The use of micro-computed tomography (micro-CT) in the diagnosis of dental and oral disease in rabbits

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Abstract

Background

The aim of this paper is to report a newly developed micro-computed tomography (micro-CT) system for the diagnosis of oral pathologies in small animals, using the rabbit as a model. The diagnosis of dental diseases in rabbits is usually based on oral endoscopy and radiographic imaging, but detailed pathological diagnosis using these methods is frequently difficult. Micro-CT was used to address this challenge.

Results

This study was conducted using 50 rabbits, which were brought by their owners to our hospital because of loss of appetite and feeding difficulty. Image recording times were 18 s in normal mode and 120 s in fine mode. The animals were successfully maintained in position for scanning by administration of sedatives.

Micro-CT captured with a slice thickness of 60-120 mm has excellent spatial resolution and is suitable for clinical diagnosis of dental disease in a rabbit weighing 1 to 3 kg.

Conclusions

Micro-CT can obtain image data that are impossible or difficult to recognize with radiography or conventional CT. This study determined that this novel imaging modality can be utilized for the accurate assessment of dental and oral disease in the
rabbit.

Keywords: computed tomography; dentistry; rabbit
Introduction

Dental disease and its complications, such as molar or incisor malocclusion and apical abscesses of the upper and lower jaw, are common in pet rabbits. These conditions can become quite severe, which may lead to a loss of feeding ability and even death if left untreated [1].

Diagnosis of dental disease in rabbits is based on clinical signs, oral endoscopy, and radiography of the head [1, 2]. Radiography is a useful diagnostic method in rabbits suspected of having dental diseases. Owing to the overlapping of anatomic structures, multiple radiographic projections are needed to obtain a diagnosis [3].

Micro-computed tomography (micro-CT) has a remarkable space resolution and a shorter capture time compared with Cone beam computed tomography used in human medicine, coupled with highly developed image reconstruction technology, making it possible to actively conduct imaging examinations in laboratory animals and other small animals [4]. Cone beam computed tomography (CBCT) has been used in the image-based evaluation of medical conditions in dogs and cats [5]. Computed tomography, particularly CBCT, has been used in anatomical studies on rabbits and guinea pigs [3, 6-8]. In most cases, its clinical applications have been limited because of low resolution or an excessively long image processing time [7-9].
Radiographic evaluation of the state of the teeth, bones, and soft tissue requires shooting multiple images from various angles. Endoscopy is limited to the crown portions. Micro-CT imaging does not require the use of various positions, as is the case with radiography. The shortest possible implementation is 18 s, however, and the time needed for image reconstruction is one minute. Because multi-planar reconstruction images and three-dimensional (3D) images are obtained at the same time, the length of the diagnostic procedure is significantly shortened.
Materials and methods

Description of rabbits included in the study

Clinical examinations and prognostic evaluations were performed using micro-CT on 50 rabbits (mean age, 4.7 ± 2.6 years), which were brought to our clinic because of loss of appetite or feeding difficulty resulting from dental diseases. The study included 36 males and 14 females, and the breeds represented included Netherland Dwarfs (n = 8), Holland Lop-eared (n = 8), mini-rabbits (n = 10), and other breeds (n = 24). The diagnoses included mandibular abscess and osteolysis (n = 24), maxillary tooth root growth lesion (n = 11), excessively long molar ends (n = 12), excessively long molar crowns (n = 25), excessively long incisors (n = 5), incisor tooth end abscess (n = 4), maxillary abscess (n = 4), and orbital abscess (n = 3).

Depending on the animal's health condition, anesthetics such as medetomidine 0.04–0.08 mg/kg, midazolam 0.2 mg/kg, butorphanol 0.2 mg/kg, and ketamine 5 mg/kg were used during the examination to maintain the animal in a stationary position during the scan.

Description of CT device and image acquisition conditions

An X-ray tube with 5-μm focus and a two-dimensional (2D) flat panel detector
was used to acquire 512 images of slice image data in a cylindrical range with a
diameter of 60 mm × 60 mm or 73 mm × 60 mm in 18 s with one rotation of the rotating
arm; in a whole-body scan mode, 512 × 2 images of slice image data were acquired in a
cylindrical range of 60 mm × 120 mm or 73 mm × 120 mm. These were used as
appropriate for the size of the rabbit's skull.

The device used in this study was configured to have a shield structure so that an
additional lead shield chamber was not required to protect the veterinarians operating
the device from X-ray exposure. Its compact size allows it to be used even in common
examination rooms, and its diameter of 190 mm can accommodate animals weighing up
to 3 kg inside the gantry. Depending on the rabbit's level of activity and symptoms, CT
imaging was successfully conducted with or without the administration of anesthesia
(Figure 1). Many individual rabbits become docile when covered with a cloth or net.
Taking advantage of this behavior, we diagnosed 70% of the rabbits with 18 s of
imaging without the use of anesthesia. Anesthesia was used if the rabbit was active or if
detailed diagnosis required imaging in the fine mode, which required 120 s of scanning.
Imaging was conducted under the following conditions: tube voltage = 90 kV and tube
current = 160 mA or tube voltage = 70 kV and tube current = 80 µA. The face spot size
was set to a minimum of 5 µm and a maximum of 27 µm. An amorphous silicon
detector was used; image reconstruction was performed by using the Feldkamp–Davis–
Kress algorithm. Measurement of body fat and synchronization with respiration were also conducted.

Computed tomography images (minimum: 10 mm pixel) were visualized; the number of pixels was set to 512 × 512 × 512 (voxel = 10 × 10 × 10 µm) for an imaging time of 18 s, and the number of pixels was set to 512 × 512 × 512 (voxel = 100 × 100 × 100 µm) for an imaging time of 120 s. Volume data was obtained from a cylindrical area 73 mm in diameter and 60 mm–120 mm based on the height of the animal.

During anesthesia, the plane was vertical because complete positioning was possible. Obtaining the image with the micro-CT does not need a vertical plane, so we could provide a diagnosis without anesthesia.

We modified an approach to micro-CT used in laboratory guinea pigs and rats [10-14] to perform diagnostic evaluations in companion animal patients.
Results

Imaging

The resolution of the resulting 2D or 3D images allowed for a thorough assessment of each animal’s condition. The structure of the upper and lower jaw, the tooth structure, and the extent of the occlusion between the upper and lower jaws, which is difficult to evaluate by radiography and endoscopy, were visualized clearly with sufficient detail (Figure 2).

Evaluation criteria

As there is no appropriate diagnostic criteria, we defined the sagittal plane as the X axis, the transverse plane as the Y axis, and the dorsal plane as the Z axis (Figure 2). The 3D images used in the diagnosis showed right lateral internal views, as well as right lateral internal cross-sectional images. The condition of the apices of the premolars and molars was assessed.

The occlusion between the upper and lower jaw incisors and between the premolars and molars could be easily observed in the X and Y axes. Dorsal cross-sectional images of the lower and upper jaws were observed from the Z axis (Figure 3).
The 3D images clearly depicted alterations and deformations in the upper jaw bone and teeth, as well as the absence, excessive length, or curvature of premolars and molars, and facilitated the understanding of the 3D positional relationship.

Rabbit oral cavity pathology as observed by endoscopy and CT imaging

The endoscopy revealed traumatic ulcers in the buccal mucosa. Accurate diagnosis by endoscopy requires positioning using a suitable device with sedation, which is thus associated with an anesthetic risk. By contrast, a feature of micro-CT is the ability to capture images without using anesthesia.

Micro-CT images are an excellent means of intuitively and accurately providing information about the changes in molars of rabbits whose owners are unable to check their appearance macroscopically and work in favor of informed consent (Figure 4). Anesthesia is often a major risk.

In 90% or more cases, rabbits whose molars have small spines do well without anesthesia, and with excellent openings, the molar spines are removed with a small nipper. This improves the clinical symptoms. Treatment is sometimes performed by thoroughly bringing the occlusal surfaces into contact under anesthesia, but there was no significant difference in the treatment interval. Computed tomography images before
and after treatment are shown in Figure 5. The occlusion between the premolars and molars was improved. The improvement in clinical symptoms, visual assessment using the laryngoscope, and observation results using the endoscope confirmed that there was normal healing, and no occlusal problems were produced.

Mandibular abscess

In cases where a lower jaw abscess developed, it was usually an abscess whenever a biopsy was performed. Tumors were rare.

Whereas CT has high diagnostic sensitivity, multi-planar reconstruction (MPR) images have clear positions. Because changes in the surrounding bone tissue can be captured three-dimensionally, treatment locations for abscesses can be determined (Figure 6).

Mandibular osteolysis

Radiologic findings allow for detection of focal lesions in the lower part of the molars. Three-dimensional images also clearly show pathological findings, such as pus around the dental apices, bone resorption lesions, and mandibular fractures, and provide detailed image information regarding anatomical, dental, or skeletal abnormalities.
(Figure 7). The 2D CT image is indispensable, but the 3D surface and volume rendering image facilitate evaluation of a location with a morbid change.

Bone resorption suggested periapical infection of the teeth or infection osteomyelitis which is generally visible with 2D images. 3D images help us to understand the extension of osteomyelitis in the region (Figure 8).

The 2D CT image is indispensable, but the 3D surface and volume rendering image is more easy to understand the place with a morbid change. In addition, we were able to safely examine all the animal patients during the period of this study.
Discussion

Our findings demonstrated that the micro-CT approach used in this study could be applied to diagnosis in clinical settings. The equipment allowed for collection of accurate data, as well as a rapid image processing time and reconstruction time (approximately 1 minute). Additionally, since it is equipped with software that synchronizes images with respiration, as well as a 2D/3D image processing software, the device is extremely easy to use [10-14].

Because the micro-CT device allows for reconstruction of images obtained as slice image data with pixel sizes ranging from 120 µm to 150 µm, the images obtained from the computer are precise, and objects are rendered very clearly in comparison with those from conventional images. The same performance has also been achieved with the imaging of laboratory animals. While the bone structure and detailed morphological aspects of teeth in rabbits have been difficult to visualize with conventional CT designed for humans because of the inherently small size of the rabbits' skull and teeth, they were clearly depicted by micro-CT.

In this study, we attempted to compare the diagnostic utility of 2D and 3D images. Two-dimensional images allowed for a comparative study of the length, thickness, and curvature angles of teeth by using numerical evaluations. These data
were obtained by conducting imaging only once, and this minimized the animals’
exposure to radiation. However, osteolysis and bone hyperplasia were difficult to
identify with 2D imaging. This was compensated for by acquiring 3D images. Another
advantage of this device is that the images are digitally processed; consequently, they
can be rotated in three dimensions for enhanced understanding of the physical
presentation of disease or abnormalities.

This excellent imaging capability allowed for the visualization of pathological
images associated with diseases specific to rabbits. For the evaluation of each of the
following individual sites, 2D images allowed for an assessment of dentition in the X, Y,
and Z axes on a planar surface, and 3D images allowed for assessments in terms of 3D
structure. Thus, the advantages of the micro-CT scan include the following: (1) overall
assessment of dentition, occlusion, evaluation of the morphology of the upper and lower
jaw, as well as abnormalities in terms of their length and angle; (2) evaluation of
deformations, excessive length, and occlusion in the clinical crown; (3) correlation
between the alveolar bone and excessive elongation in the dental apices or deformations
of dental apices; and (4) changes in resorption due to bacterial infection of the dental
apex, proliferative changes, fracture-related deformations, and occlusal changes in the
upper and lower jaw.
Furthermore, the changes showed dental, skeletal, anatomical, and pathological abnormalities, excessive elongation, and internal or external deviation of the orientations of upper and lower jaw molars, which were difficult to detect by radiography.

Finally, the device described in this study allowed for comprehensive assessments by clear imaging of lesions such as those associated with changes in the dental apices and alveolar bones, as well as changes in the dental roots or alveolar bones in patients with chronic severe diseases. These evaluations can lead to an improved determination of prognosis for the animal. The clear image data obtained from tests using micro-CT facilitated the provision of explanations to the owners and was extremely useful for obtaining informed consent for subsequent procedures.

Furthermore, the data obtained from the imaging device was useful in educating the owners regarding the importance of conducting routine observation of delicate changes such as the refusal to eat food, spilling of food, reduced amount of stool, drooling, and nasal discharge [2].

When tests using micro-CT were conducted with sick rabbits, the use of a specific X-ray transparent positioner (Figure 1) made it possible to take images without having to anesthetize the animal and to obtain useful information. This was a unique
and remarkable advantage when the tests were applied in clinical settings.

While dental diseases in rabbits develop gradually, we have diagnosed cases in which a failure to treat the condition during the acute phase caused the animal’s condition to deteriorate severely. To deal with such cases, the diagnosis needs to be made as early as possible, and the positioning device described in this study can be used for conducting diagnostic procedures while avoiding the risks associated with the use of anesthetics during endoscopic examination of the rabbit’s deep and narrow oral cavity.
Conclusions

Micro-CT can provide new and accurate image data that have been impossible to obtain fully with conventional diagnostic methods and that are important for the definitive diagnosis of significant dental and oral lesions in rabbits. We have determined that in the future, tests using this device can be utilized for accurately diagnosing and elucidating details regarding dental diseases of the rabbit.
References


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Figure legends

Figure 1: (A) Non-anesthetized rabbit placed under a cone beam computed tomography (CBCT) scanner. (B) An animal positioning cover with netting was created to maintain unsedated animals in position during scans.

Figure 2. The planar images of the sagittal, transverse, and dorsal axes are represented as the (A) X, (B) Y, and Z axes, respectively. Three-dimensional images were reconstructed on the basis of two-dimensional images.

Figure 3. (A) The X axis shows a right lateral internal view and a cross-sectional view. (B) The Y axis shows a transverse view and a cross-sectional view. (C) The Z axis shows a dorsal cross-sectional view of the lower jaw and a dorsal cross-sectional view of the upper jaw.

Figure 4. Computed tomography (CT) image of a diseased oral cavity of a rabbit. The upper jaw first molar curves outwardly and is excessively long, and the tip has become sharp, leading to damage to the buccal mucosa and ulcer formation.

Figure 5. Computed tomography (CT) images of elongated premolars and molars taken
before and after treatment. (A) A case of excessively long premolars and molars. (B) Image taken after treatment.

Figure 6. Comparison between the radiologic findings and computed tomography (CT) image of a lower jaw abscess. Radiographic image of a mandibular abscess (Inset: the CT scan image).

Figure 7. Comparison between the radiologic findings and computed tomography (CT) image of lower jaw osteolysis. Radiographic image of mandibular osteolysis (Inset: the CT scan image).

Figure 8. (A, B) Computed tomography imaging of a 6-year-old male Holland Lop weighing 1.9 kg. Osteomyelitis of the right and left mandible following periapical infection of the premolar tooth is visible. (C, D) Three-dimensional (3D) volume-rendering reconstruction, right lateral view of the same rabbit. The 3D image shows the extent of osteomyelitis of the right mandible (C), while cross-sections (D) reveal the extent in the left mandibular region.