation of both maxillary and mandibular cheek teeth is present. Because both mandibular cheek teeth 1 do not have another tooth rostral to them, they begin to curve, with increasing rostral convexity (*yellow arrow*). Slight deformation of the ventral mandibular cortical bone owing to apical elongation of mandibular cheek tooth 2 is visible (*white arrow*). Owing to the abnormal convexity, the interproximal spaces of mandibular cheek teeth are widened (*orange arrows*). Malocclusion of the incisor teeth is not present at this stage, but apical elongation of a primary maxillary incisor is present (*green arrow*). The zig-zag pattern of the cheek teeth occlusal plane is still normal, but the radiotransparent line is not as discernible when the mandible is at rest. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

when magnified. Because spiral and multislice scanners offer very thin slices (even <1 mm) and large image matrices (512 × 512 pixels), resolution is superior to that obtained with most single slice scanners. High-resolution CT images can be magnified 1.5 to 2.0 times with computer software allowing better detection of subtle anatomic changes.

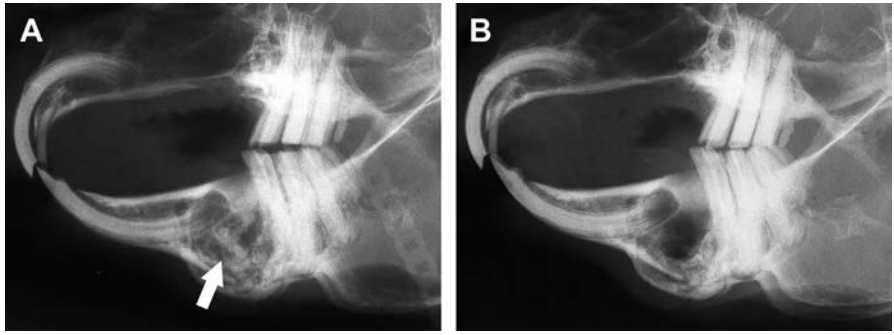

Fig. 2. Radiography of the head of a rabbit, latero-lateral view, demonstrating osteomyelitis of the mandible before (*A*) and after (*B*) surgical treatment. (*A*) A retained reserve crown of mandibular cheek tooth 1 (*arrow*) is visible inside the circular osteolytic area. Severe deformity of the cortical bone and periosteal reaction are visible. Both maxillary cheek tooth 1 and cheek tooth 2 had been extracted previously. Radiotransparency of the surgical site after debridement with extraction of the tooth fragment and necrotic bone tissue. The osteolytic area contained purulent material. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

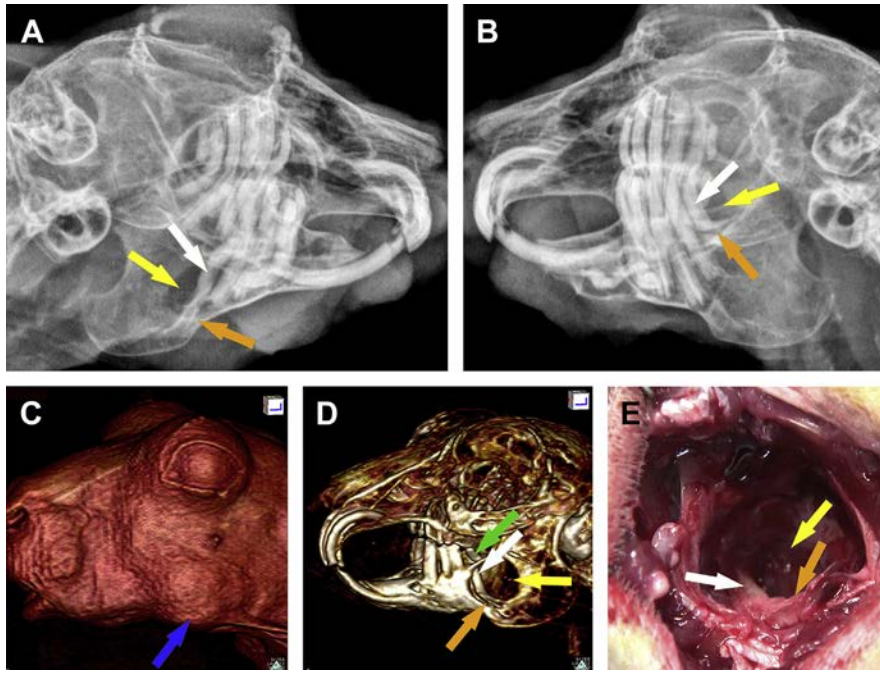

Fig. 3. Comparison between radiography and computed tomography (CT) for diagnosis of a retromasseteric abscess after periapical infection of the mandibular cheek tooth 4 and osteomyelitis affecting the masseteric fossa of the left mandible of a rabbit. (*A*, *B*). Oblique radiographic views of the skull. Rt 35° V-Lt D projection (*A*), and Lt 35° V-Rt D projection (*B*). Extensive bone lysis (*A*) affecting the left masseteric fossa (*yellow arrow*) and surrounding the abnormal reserve crown of mandibular cheek tooth 4 (*white arrow*) is present. Elongated and deformed apex of mandibular cheek tooth 4 is also visible (*orange arrow*). The apparent different elongation is owing to opposite obliquities of the 2 projections. (*C*, *D*). CT scan, 3-dimensional volume rendering of the head at the surface level (*C*), and after subtraction of soft tissues, at the level of the skull surface (*D*). The retromasseteric swelling (*blue arrow*) and the dental and skull abnormalities are displayed as a real model. (*D*) Bone lysis (*yellow arrow*), elongated reserve crown (*white arrow*), and diseased apex (*orange arrow*). The clinical crown of left mandibular cheek tooth 5, and the abnormal clinical crown of cheek tooth 4 just rostral to it, are also visible (*green arrow*). (*E*) Surgical exposure of the extensive and circular bone lysis of the masseteric fossa (*yellow arrow*), of the diseased reserve crown of mandibular cheek tooth 4 (*white arrow*), and of its apex (*orange arrow*) before extraction. Rt, right; Lt, left; V, ventral; d, dorsal; -, to. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

Patient positioning and anesthesia

Despite the flexibility of viewing modalities, proper positioning of the patient and the patient's head are of critical importance to obtain a good scanning and then interpreted by the radiologist and/or veterinarian.

Modern CT units are capable of scanning the entire head in a few seconds. Although owners are reluctant about anesthesia that is not related to surgery or other procedures, deep sedation or anesthesia are essential for proper positioning for CT and to reduce breathing artifact, especially in smaller mammals with higher respiratory rate.

The patient is positioned commonly in sternal recumbency, with the head elevated slightly and kept horizontal, parallel to the table.[1,6] The endotracheal tube will not

create a superimposition as in conventional radiographs. However, care must be taken that the connection with the anesthetic circuit does not prevent proper symmetric positioning of the head. The use of face masks is not recommended during scanning because the rubber material may create artifacts, or simply cover part of the face in the 3-dimensional renderings. Even though the scanning time is short, simple inhalant induction of anesthesia is not an effective option, increasing the chance the patient will revive and move during the scanning procedure. The author's preferred anesthetic protocol for any stable patient is with injectable drugs and oxygen administration via a face mask. The anesthetic effect allows adequate time for positioning, scanning, and verification of the CT images. Before scanning, a scout view is collected in both dorsoventral and lateral projection. Scout projections are standard radiographic images that are used to ensure accurate positioning and symmetry of the patient's head for CT scanning. The dorsoventral scout view is useful for evaluating bilateral symmetry, and the lateral projection is useful to assess the proper angle of the scanning plane. A provisional transverse scan through the tympanic bullae allows a further assessment of symmetric position of the head. The thickness of the slices is selected, as well as the extent of the scan. The face mask is then removed during the short scanning time and replaced once the scanning is completed.

Intravenous contrast medium can be used during CT imaging of rabbits.[16]

Interpretation of computed tomography

Data are usually acquired in the transverse plane (axial views) but can be reformatted by the computer and displayed also in sagittal, coronal, and oblique planes.[5] This capability is called multiplanar reformation. Although the resolution of analog or digital radiography is superior, viewing slices of the patient in sagittal and coronal planes as well as the standard axial plane offers tremendous advantages. Radiologists agree that axial views and additional 2-dimensional views represent the standard interpretation and are the most sensitive for diagnosis. However, dedicated imaging software allows various reconstruction techniques, including 3-dimensional volume rendering techniques and shaded surface displays.[5,6,16] Image volume presented in this fashion is virtually 3-dimensional, because the actual image is obviously 2-dimensional on the computer monitor. Volume rendering can be rotated on the monitor to allow the observer to visualize any surface. Also, additional functions can be performed, such as cropping part of the volume for evaluation of deeper anatomic structures. Both hard and soft tissues can be added virtually or subtracted to different extents and degrees of density, providing detailed relationship between soft and hard tissues. Shaded surface displays presents a contoured surface map of the entire image volume, converting CT data into an image very similar to an image of an anatomic specimen, well within the range of interpretation of a trained clinician. Although it has limited value because deep structures are masked, it is still very important for evaluating abnormalities of the bones of the skull such as deformities, osteomyelitis, and skull fractures. Depending on the specific case, volume and surface renderings may be of critical importance for diagnostic accuracy and to select the best surgical approach, when indicated.[18,19] Software for viewing DICOM images is readily available. Several products with varying operating system requirements and pricing are available; however, freeware is also available. CT images presented in this article have been produced with OsiriX, which is the most popular and user-friendly online freeware currently available to Apple users.

Indication for computed tomography

CT of the skull is a critical diagnostic imaging tool in rabbits for acquired dental disease and its related complications, such as osteomyelitis of the mandible (see **Figs. 3** and **4**)

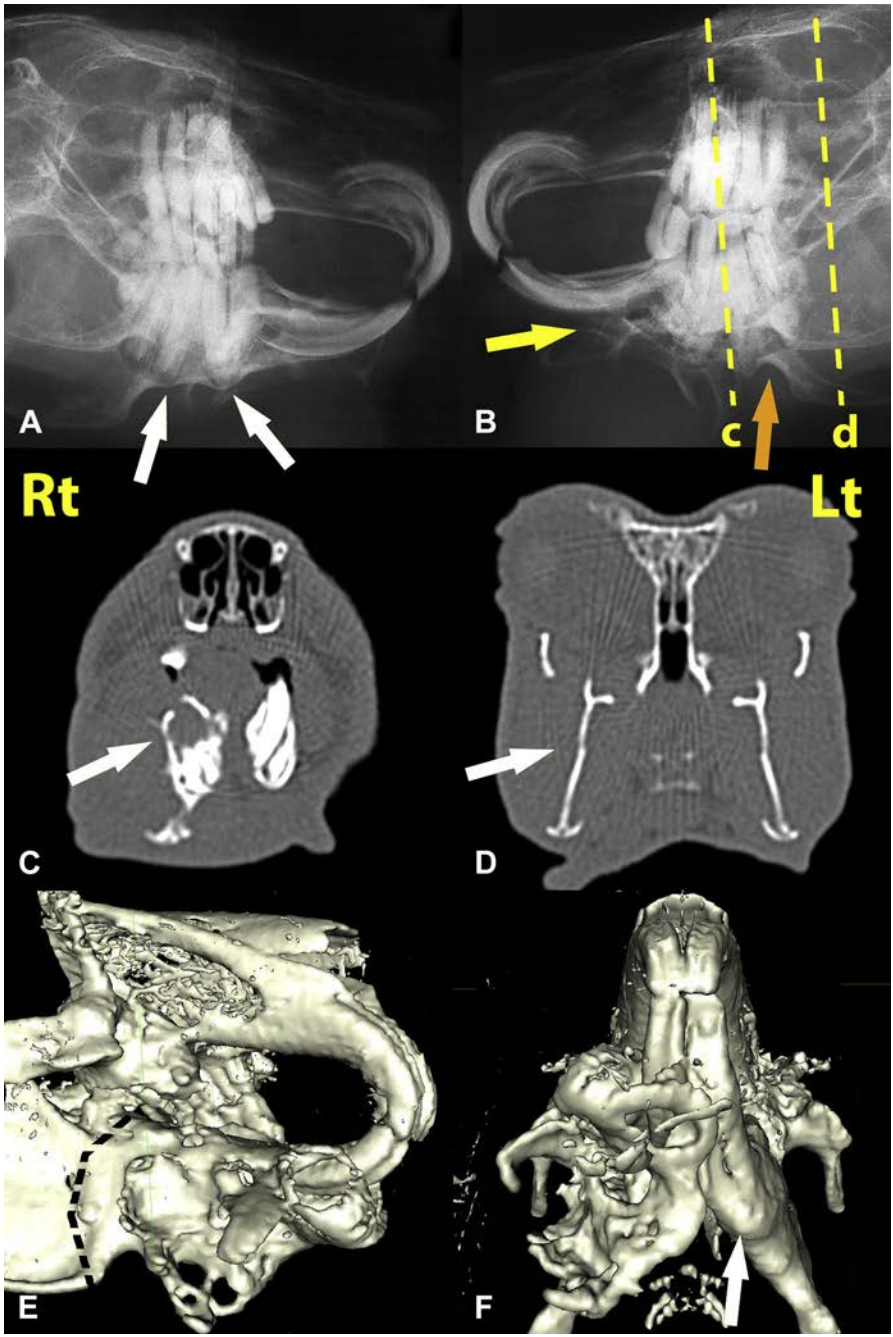

Fig. 4. Comparison between radiography and computed tomography (CT) scan for diagnosis of diffuse osteomyelitis of the incisive portion and of the body of the right mandible, after end-stage dental disease of the mandibular cheek teeth arcade of a rabbit. (*A*, *B*). Oblique radiographic views of the skull. Rt 15° V-Lt D oblique projection (*A*), Lt 15° V-Rt D oblique projection (*B*). (*A*) Elongation of reserve crowns and apices of left mandibular cheek teeth

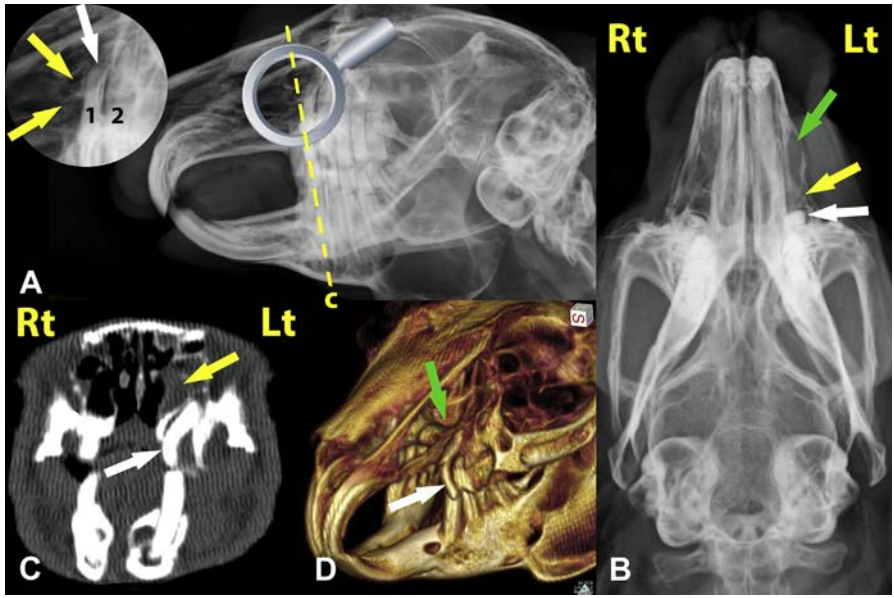

Fig. 5. Comparison between radiography and computed tomography (CT) for diagnosis of a zygomatic abscess after periapical infection of the maxillary cheek tooth 1, and empyema of the maxillary recess in a rabbit. (*A*, *B*) Radiographic views of the skull. Lt 15° V-Rt D oblique projection (*A*) and ventrodorsal projection (*B*). (*A*) Abnormal coronal and apical elongation of maxillary cheek tooth 1 (*inset*, *white arrow*), and abnormal radiodensity in the area of the left maxillary recess (*inset*, *yellow arrows*). (*B*) Abnormal apex of left maxillary cheek tooth 1 (*white arrow*); increased radiodensity of the left maxillary recess (yellow *arrow*); lysis at the perforated area of the maxilla just beneath the facial swelling (green *arrow*). (*C*) CT scan, axial view, of the scanning plane shown in (*A*; *yellow dotted line*). Abnormal left maxillary cheek tooth 1 (*white arrow*) and empyema of the left maxillary recess (*yellow arrow*). (*D*) CT scan, 3-dimensional volume rendering of the skull at the surface level. Abnormal left maxillary cheek tooth 1 (*white arrow*). After subtraction of soft tissues, the perforated surface of the maxilla may disappear because it is very thin. The green arrow indicates the position of the maxillary recess. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

with wider interproximal spaces are present. Compression and deformity of the ventral cortical bone of the left mandible is present (*white arrows*; see also *F*), but the overall bone is intact. (*B*) Elongation, deformity, and demineralization of reserve crowns and apices of the right mandibular cheek teeth. The cortical bone of the mandible is lytic and destroyed from the rostral end of the incisive portion (*yellow arrow*) to the incisure for facial vessels between the body and the masseteric fossa of the mandible (*orange arrow*). (*C*, *D*) CT scan, axial views of the scanning planes shown in (*B*; *yellow dotted lines*). Extensive lysis of the cortical bone of the incisive portion (*C*) and of the body of the right mandible (*arrow*) is visible; while the masseteric fossa (*arrow*) is intact (*D*). (*E*, *F*). CT scan, 3-dimensional surface rendering of the skull from the right lateral view (*E*), and from oblique rostroventral view (*F*). The "moth-eaten" enlarged and deformed incisive portion, and body of the right mandible, are displayed as a real model (*E*). The comparison with the destroyed and the intact mandible is emphasized (*F*). The black dotted line in (*E*) indicates the osteotomy line between the rostral diseased bone tissue and the caudal intact masseteric fossa for rostral mandibulectomy. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

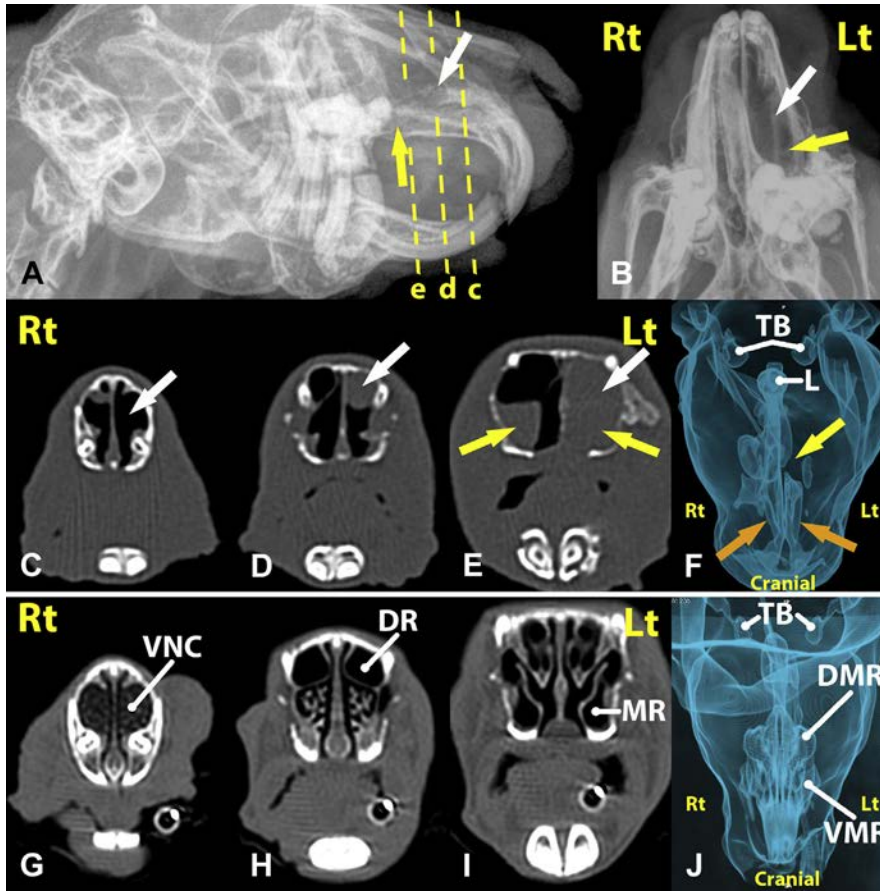

Fig. 6. Comparison between radiography and computed tomography (CT) scan for diagnosis of chronic odontogenic rhinitis with bilateral empyema of the nasal cavities of a rabbit (*A–F*) and the normal nasal cavities as a reference (*G–J*). (*A*, *B*). Radiographic views of the skull. Rt 15° V-Lt D oblique projection (*A*) and ventrodorsal projection with the mandible shifted to the right side (*B*). Severe acquired dental disease, including osteolysis and deformities of the right mandible after abscesses previously addressed with surgical procedures (*A*) and deformity of the left alveolar bulla. Irregular radiodensities of the nasal cavity in the areas of the ventral nasal concha (*white arrows*), and of the left maxillary recess (*yellow arrows*). (*C–E*). CT scans, axial views, of the scanning planes shown in (*A*; *yellow dotted lines*). (*C*) Bilateral lysis of the rostral portion of the ventral nasal concha (*arrow*). (*D*) Bilateral lysis of the caudal portion of the ventral nasal concha and empyema of the left dorsal conchal recess (*arrow*). (*E*) Bilateral lysis of turbinates, empyema of the left nasal cavity (*white arrow*), and bilateral empyema of the maxillary recesses (yellow *arrows*). (*F*) CT scan, 3-dimensional volume rendering of the skull applying the "airways" modality. The rostral portion of the nasal cavities is narrowed (*orange arrows*); the empty space of maxillary recesses are reduced, in particular the left (*yellow arrow*). L, larynx; TB, tympanic bullae. (*G–I*). CT scan, axial views, of the normal skull corresponding with the axial views shown in (*C–E*). DR, dorsal nasal concha; MR, maxillary recess; VNC, ventral nasal concha. (*J*) CT scan, 3-dimensional volume rendering of the normal skull applying the "airways" modality. DMR, dorsal portion of the maxillary recess; VMR, ventral portion of the maxillary recess. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

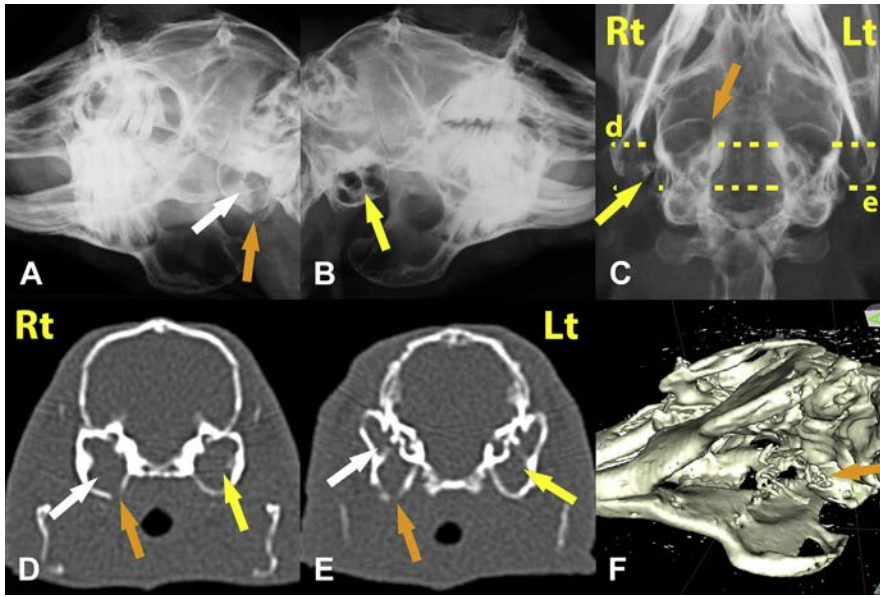

Fig. 7. Comparison between radiography and computed tomography (CT) scan for the diagnosis of bilateral empyema and otitis media of the tympanic bullae of a rabbit. (*A*, *B*) Radiographic views of the skull. Lt 30° V-Rt D oblique projection (*A*), Rt 30° V-Lt D oblique projection (*B*), and ventrodorsal projection (*C*). (*A*) Abnormal radiodensity within the right tympanic bulla (*white arrow*). The bony wall of the bulla is thinner than normal and lysis is present (*orange arrow*). (*B*) Abnormal radiodensity within the left tympanic bulla (*yellow arrow*). The bone is thinner than normal, but intact. (*C*) Bilateral, abnormal radiodensities within the tympanic bullae. The bony wall is thinner than normal and lytic on the right bulla (*orange arrow*). Periosteal reaction is also present close to the right acoustic meatus (*yellow arrow*). (*D*, *E*) CT scan, axial views, of the scanning planes shown in (*C*; *yellow dotted lines*). Bilateral radiodensity of the alveolar bullae indicative of empyema (*white* and *yellow arrows*) including the acoustic meatus (*E*, *white arrow*) and lysis of the ventral dome of the right bulla (D, E, *orange arrows*). (*F*) CT scan, 3-dimensional surface rendering of the skull with 45° obliquity, displaying the lytic, ventromedial part of the right tympanic bulla (*orange arrow*). (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

and the maxilla[5,6,16,20,21] (**Fig. 5**), empyemas of the bony cavities of the skull (**Figs. 5** and **6**), and the tympanic bullae for diagnosis of otitis media[20,21] (**Fig. 7**). Nasal and paranasal cavities, including meatuses, nasal septum, turbinates, and recesses, can be visualized in detail, making CT complementary to rhinoscopy.[22,23]

Despite smaller patient size, CT is also very important for detailed diagnosis of dental disease in rodent species,[24–28] including space occupying masses such as elodontomas,[29] or pseudoodontomas in prairie dogs, which compress the nasal cavities.[30,31]

Radiography versus computed tomography

CT is generally considered to be superior to standard radiography by default. A recent retrospective study performed on 30 rabbits with dental disease and its related complications compared radiography and CT on 2 different levels: diagnostic consistency and diagnostic accuracy.[18] Observations were statistically consistent for diagnosis between the 2 techniques. Nonetheless, the diagnostic accuracy of CT was superior in 80% of patients with regard to diagnosis and prognosis, and in 56.6% of patients for

guiding extraoral dental and surgical treatment. Greater sensitivity and superior accuracy for clinical diagnosis and prognosis was particularly valuable for cases of osteomyelitis after periapical infections, for rhinitis and otitis media. Radiography provided superior accuracy in 16.6% of patients for guiding intraoral dental treatment. Radiography and CT should be ideally performed together in most cases to improve diagnostic quality.

Microcomputed tomography

Micro-CT has recently emerged in private practice for small exotic mammals. Originally designed for laboratory animal imaging,[32] it may represent the new, advanced modality for diagnosis of dental disease in rabbits and rodents. The pet rabbit has been used as a model for a new micro-CT unit of 190 mm diameter, with 5 μm resolution, producing 2-dimensional standard images and 3-dimensional renderings of exceptional quality and with a superior level of detail[33] (**Fig. 8**). The basic principles of CT scanning and operation are the same; however, advantages are represented by a much smaller CT unit, which has been configured with a shield structure so that an additional lead shield chamber is not required to protect the operator from x-ray exposure.

Its compact size and design allows it to be used in a room much smaller than that needed by a traditional CT unit and this particular model can accommodate animals weighing up to 3 kg inside the gantry. A disadvantage of this model is represented by the limited range of species that can fit into the gantry, including large rabbits, precluding its use by small animal veterinarians. Other micro-CT units allow 20 cm of scanning extent, and can accommodate animals up to 15 kg, with lower resolution (**Fig. 9**).

The accurate and detailed images make micro-CT an outstanding diagnostic tool for small exotic patients.

ORAL ENDOSCOPY

Indications

Unlike other diagnostic imaging modalities, endoscopy (meaning *to view inside*) provides direct visualization of internal anatomic structures related to a real or virtual body cavity.[34–36] For this reason, the number of organs that can be evaluated is more limited than with the other diagnostic techniques. The specific name of oral endoscopy is *stomatoscopy*, and it represents an essential tool for diagnosis of dental disease in pet rabbits and rodent species.[1,2,34–39]

The most important advantages of stomatoscopy can be summarized as follows:

- The basic equipment is not very expensive;
- It requires basic skills by the veterinarian;
- The procedures are relatively simple and noninvasive;
- It allows thorough inspection of the narrow oral cavity of herbivorous species and even smaller rodent species;
- It offers a magnified perspective of dental structures;
- It highly reduces the risk of missing subtle lesions, facilitating early diagnosis;
- It facilitates coronal reduction of cheek teeth and other therapeutic procedures;
- It aids endotracheal intubation in selected patients;
- It allows the simultaneous visualization of the clinical case by multiple observers; and
- It allows documentation of images for tracking progress of disease, for medical records, and for both veterinary and client education.

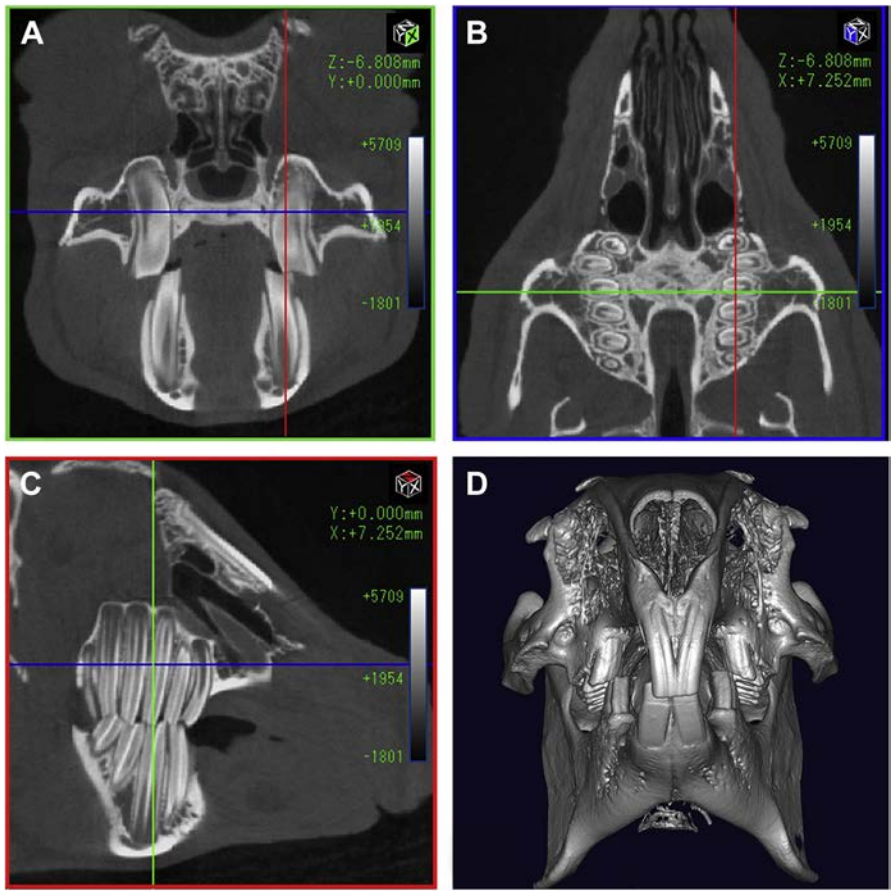

Fig. 8. Images produced with a micro-computed tomography (CT) unit of 190 mm diameter, and 5 μm resolution. This model produces 2-dimensional (2D) standard images and 3-dimensional renderings of exceptional quality and of a superior level of detail compared with standard CT units.[33] (*A–C*) The 2D multiplanar rendering displays axial (*A*), coronal (*B*), and longitudinal (*C*) views. The area of interest is targeted at the cross-point of the 2 perpendicular lines in each view, shown at the level of the left maxillary cheek tooth 3 in this normal rabbit. Each projection displays the other 2 views with a colored line. (*D*) These 3-dimensional reconstructions provide images similar to a sharply detailed real animal model. (*Courtesy of* Hiroshi Sasai, DVM; with permission.)

Rhinoscopy and pararhinoscopy (ie, endoscopy of the paranasal recesses) may be adjunct endoscopic procedures in the case of select complications of advanced dental disease such as empyema of the nasal cavity in rabbits.

Equipment

Detailed features of endoscopic instrumentation have been reported.[40] The most commonly used in exotic mammal medicine and surgery are the 2.7-mm (30° view) and the 1.9-mm telescope. Both have dedicated sheaths, either protecting or operating, the latter with several ports and instrument channels. The 1.9-mm semiflexible and the 1.7 flexible miniscopes are available and useful for smaller exotic mammals.

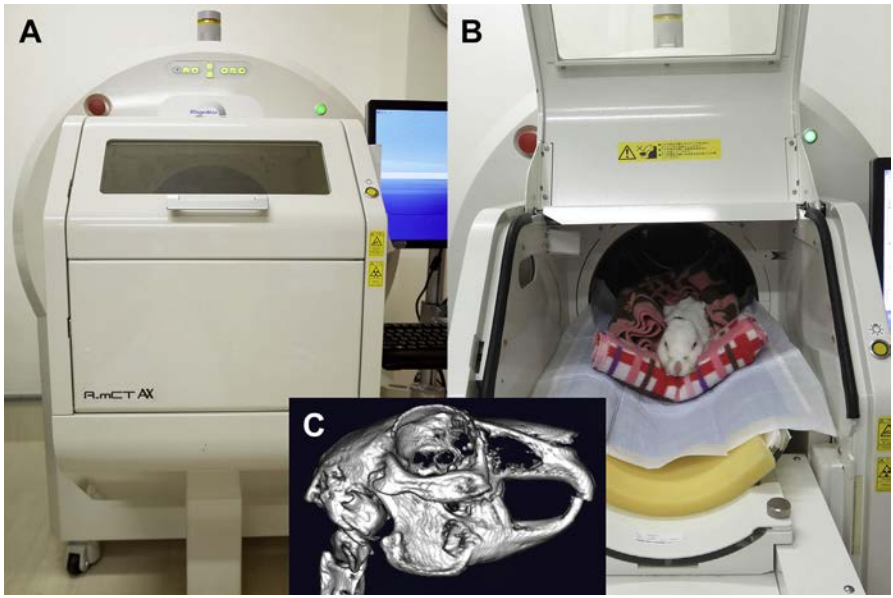

Fig. 9. Micro-computed tomography (CT) unit, R_mCT AX (Rigaku corporation, Tokyo, Japan). The CT unit is mobile and builtin shielding eliminates the requirements for a designated shielded room. Maximum resolution is 0.06 mm, which is superior to conventional CT for small patients. This unit can accommodate animals up to 15 kg. (*A*) External view of the CT unit. (*B*) Inside of the CT unit with a pet rabbit under anesthesia ready for scanning. This model produces excellent 2-dimensional images and high-resolution 3-dimensional renderings (*C*). (*Courtesy of* Yasutsugu Miwa, DVM, Tokyo, Japan; with permission.)

Additional basic endoscopic equipment includes a light source, light cable, endoscopic video camera, monitor, and digital recording device.

As with other endoscopic procedures, stomatoscopy is always performed under general anesthesia. Additional dental instruments for intraoral inspection such as mouth gags and cheek dilators are needed (see Capello V: Intraoral Treatment of Dental Disease in Pet Rabbits; Legendre L: Anatomy and Disorders of the Oral cavity of Guinea Pigs, in this issue).

Endoscopy of the Normal Oral Cavity in the Rabbit, Guinea Pig, and Chinchilla

Rabbit

Entering the mouth, the area on the dorsal aspect of the tongue is the lingual torus *(torus lingualis)*. The mucosa of the lingual torus is light pink, thick, and prominent as compared with the rest of the lingual mucosa. Mandibular cheek teeth arcades are visible lateral to the tongue. Normal length of clinical crowns must be assessed. Positioning the endoscope tangential to the occlusal plane allows detailed inspection and assessment of the normal zig-zag pattern. Normal, small enamel points are visible on the lingual aspect of the mandibular cheek teeth (**Fig. 10**A).

The inferior alveolar vessels are visible below the thin oral mucosa distal to mandibular cheek tooth 5. Special attention must be paid to avoid injuring these vessels during coronal reduction of cheek teeth. Clinical crowns of maxillary cheek teeth are normally shorter than those of the mandibular teeth, and maxillary cheek tooth 6 is significantly smaller than the other 5 cheek teeth (**Fig. 10**B). A better view of the maxillary dental arcades may be obtained by turning the endoscope 180°.

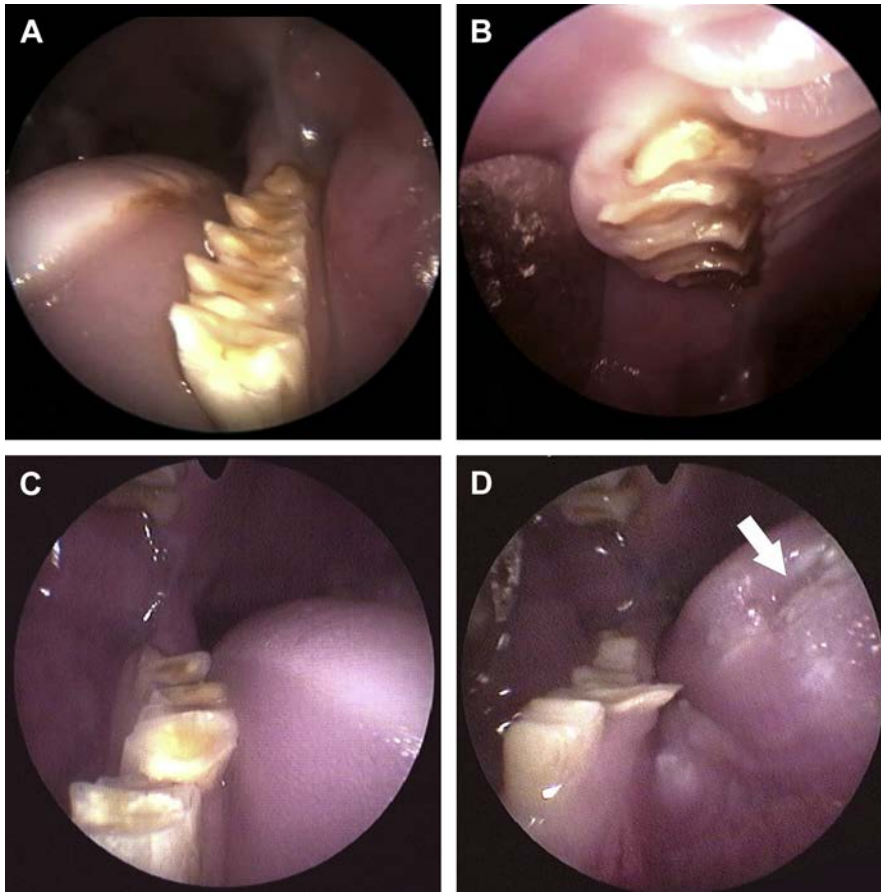

Fig. 10. Oral endoscopy in the rabbit. (*A*) Normal appearance of the left mandibular cheek teeth. Small enamel points visible on the lingual aspect are normal. (*B*) Normal appearance of the right maxillary cheek teeth. The clinical crowns are shorter than those of the mandibular arcade. The tiny clinical crown of cheek tooth 6 is not visible from this view. (*C*) Acquired dental disease and malocclusion of the right mandibular arcade. Abnormal elongation and shortening of clinical crowns, uneven occlusal plane ("step mouth"), and initial lingual bending of the teeth are present. (*D*) Sharp lingual spike of the second premolar tooth (cheek tooth 4) caused by improper wearing and related lesion of the lingual mucosa (*arrow*). (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

Guinea pig

The anatomy, structure, and function of the tongue of guinea pigs are unique. The tongue is divided by a visible groove into a rostral and a caudal portion that move independently. The prominent lingual torus is covered by papillae. Bilateral mucosal folds (frenula) extend laterally from the rostral portion to the mandible.

Food debris on the dental surfaces is a common finding in normal guinea pigs. Before inspection, the oral cavity should be gently flushed and cleaned with cotton swabs.

Cheek teeth of guinea pigs have a 30° sloped occlusal plane from buccal to lingual, dorsal to ventral. The normal oblique angle of the occlusal plane must be carefully

assessed, and evaluation should not be affected by improper orientation of the endoscope (Fig. 11A, B).

Chinchilla

Inspection of the oral cavity is easier in chinchillas than in guinea pigs, because there is no angulation of the cheek teeth occlusal plane. The torus of the tongue is not present in chinchillas. The clinical crowns of mandibular cheek teeth are very short, and the occlusal surface is flat but rough because of the presence of dentinal grooves interspersed in between enamel ridges. The mandibular first premolar is almost triangle shaped (Fig. 12A, B).

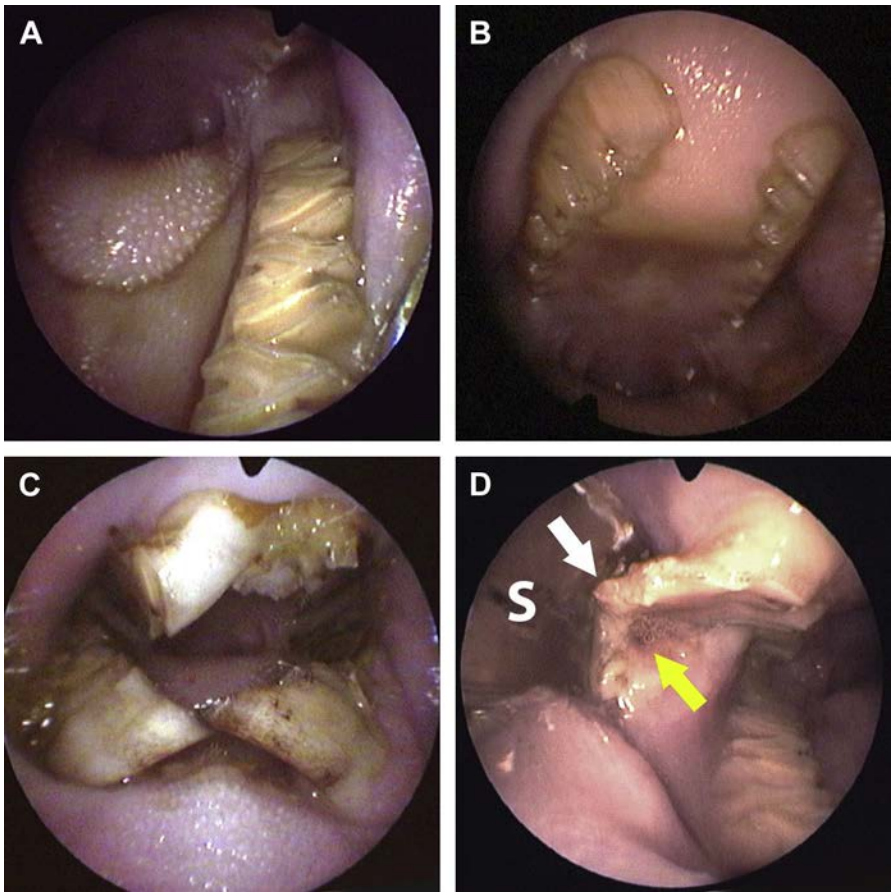

Fig. 11. Oral endoscopy in the guinea pig. (*A*) Normal appearance of the left mandibular cheek teeth. Enamel crests and dentinal grooves are visible over the sloped occlusal plane. (*B*) Normal appearance of the maxillary cheek teeth, with focus on the left arcade. (*C*) Severe coronal elongation and uneven occlusal plane of cheek teeth. Right and left mandibular cheek tooth 1 cross each other in a "bridge-like" malocclusion over the tongue. (*D*) Sharp buccal spike of the first maxillary premolar tooth (*white arrow*) after improper wearing, causing ulcerations of the buccal mucosa (*yellow arrows*). Spikes must be identified thoroughly during inspection by deflecting the buccal mucosa with the aid of a curved spatula (*S*). (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

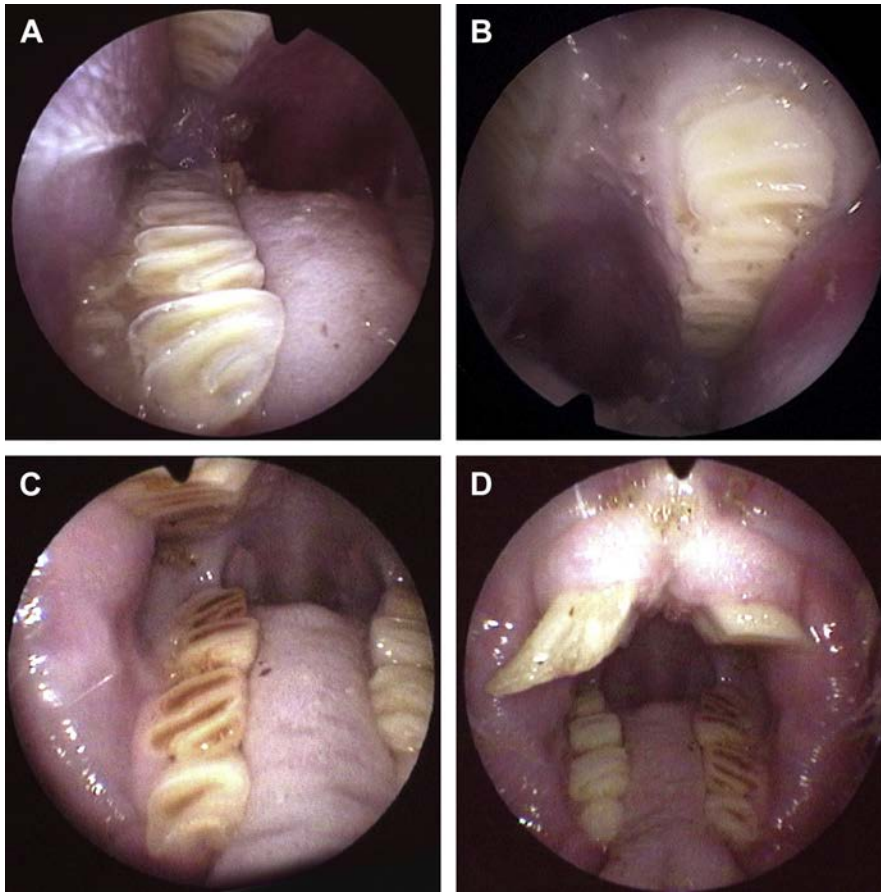

Fig. 12. Oral endoscopy in the chinchilla. (*A*) Normal appearance of the right mandibular cheek teeth. Enamel crests and dentinal grooves are visible over the occlusal plane. (*B*) Normal appearance of the left maxillary cheek teeth. Clinical crowns of cheek teeth are much shorter than in rabbits, and the occlusal plane is not oblique, as in guinea pigs. (*C*) Acquired dental disease of cheek teeth. Coronal elongation, "wave mouth," widened interproximal spaces, and a laterally deviated occlusal plane are present. (*D*) Severe coronal elongation and sharp buccal spikes of the first maxillary premolar teeth caused by improper wearing. Increase of both the alveolar crest and the gingival margin of the maxillary cheek teeth is typical in chinchillas with advanced dental disease. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

Endoscopic Abnormalities of the Cheek Teeth in the Rabbit, Guinea Pig, and Chinchilla

Many different abnormalities from mild to severe may be recognized in cases of acquired dental disease of cheek teeth. The severity of the pathologic changes can be staged. Early diagnosis is the key to early treatment and resolution of lesions affecting the gingiva, tongue, and oral mucosa. These lesions can be a source of constant discomfort or pain. Prompt treatment also prevents the progression of dental disease.

Rabbit

The earliest stage of acquired dental disease of cheek teeth in rabbits detectable with stomatoscopy is elongation of the clinical crowns. Changes of the occlusal plane are

owing to excessive and irregular coronal elongation, with differences in height of up to a few millimeters between 1 cheek tooth and the adjacent tooth. This abnormal occlusal plane is called "wave mouth." When abnormality of the occlusal plane is evident, with marked differences of crown length between 2 adjacent cheek teeth, this abnormal occlusal plane is called "step mouth" (**Fig. 10**C). Usually, in cases of both "wave mouth" and "step mouth," sharp spurs are not present, and clinical signs and symptoms may be mild or absent.

Lingual curvature of clinical crowns of mandibular cheek teeth and buccal curvature of clinical crowns of maxillary cheek teeth lead to the development of points and sharp spikes. Spikes and spurs from mandibular cheek teeth may develop over the tongue, or may be oriented to the side the tongue producing severe damage to the lingual mucosa (**Fig. 10**D). To detect small but sharp spikes, the tongue must be deflected carefully during stomatoscopy. For this reason, these spikes may be very difficult to visualize during examination of the oral cavity in the conscious patient. Symptoms such as excessive salivation can suggest these types of lesions.

Bilateral dental spurs of 1 or more mandibular teeth represent a more severe stage of dental disease than "wave mouth" or "step mouth." The lingual edge may not always be sharp, but overgrown mandibular cheek teeth can impinge on the tongue and affect chewing and swallowing. Discomfort is present and at this stage clinical signs may include teeth grinding, reluctance to chew, changes in food preference, excessive salivation, and signs related to secondary gastrointestinal disorders.

A common sequela of excessive coronal elongation of cheek teeth is fracture, especially of mandibular cheek teeth. The longitudinal fracture of the mandibular first premolar (cheek tooth 1) is relatively common. This often occurs when the rabbit chews improper hard foods such as seeds. Inspection of the oral cavity with a metal cone (especially when improperly inserted between the cheek teeth arcades) may also cause or predispose to this fracture. The most common sequela of fractures is periapical infection and abscess. Fractures often produce no clinical signs and symptoms; therefore, the first clinical sign may be the appearance of a lump representing the developing abscess.

Excessive coronal elongation and malocclusion (including "wave mouth" and "step mouth") also affect maxillary cheek teeth. Coronal elongation is usually accompanied by an increase in the height of both the alveolar crest and the gingival margin. These changes are more apparent in maxillary rather than mandibular cheek teeth malocclusion.

Spurs of maxillary cheek teeth typically form on the buccal aspect of the tooth and may cause ulcerations of the mucosal surface of the cheek. Clinical signs and symptoms are usually less severe than those associated with spurs of mandibular cheek teeth. Nevertheless, in other cases they can lead to odontogenic, nonperiapical abscesses.

Guinea pig

The most common early stage of malocclusion of cheek teeth in guinea pigs is elongation of 1 or both mandibular premolars. Symptoms may be mild or absent, and this stage represents a common finding of early malocclusion in healthy guinea pigs. Bridgelike overgrowth of the mandibular premolars is a common finding and depicts a more advanced form of cheek teeth malocclusion in guinea pigs.

Owing to the peculiar orientation of the cheek teeth and the anatomy of the tongue, abnormal coronal elongation of mandibular cheek teeth is always oriented lingually. However, unlike rabbits, the tongue is almost never traumatized by sharp edges or spurs. Discomfort is a result of entrapment of the tongue by elongated cheek teeth, affecting tongue movements and deglutition (see **Fig. 11**C).

Intermediate stages include malocclusion of the entire mandibular cheek teeth arcade. Coronal elongation and the abnormal occlusal plane must be assessed carefully with the aid of an endoscope. Gingivitis is a common sequela of coronal elongation, impaction of food debris, or hair impaction in long-haired breeds. Severe coronal elongation, malocclusion, and sharp buccal margins develop at maxillary cheek teeth (**Fig. 11**C).

Chinchillas

Coronal elongation and malocclusion of cheek teeth occurs in chinchillas, and is similar to some extent to dental disease in guinea pigs and in rabbits. However, presenting signs and symptoms are usually much less severe when compared with guinea pigs, and may also vary from the typical presentation in rabbits. Mild abnormalities include slight elongation of the clinical crowns, mild alteration of the normal enamel crests and dentinal grooves, and slightly widened interproximal spaces. Pattern of malocclusion similar to "wave mouth" and "step mouth" of rabbits are present in chinchillas (**Fig. 12**C). Like guinea pigs but unlike rabbits, chinchillas seldom develop sharp spurs of mandibular cheek teeth. When present, spurs usually do not traumatize the tongue, but rather impair its movement and entrap it under the elongated crowns. Advanced dental disease exhibits widened interproximal spaces. Food impaction in between the clinical crowns is a common consequence, leading to gingivitis. Unlike rabbits and guinea pigs, cavities are a frequent finding in chinchillas affected by dental disease. Partial or complete fracture of the clinical crowns is a further complication.

Coronal elongation of maxillary cheek teeth and abnormal sharp edges are frequently accompanied by an increase in height of both the alveolar crest and the gingival margin (see **Fig. 12**C). Proliferation of the gingiva makes coronal reduction more difficult and seems to be associated with increased discomfort and a poorer prognosis in chinchillas. Simple burring of elongated crowns may not relieve discomfort and should be considered when formulating a prognosis. In the case of end-stage dental disease, clinical crowns may be worn out and fractured, reserve crowns may no longer replace clinical crowns, and gingiva may heal over reserve crowns.

MRI

MRI is considered a non-invasive imaging modality because it does not use radiation for generating images. Similar to CT, it is a computer-based technique; but in MRI, images are obtained visualizing the movements of hydrogen atoms in the body of the patient in reaction to a very strong magnetic field placed around the patient.[16,20,41] The animal undergoing MRI examination should always be under general anesthesia.

MRI represents the diagnostic imaging procedure of choice for soft tissues. It is most commonly used for the central nervous system, but other soft tissues can be visualized in detail. MRI has superior quality to CT, even exceeding CT with contrast. Different types of sequences (images) can be obtained depending on the tissues to be emphasized. Sequences are produced and visualized in one of the 3 standard views (transverse or axial, dorsal or coronal, lateral or sagittal). Unlike CT, complex manipulation and 3-dimensional volume and surface renderings are not possible, because images are not based on voxels. Acquisition of MRI sequences also depends on several technical factors that are beyond the scope of this article. However, the most important and most practical are the type of sequence, the sequence views, and the overall number of sequences. These factors, together with resolution, have an impact on the time for resonance.

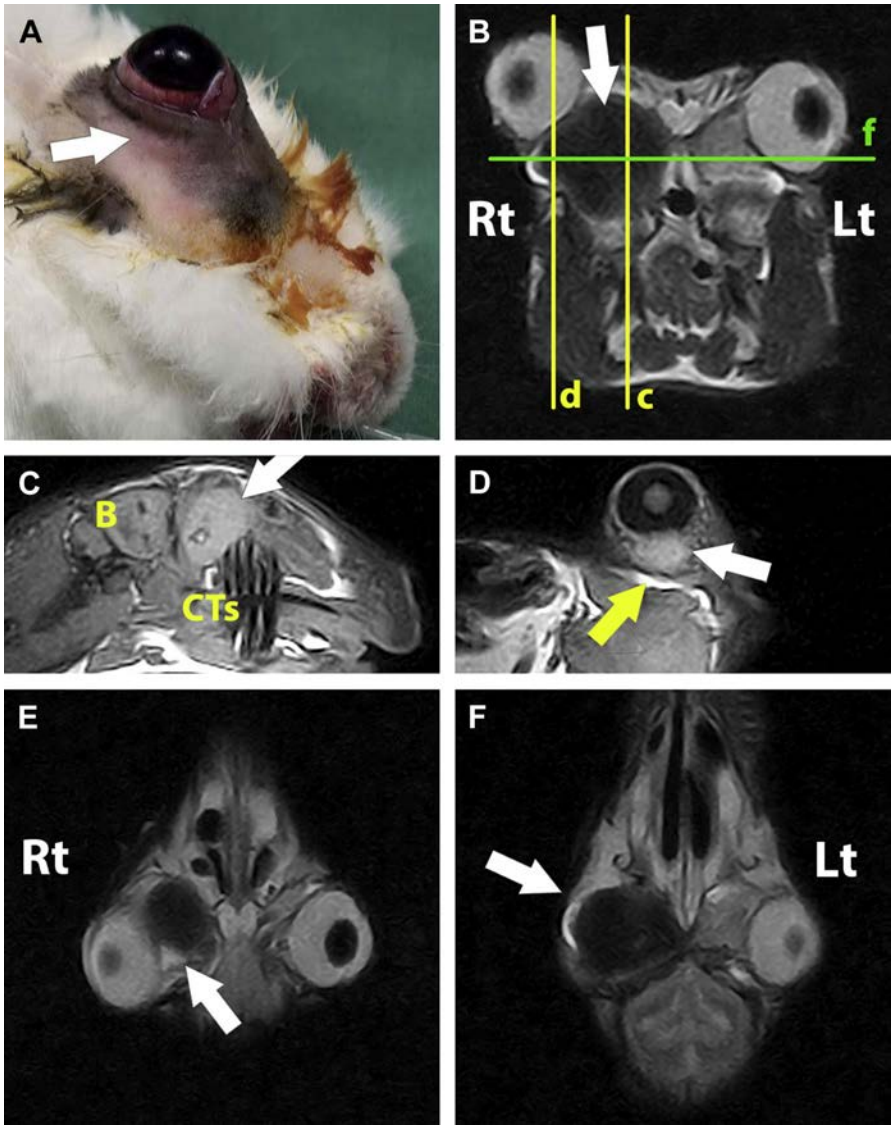

Fig. 13. MRI for diagnosis of a retrobulbar abscess after periapical infection of right maxillary cheek teeth in a rabbit. (*A*) Clinical aspect of the exophthalmos. The *white arrow* indicates the lateral surgical approach to the abscess. (*B*) T2 sequence, axial view, demonstrating a large retrobulbar mass (*white arrow*). Thick pus appears dark in T2 sequences. The yellow lines display the longitudinal views in (*C*, *D*). The green line displays the coronal view in (*F*). (*C*, *D*) Longitudinal views, T1 sequences, demonstrating the retrobulbar mass (*white arrow*) over the alveolar bulla (*C*) and the top of the mass (*white arrow*) protruding just over the zygomatic arch (*yellow arrow*) and just below the eye globe (*D*). Thick pus appears white in T1 sequences. (*E*, *F*) Coronal views, T2 sequences, demonstrating that the caudal approach to the retrobulbar space was not an option because of the dislocation of the optic nerve (*E*, *white arrow*), and indicating a viable lateral approach to the mass (*F*, *white arrow*). (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

Two potential disadvantages of MRI are actually resolution (especially for small patients) and prolonged scanning time, when compared with CT. Resolution depends on the magnet of the MRI unit. Low power magnets capable of field strengths of 0.2 to 0.4 T will produce lower resolution images than magnetic fields of 1 T or higher. Higher resolution can also be achieved with prolonged resonance time. The average time for acquisition of diagnostic sequences for a rabbit patient using a low-field MRI unit can range from 20 to 40 minutes, whereas the acquisition time for CT scanning can be less than a minute. Owing to long acquisition time, images may be affected by respiratory and cardiac rate, which are higher in small sized mammals. However, this does not usually represent a concern because they are reduced significantly under anesthesia and when the thorax is not the diagnostic target.

Indications and Applications for Rabbit and Rodent Dental Disease

Thick pus and the capsule, typical of rabbit odontogenic abscesses, have a signal intensity similar to other soft tissues. However, standard fluid pus can be displayed as well. For this reason, MRI of the head for indications other than investigation of the central nervous system represents an interesting and very useful application in pet rabbits and rodents to diagnose the presence and the extent of abscesses[20,21,27] (**Figs. 13** and **14**). In cases of mandibular abscesses, retrobulbar and parabulbar abscesses, and single or multiple empyema affecting 1 or more cavities of the rabbit skull (nasal cavities, maxillary recess, diseased alveolar bulla, and tympanic bulla) MRI provides excellent information, even superior to CT, which is less specific for lower radiodensities.[20,21] Like CT, MRI can provide a high level of diagnostic accuracy, providing

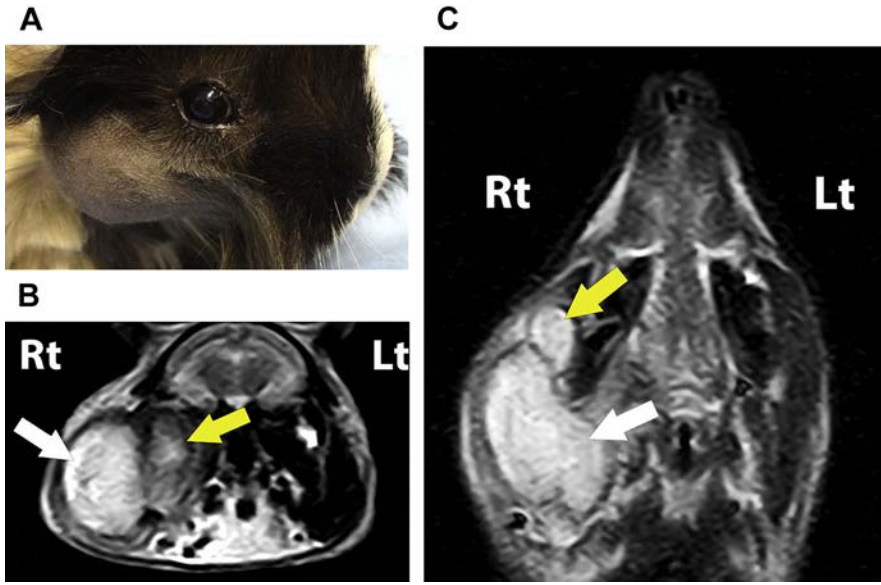

Fig. 14. MRI for diagnosis of a retromasseteric abscess after periapical infection of the right mandibular cheek tooth 4 in a guinea pig. (*A*) Clinical aspect of the facial swelling after fur shaving. (*B*, *C*) T1 sequences, axial (*B*) and coronal (*C*) views demonstrating a bilobed mass, with a main large lobe (*white arrows*) and a smaller, anteromedial lobe (*yellow arrows*). Owing to the caudal surgical approach to the abscess, the cranial lobe might have easily been missed during surgery without the accurate diagnostic information provided by MRI. (*Courtesy of* Vittorio Capello, DVM, Milano, Italy; with permission.)

a critical guide in preoperative planning. For example, most odontogenic abscesses of guinea pigs are retromasseteric owing to anatomic features of the skull, cheek teeth, and masseter muscle. The exact visualization of the abscess, superior to the soft tissue window of CT, may optimize the difficult surgical approach.

CT remains superior for diagnosis of dental disease and related bone infection.[16,20,21] For this reason, CT and MRI of the head are best used as complementary tests. In most cases, this is not feasible for practical and financial reasons; therefore, the clinical examination and survey radiographs would guide the clinician to choose the most useful adjunct diagnostic imaging test for the specific case.

SUMMARY

After the clinical examination, several diagnostic imaging techniques are beneficial for diagnosis, prognosis, and treatment of dental disease in rabbits and rodents. Beside standard radiography and stomatoscopy, advanced imaging such as CT and MRI are critical for diagnostic accuracy.

REFERENCES

1. Capello V, Gracis M, Lennox AM, editors. Rabbits and rodents dentistry handbook. Lake Worth (FL): Zoological Education Network; 2005. p. 1–272.
2. Capello V, Lennox AM. Small mammal dentistry. In: Quesenberry KE, Carpenter JW, editors. Ferrets, rabbits and rodents clinical medicine and surgery. 3rd edition. St Louis (MO): Elsevier Saunders; 2012. p. 452–71.
3. Lennox A. Diagnosis and treatment of dental disease in pet rabbits. J Exot Pet Med 2008;17:107–13.
4. Jekl V. The dental examination. In: Harcourt-Brown F, Chitty J, editors. Manual of rabbit surgery, dentistry and imaging, vol. 25, 1st edition. Quedgeley, Gloucester British Small Animal Veterinary Association; 2013. p. 337–48.
5. Capello V, Lennox AM. Clinical radiology of exotic companion mammals. Ames (IA): Wiley Blackwell; 2008.
6. Capello V, Cauduro M. Application of computed tomography for diagnosis of dental disease in the rabbit, guinea pig, and chinchilla. J Ex Pet Med 2008;17:93–101.
7. Jekl V. Principles of radiography. In: Harcourt-Brown F, Chitty J, editors. Manual of rabbit surgery, dentistry and imaging, vol. 3, 1st edition. Quedgeley, Gloucester British Small Animal Veterinary Association; 2013. p. 39–58.
8. Gracis M. Clinical technique: normal dental radiography of rabbits, guinea pigs, and chinchillas. J Ex Pet Med 2008;17:78–86.
9. Boehmer E. Intraoral radiographic technique in lagomorphs and rodents. Exotic DVM 2007;9(3):2–27.
10. Boehmer E, Crossley D. Objective interpretation of dental disease in rabbits, guinea pigs and chinchillas. Tierarzliche Praxis Kleintiere 2009;73:250–60.
11. Silverman S, Tell LA. Radiology of rodents, rabbits and ferrets. An atlas of oral anatomy and positioning. St Louis (MO): Elsevier Saunders; 2005.
12. Reese S, Fehr M. Small mammals. In: Krautwald-Junghanns ME, Pees M, Reese S, et al, editors. Diagnostic imaging of exotic pets. Hannover (Germany): Schlütersche Verlagsgesellschaft GmbH & Co; 2011. p. 143–307.
13. Raftery A. Radiographic interpretation of the skull. In: Harcourt-Brown F, Chitty J, editors. Manual of rabbit surgery, dentistry and imaging, vol. 4, 1st edition. Quedgeley, Gloucester British Small Animal Veterinary Association; 2013. p. 59–68.

14. Fischetti AJ. Diagnostic imaging. In: Quesenberry KE, Carpenter JW, editors. Ferrets, rabbits and rodents clinical medicine and surgery. 3rd edition. St Louis (MO): Elsevier Saunders; 2012. p. 502–10.
15. Boehmer E. Dentistry in rabbits and rodents. Philadelphia: Wiley-Blackwell; 2015.
16. Veraa S, Schoemaker N. CT and MRI scanning and interpretation. In: Harcourt-Brown F, Chitty J, editors. Manual of rabbit surgery, dentistry and imaging, vol. 9, 1st edition. Quedgeley, Gloucester British Small Animal Veterinary Association; 2013. p. 107–14.
17. Van Caelenberg AI, De Rycke LM, Hermans K, et al. Computed tomography and cross-sectional anatomy of the head in healthy rabbits. Am J Vet Res 2010;71(3): 293–303.
18. Capello V, Cauduro A. Comparison of diagnostic consistency and diagnostic accuracy between survey radiography and computed tomography of the skull in 30 rabbits with dental disease. J Exotic Pet Med 2016;25(2):115–27.
19. Van Caelenberg AI, De Rycke LM, Hermans K, et al. Comparison of radiography and CT to identify changes in the skulls of four rabbits with dental disease. J Vet Dentistry 2011;28(3):172–81.
20. Capello V. Application of computed tomography and magnetic resonance in exotic companion mammals. In: Proceedings of the 16th ABVP symposium. St Louis (MO): 2011.
21. Capello V. Novel diagnostics and surgical techniques for treatment of difficult facial abscesses in pet rabbits. In: Proceedings of the North Am Vet Conference. Orlando (FL): 2011. p. 1685–9.
22. Capello V, Lennox AM. Diagnostic imaging of the respiratory system in exotic companion mammals. Vet Clin North Am Exot Anim 2011;14(2):369–89.
23. Capello V. Rhinostomy as surgical treatment of odontogenic rhinitis in three pet rabbits. J Exotic Pet Med 2014;23(2):172–87.
24. Chesney CJ. CT scanning in chinchillas. J Small Anim Pract 1998;39:550.
25. Crossley DA, Jackson A, Yates J, et al. Use of computed tomography to investigate cheek tooth abnormalities in chinchillas (Chinchilla laniger). J Small Anim Pract 1998;39:385–9.
26. Brenner SZG, Hawkins MG, Tell LA, et al. Clinical anatomy, radiography, and computed tomography of the chinchilla skull. Comp Cont Ed Pract Vet 2005; 27:933–44.
27. Capello V, Lennox A. Advanced diagnostic imaging and surgical treatment of an odontogenic retromasseteric abscess in a guinea pig. J Small Anim Pract 2015; 56(2):134–7.
28. Souza MJ, Greenacre CB, Avenell JS, et al. Diagnosing a tooth root abscess in a guinea pig (Cavia porcellus) using micro computed tomography imaging. J Exot Pet Med 2008;15:274–7.
29. Capello V, Lennox AM, Ghisleni G. Elodontoma in Two Guinea Pigs. J Vet Dent 2015;32(2):111–9.
30. Capello V. We are not smaller rabbits, either. Dentistry of other rodent species and ferrets. In: Proceedings of the North Am Vet Conference. Orlando (FL): 2011. p. 1681–4.
31. Pelizzone I, Vitolo GD, D'Acierno M, et al. Lateral approach for excision of maxillary incisor pseudo-odontoma in prairie dogs (Cynomys ludovicianus). In vivo 2016;30:61–8.
32. De Rycke LM, Boone MN, Caelenberg Van, et al. Micro-computed tomography of the head and dentition in cadavers of clinically normal rabbits. Am J Vet Res 2012;73(2):227–32.

33. Sasai H, Iwai H, Fujiita D, et al. The use of micro-computed tomography in the diagnosis of dental and oral diseases in rabbits. BMC Vet Res 2014;10:209.
34. Divers SJ. Exotic mammal diagnostic endoscopy and endosurgery. Vet Clin Exot Anim 2010;13:255–72.
35. Hernandez-Divers SJ. Clinical technique: dental endoscopy of rabbits and rodents. J Ex Pet Med 2008;17:87–92.
36. Divers SJ. Exotic mammal diagnostic and surgical endoscopy. In: Quesenberry KE, Carpenter JW, editors. Ferrets, rabbits and rodents clinical medicine and surgery. 3rd edition. St Louis (MO): Elsevier Saunders; 2012. p. 485–501.
37. Taylor M. Endoscopy as an aid to examination and treatment of the oropharyngeal disease of small herbivorous mammals. Sem Avian Exot Pet Med 1999;8:139–41.
38. Capello V. Application of rigid oral endoscopy in exotic companion mammals. In: Proceedings of the 16th ABVP Symposium. St Louis (MO): 2011.
39. Melillo A. Endoscopy. In: Harcourt-Brown F, Chitty J, editors. Manual of rabbit surgery, dentistry and imaging, vol. 10, 1st edition. Quedgeley, Gloucester British Small Animal Veterinary Association; 2013. p. 115–22.
40. Divers SJ. Endoscopy equipment and instrumentation for use in exotic animal medicine. Vet Clin Exot Anim 2010;13:171–85.
41. Gavin PR, Bagley RS. Practical small animal MRI. Ames (IA): John Wiley & Sons; 2009.