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# COMPARISON OF DIAGNOSTIC CONSISTENCY AND DIAGNOSTIC ACCURACY BETWEEN SURVEY RADIOGRAPHY AND COMPUTED TOMOGRAPHY OF THE SKULL IN 30 RABBITS WITH DENTAL DISEASE

*Vittorio Capello, DVM, Dip. ECZM (Small Mammal), Dip. ABVP (Exotic Companion Mammal), and Alberto Cauduro, DVM*

***Abstract***

Accurate diagnosis of dental disease and related complications is extremely important in companion rabbit medicine. When dental disease is diagnosed, a proper prognosis and surgical plan is essential for treatment success. The objectives of this retrospective study were to compare survey radiography and computed tomography (CT) of the skull and teeth in rabbit patients affected by dental disease verifying consistency between observers and diagnostic significance of the 2 techniques, and to evaluate diagnostic accuracy of the 2 modalities for prognostic and therapeutic purposes. In total, 27 pet rabbits were included in the study. A second diagnostic procedure was performed on 3 patients with dental disease for a total of 30 examinations for each technique. A full series of 5 extraoral radiographic views and CT scans of the head without contrast medium were obtained from each patient while under general anesthesia. With both series of imaging modalities, 13 bilateral anatomic and dental structures were evaluated by 2 observers for each patient's skull. Observations were statistically consistent for diagnosis, within the same technique and between the 2 techniques. Diagnostic accuracy of CT was superior in 24 patients (80%) in diagnosis and prognosis and in 17 patients (56.6%) for guiding extraoral dental and surgical treatment. Radiography provided superior accuracy in 5 patients (16.6%) for guiding intraoral dental treatment. Copyright 2016 Elsevier Inc. All rights reserved.

***Key words:*** rabbit; radiography; computed tomography; skull; dental disease

Dental disease is often diagnosed in pet rabbits and represents one of the most common presenting problems with this companion exotic species.[1-3] Dental disease is acquired in most cases although the underlying etiology can be varied including congenital.[1,2] Hypotheses for pathophysiologic development of clinical dental problems in rabbit patients have been reported to be associated with developmental abnormalities,[1,4] trauma,[1,2,4,5] insufficient wearing of elodont teeth,[1,2,4,5] or as a consequence of metabolic bone disease.[1-3] Dental disease is a syndrome[1-3] and can cause a wide range of clinical signs and symptoms including reduced food intake or anorexia, reduced or abnormal feces, dehydration, painful posture, epiphora, exophthalmos, nasal discharge, dermatitis, mandibular, and/or maxillary swellings.[1,2] Dental abnormalities of incisor and cheek teeth, related complications such as periapical infections, osteomyelitis of the maxilla and/or the mandible, facial abscesses, and empyemas of anatomic cavities of the skull are widely recognized as various disease conditions affecting the head and oral cavity of rabbits.[1,2]

*From the Clinica Veterinaria S. Siro, Milano, Italy; and the Clinica Veterinaria Neurovet, Legnano, Italy.*
*Address correspondence to: Vittorio Capello, DVM, Dip. ECZM (Small Mammal), Dip. ABVP (Exotic Companion Mammal), Clinica Veterinaria S. Siro, Via Lampugnano 99, 20151 Milano, Italy. E-mail: capellov@tin.it*

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A tentative diagnosis of dental disease in rabbits can be made based on clinical presentation, but a definitive diagnosis relies primarily on diagnostic imaging. Oral endoscopy and survey radiographs represent the standard imaging modalities used for evaluating the rabbit head.[1,2] Advanced imaging techniques (e.g., computed tomography [CT]) may provide a more detailed view of anatomic structures of the head for better patient assessment, especially in advanced and complex dental disease cases.[2,6-11] The normal CT appearance of the rabbit skull-associated soft tissue structures and examples of disease conditions have been well described.[7,10,12-14] Additional diagnostic tests including culture and sensitivity, and magnetic resonance imaging may be helpful in developing a treatment plan where secondary abscess formation is present.[1,6,10,11]

A previously published investigation compared the ability of radiography (RAD) and CT to identify dental disease in 4 rabbits.[15] The purpose of this retrospective study was to compare a larger number of patients, examine in detail abnormalities of dentition and other related abnormalities of the skull, and assess diagnostic consistency between observers within each modality and between the 2 imaging modalities themselves. Further objectives were to assess diagnostic accuracy regarding the clinical prognosis, intraoral dental treatment, and extraoral surgical treatment.

## MATERIAL AND METHODS

### Patients

A retrospective study was performed on 27 pet rabbits affected by dental disease and related complications, undergoing both RAD and CT of the head between 2006 and 2014. Clinical disease signs and symptoms at presentation included reduced food intake and difficulty chewing, facial swelling, epiphora, exophthalmos, nasal discharge, otitis externa, and/or head tilt.

The radiographic equipment used for this study was located at the Clinica Veterinaria S. Siro, whereas the CT was in a referral veterinary diagnostic center (Clinica Veterinaria Neurovet). Depending on available schedule and owner's preference, most imaging procedures were not performed the same day and under the same anesthetic procedure. However, all of the imaging procedures were performed within 7 days of presentation. A second diagnostic imaging procedure was completed on 3 rabbits (patients #5, #11, and #15) for a total of 30 CT examinations, coupled with corresponding radiographic examinations. The additional imaging procedures for these 3 patients were repeated for evaluation of new facial swellings unrelated to the previous diagnosis, at intervals of 9, 32, and 9 months, respectively.

The rabbit breeds included in the study were 17 dwarf standard rabbits (63.0%), 9 dwarf lops (33.0%), and 1 European standard rabbit (3.7%). Further, 19 were male rabbits (70.4%), 8 were females (29.6%), while the age range of the subject animals was from 1.5 to 11 years (mean 6.17; standard deviation 2.87). Body weight ranged from 1.2 to 3.0 kg (mean 1.65; standard deviation 0.42).

## ANESTHETIC PROTOCOL

All radiographic and CT evaluations were performed while the rabbits were under general anesthesia. Standard physical examination and routine blood analysis were performed prior the anesthesia. The following anesthetic protocol was used: butorphanol 0.2 mg/kg subcutaneous (Dolorex, Intervet, Boxmeer, The Netherlands), dexmedetomidine 35 μg/kg intramuscular (Dexdomitor, Pfizer, New York, USA), and ketamine 20 mg/kg intramuscular (Ketavet, Intervet International, Milano, Italy). Intravenous access was maintained via a 24-gauge catheter placed in the cephalic vein. Endotracheal intubation was not performed on any rabbit during the imaging procedures. Patients were administered oxygen via a facemask that was removed during image production; monitoring was performed with a pulse oximeter detecting oxygen level and heart rate. Atipamezole 175 μg/kg intramuscular (Antisedan, Pfizer Animal Health, NY USA) was administered at the end of the diagnostic procedure.

### Radiography

Mammography films were used for 14 examinations, computed radiography (CR) for 11 examinations, and direct digital radiography (DDR) for 5 examinations. To obtain the images, ultraslow mammography film was used (Mamoray HDR, Agfa-Gevaert, Mortsel, Belgium) with a single low-speed intensifying screen (Mamoray screen, Agfa-Gevaert). Standard settings of the radiographic unit were 12 mAs (300 mA × 0.04 second) and 40 to 45 kV; based on rabbit size (40 kV was the most commonly used setting), with no use of the scatter grid. Mammography films were processed with an automatic processor (Cawomat 2000 IR; CAWO Photochemisches

Werk, Schrobenhausen, Germany) and digitally converted at 300 pixels per inch (ppi) with a digital scanner for transparencies (Snap Scan 1236, Agfa).

CR was performed with the Fuji FCR Capsula XL (Fujifilm, Tokyo, Japan), no scatter grid, with standard settings of 10 mAs and 55 kV regardless of rabbit size. Digital resolution of the CR images was 265 ppi. DDR images with resolution of 180 ppi were obtained using the Agfa DX-D 400 (Agfa HealthCare, Mortsel, Belgium) with standard settings for the DDR images maintained at 10 mAs and 55 kV regardless of the rabbit's body size.

For every radiographic examination of the skull and teeth, 5 standard projections were performed: laterolateral, either left-to-right or right-to-left view; oblique view left 15° ventral-right dorsal (Lt 15° V-Rt D); oblique view right 15° ventral-left dorsal (Rt 15° V-Lt D); ventrodorsal; rostrocaudal (RC).[1,7] Additional projections were obtained in some patients, when necessary, for the reassessment and evaluation of selected radiographic abnormalities. The projections used for additional assessment of the selected rabbit head abnormalities were 30° oblique views to image the caudal portion of the mandible and the masseteric fossa (16 examinations), and ventrodorsal with the mandible shifted to investigate the nasal cavities and the maxillary recesses (3 examinations).

### Computed Tomography

Sequential transverse images were scanned with a helical CT unit (Pronto Hitachi CT scanner, Hitachi Medical Systems Europe, Zurich, Switzerland). The scan included the whole head, from the labial surface of maxillary incisor teeth to the occipital bone. Patients were positioned in sternal recumbency, with the head elevated parallel to the sliding table. Scanning planes were perpendicular to the palatine bone. Scanning parameters were 120 kVP, 25 to 75 mA; window level: 300; window width: 1500; image size (matrix) 512 × 512 pixels; slice thickness 1.0 mm; scan time 1 second; pitch 1.5. The overall scanning time was 60 to 70 second. The approximate time each rabbit was involved in the CT procedure (i.e., induction, imaging, and recovery of anesthesia) ranged from 12 to 15 minutes. Contrast medium was not administered in any of the rabbit subject animals that were assessed with CT.

The assessments/evaluations of the rabbit CT images for evaluation were based on the following modalities: axial views, 2-dimensional multiplanar reformation (2D MPR), 3-dimensional volume rendering, and 3-dimensional surface rendering (shaded surface display). Additional 3-dimensional modalities including "airways modality" and the double surface rendering (soft tissues/hard tissues) were used in selected patients with specific or severe involvement of the nasal and paranasal cavities, and affected by large abscesses, respectively.

## METHOD OF EVALUATION

Evaluations of the RAD and CT examinations were performed by a board-certified exotic companion mammal veterinarian (the first author) and by an experienced veterinary radiologist (the second author). For examination of digital radiography and CT images, open-source software was used (OsiriX).[16]

Evaluations of radiographs and CT of every single patient were performed independently by the 2 veterinarians. For each patient, radiographs were examined before CT. In patients where mammography films were examined, scanned digital views of the films were also available to make image assessment consistent with digital radiographs obtained in the other patients.

A total of 13 bilateral anatomic and dental structures (i.e., teeth and other features of the head) were evaluated on each patient in the investigation (Table 1). Also, 4 characteristics were evaluated for each group of teeth (occlusal plane, clinical crowns, reserve crowns, and apices). For each, nasal cavity, turbinates, meatuses, maxillary recesses, and other recesses were evaluated. Including bilateral structures, 780 anatomic and dental structures were evaluated in the rabbit patients. If a single feature was abnormal among the 4 characteristics measured, for each group of teeth and for each nasal cavity, then anatomic structure was scored as abnormal. Results from each observer were compared within the same diagnostic imaging modality (RAD, CT) to consider interobserver variability. When results showed a discrepancy, it was discussed between the 2 observers, and a consensus score was reached. Results from the 2 observers were merged into a single list of scores for each of the 2 modalities.

These results were compared between the 2 diagnostic imaging modalities (RAD, CT). Statistical analysis of results was performed by the use of analysis of variance (ANOVA). A $P < 0.01$ (significant value of 99%) was considered statistically significant.

**TABLE 1. Anatomic structures observed in this study**

| | | |
|---|---|---|
| Teeth | Incisor teeth | *Maxillary** |
| | | *Mandibular** |
| | Cheek teeth | *Maxillary** |
| | | *Mandibular** |
| Skull | Mandible | *Incisive portion* |
| | | *Body* |
| | | *Masseteric fossa* |
| | | *Branch of the mandible/TMJ* |
| | Maxilla | *Perforated portion* |
| | | *Alveolar bulla* |
| | | *Zygomatic arch* |
| Anatomic cavities | | *Nasal cavities*** |
| | | *Tympanic bullae* |

The 13 anatomic elements are listed in the column highlighted in italics. In total, 4 aspects were evaluated for each group of teeth (*) (occlusal plane, clinical crowns, reserve crowns, and apices) and for each nasal cavity (**) (turbinates, meatuses, maxillary recesses, and other recesses).

RAD and CT were then scored as positive or negative in diagnostic accuracy for overall clinical diagnosis and prognosis, for planning intraoral dental treatment, and for extraoral surgical treatment of other facial surgeries associated with complications of dental disease. Surgical outcome, postoperative patient follow up, and postmortem events were included for this evaluation.

## RESULTS

### Radiography

After evaluation of the RAD examinations, observer #1 detected 281 abnormal dental/anatomic structures (mean 9.37/patient; standard deviation 3.44) out of 780 examined (36.0%). Observer #2 detected 274 abnormal structures (mean 9.13/patient; standard deviation 3.66) out of 780 examined (35.1%). Statistical analysis of the data revealed no significant difference between the 2 observers within the same RAD modality.

Discrepancy between the 2 observers regarding examination of survey radiographs was related to 27 anatomic/dental elements out of the 780 examined (3.5%), in 19 rabbits (64.3%). The structures evaluated differently by the 2 observers were distributed among the 13 bilateral structures, primarily related to abnormalities of cheek teeth. After discussion and resolution of discrepancies, merged observations accounted for 284 abnormal structures (mean 9.47/patient; standard deviation 3.47) out of 780 examined (36.4%). Detailed numbers of abnormalities for each patient (including numbers of normal structures, related percentages, standard deviations, and ANOVA) are reported in Table 2.

### Computed Tomography

After evaluation of the CT examinations, observer #1 detected 299 abnormal dental/anatomic structures (mean 9.97/patient; standard deviation 3.81) out of 780 examined (38.3%). The observer #2 detected 294 abnormal structures (mean 9.80/patient; standard deviation 3.79) out of 780 examined (37.7%). Statistical analysis of the data revealed no significant difference between the 2 observers within the same CT modality.

Discrepancy between the 2 observers regarding examination of CT scans was related to 5 structures out of the 780 examined (0.6%), in 5 rabbits (16.7%). The structures evaluated differently by the 2 observers were abnormalities of a single cheek tooth arcade in 3 patients and of the alveolar bullae in 2 patients. After discussion and resolution of discrepancies, merged observations accounted for 300 abnormal structures (mean 10.0/patient; standard deviation 3.85) out of 780 examined (38.5%).

### Abnormalities Detected

All rabbits included in this study had at least a single dental abnormality of the teeth. In 56.7% (RAD) and 63.3% (CT) of patients, the dental problem involves both incisor and cheek teeth. The most common tooth abnormalities observed were noted in the cheek teeth (93.3% [RAD] and 90% [CT]; of those, 92.9% and 81.5% involved all 4 arcades, respectively). Through both imaging modalities, abnormalities of the mandible were detected in 76.7% of patients, with bilateral involvement noted in 34.8% and 39.1%, respectively. The most commonly affected area of the mandible was the body.

TABLE 2. Diagnostic Consistency of Observations Within the Same Radiographic Technique (Between the 2 Observers) and Diagnostic Significance Between Radiography and CT

| | | Radiography | | | | | | | Computed Tomography | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Observer | | | | | Merged Observations | | Observer | | | | | Merged Observations | | |
| | | #1 | | #2 | | | | | #1 | | #2 | | | | | |
| Patient Number | Examinations Number | N | Ab | N | Ab | Discrepancy Within Radiography | N | Ab | N | Ab | N | Ab | Discrepancy Within CT | N | Ab | Discrepancy Between Radiography and CT |
| 1 | 1 | 16 | 10 | 17 | 9 | 1 | 16 | 10 | 16 | 10 | 17 | 9 | 1 | 16 | 10 | 0 |
| 2 | 2 | 21 | 5 | 21 | 5 | 0 | 21 | 5 | 22 | 4 | 22 | 4 | 0 | 22 | 4 | 1 |
| 3 | 3 | 16 | 10 | 15 | 11 | 1 | 15 | 11 | 14 | 12 | 14 | 12 | 0 | 14 | 12 | 1 |
| 4 | 4 | 14 | 12 | 15 | 11 | 1 | 14 | 12 | 14 | 12 | 14 | 12 | 0 | 14 | 12 | 0 |
| 5 | 5 | 17 | 9 | 19 | 7 | 2 | 17 | 9 | 16 | 10 | 16 | 10 | 0 | 16 | 10 | 1 |
| 5 | 6 | 17 | 9 | 17 | 9 | 0 | 17 | 9 | 16 | 10 | 16 | 10 | 0 | 16 | 17 | 1 |
| 6 | 7 | 10 | 16 | 9 | 17 | 1 | 9 | 17 | 9 | 17 | 9 | 17 | 0 | 9 | 15 | 0 |
| 7 | 8 | 14 | 12 | 14 | 12 | 0 | 14 | 12 | 12 | 14 | 13 | 13 | 1 | 11 | 14 | 3 |
| 8 | 9 | 15 | 11 | 16 | 10 | 1 | 15 | 11 | 12 | 14 | 12 | 14 | 0 | 12 | | 3 |
| 9 | 10 | 20 | 6 | 20 | 6 | 0 | 20 | 6 | 18 | 8 | 18 | 8 | 0 | 18 | 8 | 2 |
| 10 | 11 | 19 | 7 | 21 | 5 | 2 | 19 | 7 | 19 | 7 | 19 | 7 | 0 | 19 | 7 | 0 |
| 11 | 12 | 18 | 8 | 16 | 10 | 2 | 16 | 10 | 17 | 9 | 17 | 9 | 0 | 17 | 9 | 1 |
| 12 | 13 | 14 | 12 | 13 | 13 | 1 | 14 | 12 | 11 | 15 | 11 | 15 | 0 | 11 | 15 | 3 |
| 13 | 14 | 13 | 13 | 14 | 12 | 1 | 13 | 13 | 13 | 13 | 13 | 13 | 0 | 13 | 13 | 0 |
| 14 | 15 | 17 | 9 | 17 | 9 | 0 | 17 | 9 | 19 | 7 | 19 | 7 | 0 | 19 | 7 | 2 |
| 15 | 16 | 19 | 7 | 21 | 5 | 2 | 19 | 7 | 19 | 7 | 19 | 7 | 0 | 19 | 7 | 0 |
| 16 | 17 | 17 | 9 | 18 | 8 | 1 | 17 | 9 | 16 | 10 | 17 | 9 | 1 | 16 | 10 | 1 |
| 15 | 18 | 19 | 78 | 19 | 7 | 0 | 19 | 7 | 18 | 8 | 18 | 8 | 0 | 18 | 8 | 1 |
| 17 | 19 | 8 | 18 | 11 | 15 | 3 | 10 | 16 | 8 | 18 | 8 | 18 | 0 | 8 | 18 | 2 |
| 18 | 20 | 12 | 14 | 10 | 16 | 2 | 10 | 16 | 10 | 16 | 10 | 16 | 0 | 10 | 16 | 0 |
| 19 | 21 | 17 | 9 | 17 | 9 | 0 | 17 | 9 | 19 | 7 | 20 | 6 | 1 | 19 | 7 | 2 |
| 20 | 22 | 24 | 2 | 24 | 2 | 0 | 24 | 2 | 22 | 4 | 22 | 4 | 0 | 22 | 4 | 2 |
| 11 | 23 | 16 | 10 | 17 | 9 | 1 | 16 | 10 | 16 | 10 | 16 | 10 | 0 | 16 | 10 | 0 |
| 21 | 24 | 16 | 10 | 17 | 9 | 1 | 17 | 9 | 15 | 11 | 15 | 11 | 0 | 15 | 11 | 2 |
| 22 | 25 | 20 | 6 | 20 | 6 | 0 | 20 | 6 | 20 | 6 | 20 | 6 | 0 | 2 | 6 | 0 |
| 23 | 26 | 20 | 6 | 21 | 5 | 1 | 20 | 6 | 18 | 8 | 18 | 8 | 0 | 18 | 8 | 2 |
| 24 | 27 | 19 | 73 | 19 | 7 | 0 | 19 | 7 | 21 | 5 | 21 | 5 | 0 | 21 | 5 | 2 |
| 25 | 28 | 13 | 13 | 11 | 15 | 2 | 13 | 13 | 13 | 13 | 14 | 12 | 1 | 13 | 13 | 0 |
| 26 | 29 | 21 | 5 | 21 | 5 | 0 | 21 | 5 | 21 | 5 | 21 | 5 | 0 | 21 | 5 | 0 |
| 27 | 30 | 17 | 9 | 16 | 10 | 1 | 17 | 9 | 17 | 9 | 17 | 9 | 0 | 17 | 9 | 0 |
| | Total | 499 | 281 | 506 | 274 | 27 | 496 | 284 | 481 | 299 | 486 | 294 | 5 | 480 | 300 | 32 |
| | Percentage | 64.0 | 36.0 | 64.9 | 35.1 | 3.5 | 63.6 | 36.4 | 61.7 | 38.3 | 62.3 | 37.7 | 0.6 | 61.5 | 38.5 | 4.1 |
| | Mean | 16.63 | 9.37 | 16.87 | 9.13 | | 16.53 | 9.47 | 16.03 | 9.97 | 16.20 | 9.80 | | 16.00 | 10.00 | |
| | SD | 3.44 | 3.44 | 3.66 | 3.66 | VAR2/VAR1 | 3.47 | 3.47 | 3.81 | 3.81 | 3.79 | 3.79 | VAR2/VAR1 | 3.85 | 3.85 | VAR2/VAR1 |
| | VAR | 11.83 | 11.83 | 13.43 | 13.43 | 1.135581689 | 12.05 | 12.05 | 14.52 | 14.52 | 14.37 | 14.37 | 1.0099968 | 14.83 | 14.83 | 1.230446395 |

The table includes the standard deviation and the variance, and the analysis of variance for each group. N, normal; Ab, abnormal; SD, standard deviation; VAR, variance.

Abnormalities of the maxilla were detected in 70% (RAD) and 76.7% (CT) of patients with bilateral involvement in 47.6% and 52.2%, respectively. The most commonly affected area of the maxilla was the alveolar bulla 66.7% (RAD) and 70% (CT). Abnormalities of the nasal cavities were detected in 33.3% (RAD) and 56.7% (CT) of patients. The dental disease was considered bilateral in 70% and 76.5% of the affected patients and was determined to be part of a concurrent illness with at least 1 abnormality of the tympanic bulla in 42.9% and 77.8% of cases, respectively. Abnormalities of the tympanic bullae were detected in 23.3% (RAD) and 30% (CT) of patients. Disease was assessed as bilateral in 57.1% and 55.6% of affected patients, respectively. Involvement of one or both maxillary recesses was detected in 3 patients (30%) using RAD, and in 10 patients (58.8%) with CT.

### Comparison of RAD vs. CT

Statistical analysis of the data revealed no significant difference between RAD and CT. Diagnostic discrepancies between RAD and CT were related to 32 structures out of 780 examined (4.1%), in 18 rabbits. Discrepancy of merged results was therefore found in 60.0% of patients examined, whereas in 12 rabbits (40.0%) results matched. In particular, RAD scored as normal 24 abnormalities detected by CT (3.1%). These were related to mandibular incisor teeth (1), the masseteric fossa (2), the alveolar bulla (3), the zygomatic arch (1), the branch of the mandible (1), the nasal cavities (13, including 12 maxillary recesses), and the tympanic bulla (3). CT scored as normal 8 abnormalities detected by RAD (1.0%) and were related to mandibular incisor teeth (2), maxillary cheek teeth (1), and mandibular cheek teeth (5).

Detailed numbers of abnormalities for each patient (including numbers of normal structures, related percentages, standard deviations, and ANOVA) are reported in Table 2. Specific information regarding categories of radiologic abnormalities (both RAD and CT), related numbers, and percentages is reported in Table 3.

CT was considered diagnostic in 100% of the cases. In 24 cases (80%), CT provided useful or crucial information that was missed, or found to be less diagnostic, with RAD. In 6 cases (20%), the 2 techniques were scored to be equally useful. Regarding diagnostic accuracy for treatment, in 17 cases (56.6%) CT provided useful or crucial information for planning an extraoral approach for dental treatment and/or technique for facial surgery, including excision of periapical infections and abscesses, debridement of bony osteomyelitic tissue, extraoral extraction of incisors and/or cheek teeth, rostral mandibulectomy, temporary and permanent rhinostomy, and lateral bulla osteotomy. In 5 cases (16.6%), RAD provided useful information for diagnosis and for planning intraoral dental treatment that was not detected with CT. Detailed scores and discrepancies for each patient are reported in Table 4.

An example of superior diagnostic and disease assessment accuracy provided by CT is displayed in Fig. 1, which showed diffuse osteomyelitis of the incisive portion and the body of the right mandible, following end-stage dental disease of the mandibular cheek teeth arcade. Survey RAD demonstrated advanced dental disease and severe lysis of the right mandible. CT outlined the severe extent of osteomyelitis, verified the masseteric fossa to be intact, and indicated the exact line for an osteotomy of the mandible to perform a rostral mandibulectomy.

In the patient shown in Figure 2, comparison between radiographic views and different CT modalities of the abnormal occlusal planes, reserve crowns, and apices of cheek teeth demonstrated an example whereby optimal survey RAD was more accurate than the 2-dimensional multiplanar reformation slices of CT. Computed tomographic axial images displayed an artifact, showing part of 2 adjacent mandibular cheek teeth in the same slice (Fig. 2).

## DISCUSSION

The only comparative study between survey RAD and CT previously reported in the literature included 4 pet rabbits with acquired dental disease.[15] In all 4 rabbits, CT examinations were comparable to RAD; however, more detail was apparent on the CT images, and CT revealed more subtle dental and bony changes and more detailed information about the nature and extent of the pathology. The authors of the initial study concluded that the additional information gained by CT made it possible to establish a more accurate diagnosis, treatment plan, and prognosis.[15]

The current retrospective study included 30 radiographic and CT examinations performed on 27 different patients. In addition to higher case numbers, this study scored 13 bilateral dental and anatomic structures of the skull for each patient. Statistical consistency of radiologic findings was

TABLE 3. Radiologic abnormalities and related percentages diagnosed with radiography and CT

| | Radiography | | | Computed Tomography | | |
|---|---|---|---|---|---|---|
| Teeth and Anatomic Parts of the Skull | N | Percentage of the Total Group | Percentage Within the Specific Group | N | Percentage of the Total Group | Percentage Within the Specific Group |
| **Teeth** | | | | | | |
| Normal | 0 | 0.0 | | 0 | 0.0 | |
| Abnormality of teeth | 30 | 100.0 | | 30 | 100.0 | |
| Incisor teeth only | 2 | 6.7 | 6.7 | 2 | 6.7 | 6.7 |
| Cheek teeth only | 19 | 63.3 | 63.3 | 20 | 66.7 | 66.7 |
| Incisor and cheek teeth | 17 | 56.7 | 56.7 | 18 | 60.0 | 60.0 |
| *Incisor teeth* | | | | | | |
| Normal | 11 | 36.7 | | 10 | 33.3 | |
| Abnormality of at least 1 incisor tooth | 19 | 63.3 | | 20 | 66.7 | |
| Missing the whole set of incisor teeth | 9 | 30.0 | 47.7 | 9 | 30.0 | 45.0 |
| 1 or more regrown reserve crowns | 7 | 23.3 | 77.8 | 7 | 23.3 | 77.8 |
| Missing a single mandibular incisor tooth | 1 | 3.3 | 5.3 | 1 | 3.3 | 5.0 |
| *Cheek teeth* | | | | | | |
| Normal | 2 | 6.7 | | 2 | 6.7 | |
| Abnormalities of cheek teeth | 28 | 93.3 | | 27 | 90.0 | |
| Involving all 4 arcades | 26 | 89.7 | 92.9 | 22 | 73.3 | 81.5 |
| **Mandibles** | | | | | | |
| Normal | 7 | 23.3 | | 7 | 23.3 | |
| Abnormality or deformity of at least 1 mandible | 23 | 76.7 | | 23 | 76.7 | |
| Bilateral involvement of the mandibles | 8 | 26.7 | 34.8 | 9 | 30.0 | 39.1 |
| Unilateral involvement of 1 mandible | 15 | 50.0 | 65.2 | 14 | 46.7 | 60.9 |
| *Incisive portion of the Mandible* | | | | | | |
| Normal | 15 | 50.0 | 65.2 | 15 | 50.0 | 65.2 |
| Abnormal | 15 | 50.0 | 65.2 | 15 | 50.0 | 65.2 |
| Unilateral involvement | 11 | 36.7 | 73.3 | 11 | 36.7 | 73.3 |
| Most affected mandible (right) | 9 | 30.0 | 81.8 | 9 | 30.0 | 81.8 |
| Bilateral involvement | 4 | 13.3 | 26.7 | 4 | 13.3 | 26.7 |
| *Body of the Mandible* | | | | | | |
| Normal | 11 | 36.7 | 47.8 | 11 | 36.7 | 47.8 |
| Abnormal | 19 | 63.3 | 82.6 | 19 | 63.3 | 82.6 |
| Unilateral involvement | 14 | 46.7 | 73.7 | 14 | 46.7 | 73.7 |

| TABLE 3. Continued | | | | | | |
|---|---|---|---|---|---|---|
| | Radiography | | | Computed Tomography | | |
| Teeth and Anatomic Parts of the Skull | N | Percentage of the Total Group | Percentage Within the Specific Group | N | Percentage of the Total Group | Percentage Within the Specific Group |
| Most affected mandible (right) | 9 | 30.0 | 64.3 | 9 | 30.0 | 64.3 |
| Bilateral involvement | 5 | 16.7 | 26.3 | 5 | 16.7 | 26.3 |
| *Masseteric fossa* | | | | | | |
| Normal | 18 | 60.0 | 78.3 | 17 | 56.7 | 73.9 |
| Abnormal | 12 | 40.0 | 52.2 | 13 | 43.3 | 56.5 |
| Unilateral involvement | 12 | 40.0 | 100.0 | 12 | 40.0 | 92.3 |
| Most affected mandible (left) | 7 | 23.3 | 58.3 | 8 | 26.7 | 66.7 |
| Bilateral involvement | 0 | 0.0 | 0.0 | 1 | 3.3 | 7.7 |
| *Branch of the mandible/ Temporomandibular joint* | 1 | 3.3 | 4.3 | 2 | 6.7 | 8.7 |
| *Entire mandible (3 portions on the same side)* | 4 | 13.3 | 17.4 | 5 | 16.7 | 21.7 |
| **Maxillae** | | | | | | |
| Normal | 9 | 30.0 | | 7 | 23.3 | |
| Abnormality or deformity of at least 1 of the maxillae | 21 | 70.0 | | 23 | 76.7 | |
| Bilateral involvement of the maxillae | 10 | 33.3 | 47.6 | 12 | 40.0 | 52.2 |
| Unilateral involvement of the maxillae | 11 | 36.7 | 52.4 | 11 | 36.7 | 47.8 |
| *Alveolar bulla* | | | | | | |
| Normal | 10 | 33.3 | | 9 | 30.0 | |
| Abnormal | 20 | 66.7 | 95.2 | 21 | 70.0 | 91.3 |
| Bilateral involvement of the alveolar bullae | 10 | 33.3 | 50.0 | 12 | 40.0 | 57.1 |
| Unilateral involvement of the alveolar bulla | 10 | 33.3 | 50.0 | 9 | 30.0 | 42.9 |
| *Perforated portion of the maxilla* | 2 | 6.7 | 9.5 | | | |
| *Zygomatic arch* | 6 | 20.0 | | | | |
| **Nasal cavities** | | | | | | |
| Normal | 20 | 66.7 | | 13 | 43.3 | |
| Abnormality of at least 1 of the nasal cavities | 10 | 33.3 | | 17 | 56.7 | |
| Bilateral involvement of the nasal cavities | 7 | 23.3 | 70.0 | 13 | 43.3 | 76.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Unilateral involvement of the nasal cavities | 3 | 10.0 | 30.0 | 4 | 13.3 | 23.5 |
| Concurrent involvement of at least 1 tympanic bulla | 3 | 10.0 | 42.9 | 7 | 23.3 | 77.8 |
| *Maxillary recesses (only)* | 3 | 10.0 | 30.0 | 10 | 33.3 | 58.8 |
| Bilateral involvement of the maxillary recesses | 2 | 6.7 | 66.7 | 9 | 30.0 | 90.0 |
| Unilateral involvement of the maxillary recesses | 1 | 3.3 | 33.3 | 1 | 3.3 | 10.0 |
| **Tympanic bullae** | | | | | | |
| Normal | 23 | 76.7 | | 21 | 70.0 | |
| Abnormality of at least 1 of the tympanic bullae | 7 | 23.3 | | 9 | 30.0 | |
| Bilateral involvement of the tympanic bullae | 4 | 13.3 | 57.1 | 5 | 16.7 | 55.6 |
| Unilateral involvement of the tympanic bulla | 3 | 10.0 | 42.9 | 4 | 13.3 | 44.4 |
| Concurrent involvement of the nasal cavities | 3 | 10.0 | 30.0 | 8 | 26.7 | 47.1 |
| *Total* | 30 | | | 30 | | |

TABLE 4. Diagnostic accuracy of radiography and CT in overall clinical diagnosis and accurate prognosis, to planning intraoral dental treatment, and to planning extraoral surgical treatment or other facial surgeries associated with complications of dental disease

| | | Overall Diagnosis and Prognosis | | | Treatment Plan | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Intraoral | | | Extraoral | | |
| Patient Number | Examinations Number | Radiography | Computed Tomography | Discrepancy | Radiography | Computed Tomography | Discrepancy | Radiography | Computed Tomography | Discrepancy |
| 1 | 1 | + | + | | + | + | | + | + | |
| 2 | 2 | − | + | × | + | − | × | + | + | |
| 3 | 3 | + | + | | + | + | | + | + | |
| 4 | 4 | − | + | × | + | + | | − | + | × |
| 5 | 5 | − | + | × | + | + | | − | + | × |
| 5 | 6 | − | + | × | + | + | | + | + | |
| 6 | 7 | − | + | × | + | + | | − | + | × |
| 7 | 8 | − | + | × | + | + | | − | + | × |
| 8 | 9 | − | + | × | + | + | | + | + | |
| 9 | 10 | − | + | × | + | + | | − | + | × |
| 10 | 11 | − | + | × | + | − | × | − | + | × |
| 11 | 12 | − | + | × | + | + | × | − | + | × |
| 12 | 13 | − | + | × | + | + | | − | + | × |
| 13 | 14 | − | + | × | + | + | | + | + | |
| 14 | 15 | − | + | × | + | − | × | − | + | |
| 15 | 16 | − | + | × | + | + | | + | + | × |
| 16 | 17 | − | + | × | + | + | | − | + | |
| 15 | 18 | − | + | × | + | + | | − | + | × |
| 17 | 19 | − | + | × | + | + | | + | + | × |
| 18 | 20 | + | + | | + | + | | + | + | |
| 19 | 21 | − | + | × | + | − | × | − | + | |
| 20 | 22 | + | + | | + | + | | + | + | × |
| 11 | 23 | − | + | × | + | + | | − | + | |
| 21 | 24 | − | + | × | + | + | | − | + | × |
| 22 | 25 | − | + | × | + | + | | − | + | × |
| 23 | 26 | − | + | × | + | + | | + | + | × |
| 24 | 27 | + | + | | + | − | × | + | + | |
| 25 | 28 | − | + | × | + | + | | − | + | × |
| 26 | 29 | + | + | | + | + | | + | + | |
| 27 | 30 | − | + | × | + | + | | − | + | × |
| | Total | 6 | 30 | 24 | 30 | 25 | 5 | 13 | 30 | 17 |
| | Percentage | 20.0 | 100.0 | 80.0 | 100.0 | 83.3 | 16.7 | 43.3 | 100.0 | 56.7 |

(+) Positive and (−) negative.

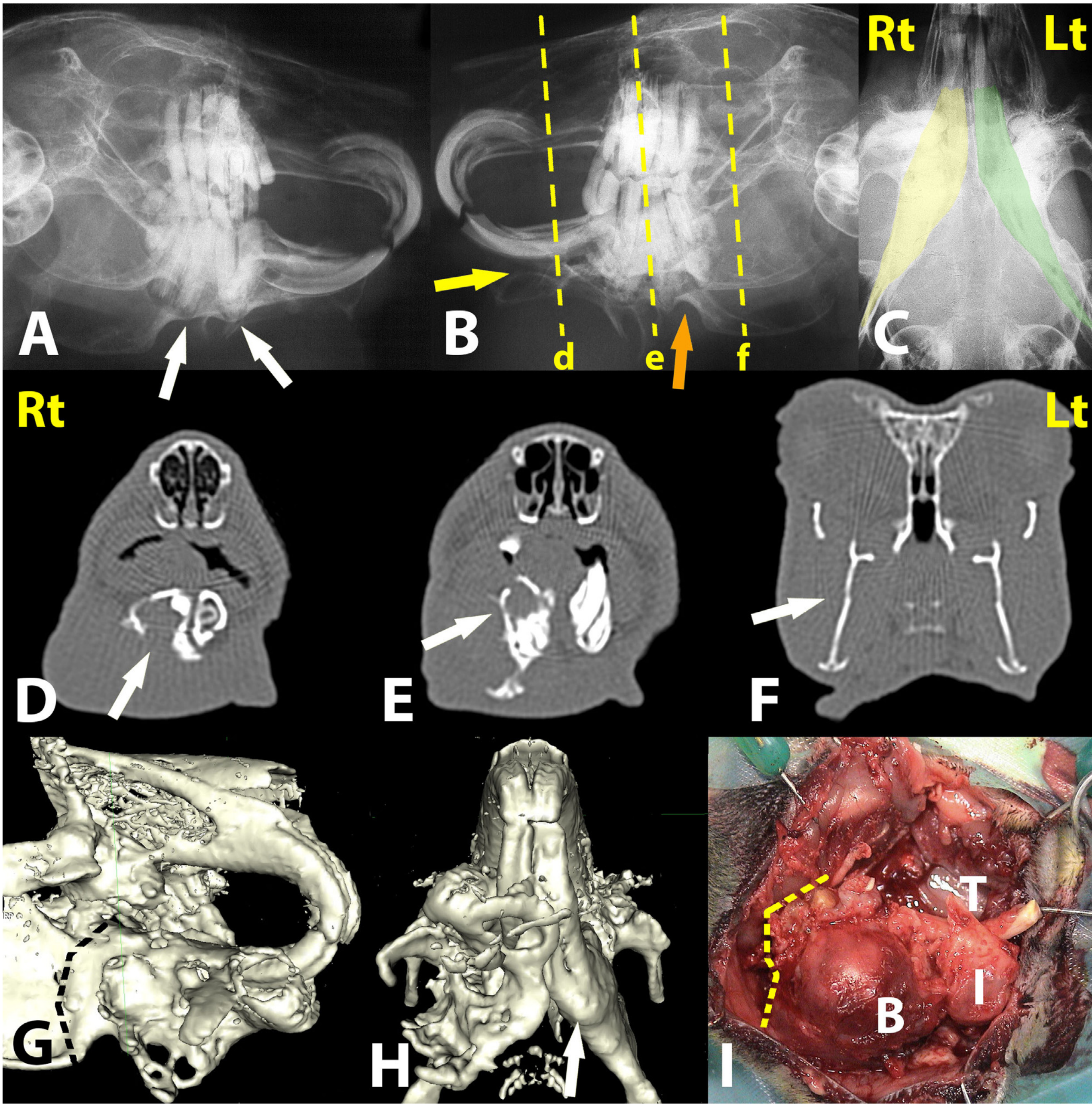


FIGURE 1. A rabbit with diffuse osteomyelitis of the incisive portion and of the body of the right mandible, following end-stage dental disease of the mandibular cheek teeth arcade. (A-C) Radiographic views of the skull (mammography films). Rt 15° V-Lt D oblique projection (A), Lt 15° V-Rt D oblique projection (B), and VD projection (C). (A) Note elongation of reserve crowns and apices of left mandibular cheek teeth, with widened interproximal spaces. Compression and deformity of the ventral cortical bone of the left mandible is present (white arrows—see also H), but the overall bone appears to be intact. (B) Elongation and deformity of reserve crowns and apices of the right mandibular cheek teeth. The cortical bone of the mandible is lytic from the rostral end of the incisive portion (yellow arrow), to the incisure for facial vessels[17] between the body and the masseteric fossa of the mandible (orange arrow). (C) The VD view outlines thickness and deformity of the right mandible (shaded yellow area), when compared to the left mandible (shaded green area). (D-F) CT scan, axial views of the scanning planes shown in (B) (yellow dotted lines). Extensive lysis of the cortical bone of the incisive portion (D) and of the body (E) of the right mandible is visible, while the masseteric fossa is intact (F). (G and H) CT scan, 3D SSD of the skull from the right lateral view (G), and from oblique rostroventral view (H). The "moth-eaten" enlarged and deformed incisive portion and body of the right mandible are displayed as a 3D image (G), and the comparison between the diseased and the intact mandible is emphasized (H). (I) Surgical exposure of the right mandible during rostral mandibulectomy. The osteomyelitic bone has been excised from the intact masseteric area (yellow dotted line; black dotted line in G). T, ventral aspect of the tongue; B, osteomyelitic body of the mandible; I, fragment of the cortical bone of the incisive portion. VD, ventrodorsal.

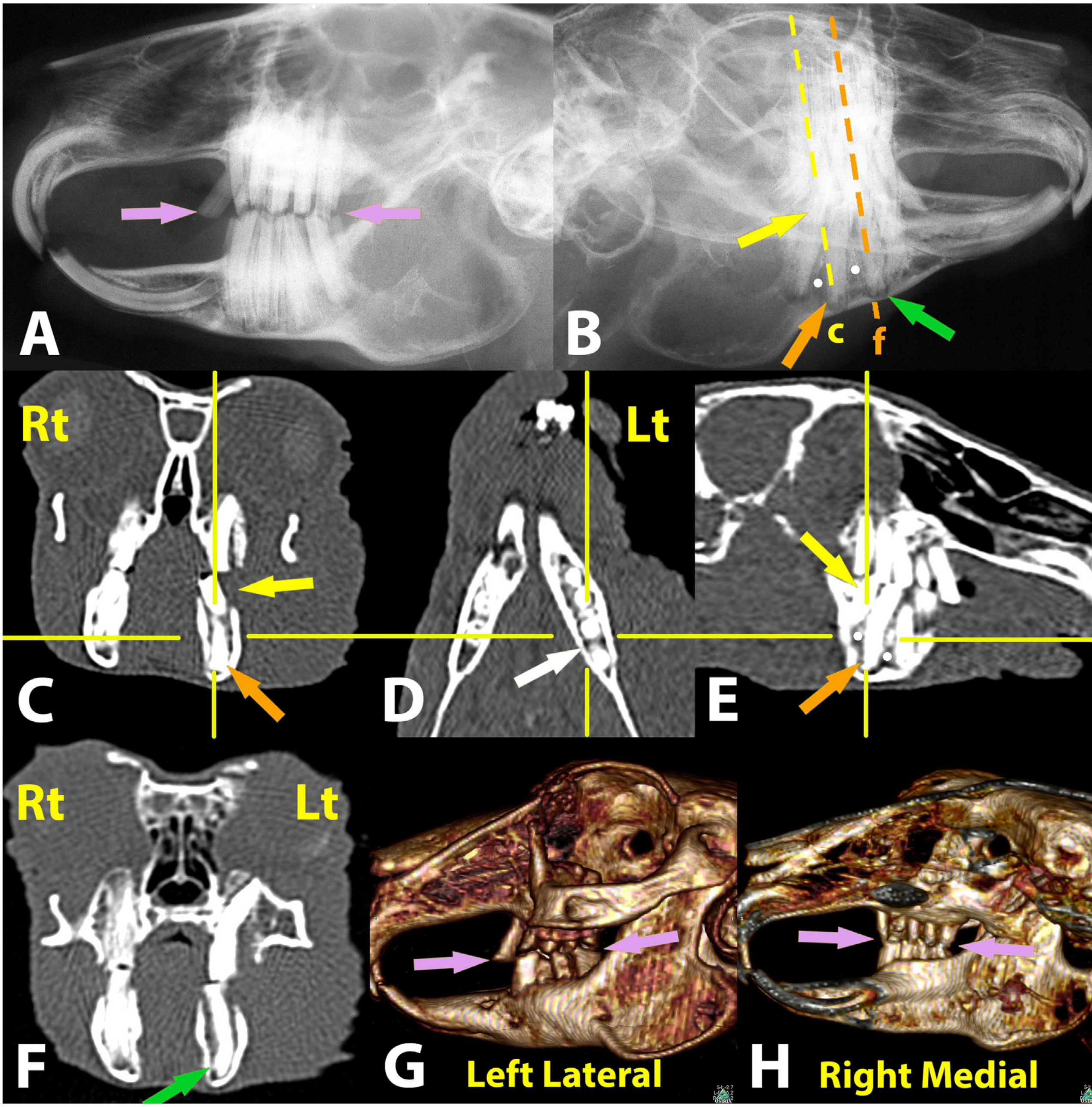


FIGURE 2. A rabbit with disease of the cheek teeth, with special emphasis on the left mandibular cheek teeth. (A and B) Radiographic views of the skull (mammography films). Lt-Rt LL projection (A), and Rt 30° V-Lt D oblique projection (B). (A) Abnormal occlusal plane of cheek teeth (pink arrows). (B) Dental disease of left mandibular CT1-CT4, including wider interproximal spaces (white dots), and deformed apex of CT1, elongated apices of CT2 (green arrow), and CT3 (orange arrow). (C-E) 2D MPR with the scanning plane focused on the interproximal space between left mandibular CT3 and CT4 (yellow dotted line in B). The area of interest is indicated by 4 perpendicular yellow lines. (C) Axial view. Artifact showing the clinical crown of CT4 (yellow arrow) and part of the reserve crown of CT3 (orange arrow) caused by the scanning plane crossing these 2 adjacent cheek teeth. (D) Coronal view. Note wider interproximal space (white arrow). (E) Lateral view. Note wider interproximal spaces (white dots), and the 2 teeth visible in the axial view (yellow and orange arrow). (F) CT scan, axial view of the scanning plane shown in B (orange dotted line). Note the "L-shaped" elongation and deformity of the apex of left mandibular CT2 (green arrow). (G and H) CT scan, 3D SSD of the skull. (G) Lateral view of the intact skull displaying the occlusal plane of left cheek teeth (pink arrows). (H) Medial view of the right side of the skull (after cropping the left half side of the skull) displaying the occlusal plane of the right cheek teeth (pink arrows).

assessed between the 2 observers within the same modality, and between RAD and CT (Table 2). Statistical differences in the ability of each modality to detect abnormalities were also assessed (Table 2), with the results suggesting that both techniques allow diagnosis of radiologic abnormalities. The quantitative discrepancy between modalities is minimal, as a complete set of properly positioned standard views (plus additional views when needed) allows complete radiologic diagnosis in most cases.

The presence of lesions that were only detectable with CT (in particular related to the alveolar bullae, the masseteric fossa, the nasal cavities and maxillary recesses, and the tympanic bullae) demonstrated that evaluation of those anatomic and dental structures is more difficult with RAD. Lesions missed on CT but diagnosed with RAD were much less common, and related to evaluation of cheek teeth and incisor teeth, suggesting that CT may be less sensitive than RAD for detailed evaluation of teeth. Discrepancy of accuracy is much more evident both regarding the diagnosis and prognosis (80%) and in respect to extraoral surgical treatment (56.6%) as CT provides superior details of surgical anatomy. When discrepancy was in favor of RAD (16.6%), it involved incisor and cheek teeth (Fig. 2). Ideally, RAD and CT should be performed together in most cases to improve diagnostic quality. The comparison of images obtained from the 2 diagnostic modalities helps clinicians recognize the technical limits of conventional RAD for complex cases involving anatomic structures of the rabbit head. This could help to optimize radiographic diagnosis when CT is unavailable, or declined due to cost.

## CONCLUSION

This study population showed that RAD and CT are similar in regard to diagnosis of radiologic abnormalities. RAD is equal or in some cases more accurate than CT in intraoral treatment of selected tooth abnormalities. Computed tomographic imaging revealed an overall higher sensitivity and superior accuracy for clinical diagnosis and prognosis (for cases of osteomyelitis following periapical infections, rhinitis, and otitis media) and planning extraoral dental treatment and surgery involving other areas of the skull. The results of this retrospective study suggested that conventional RAD should not be considered a diagnostic imaging modality of lesser value, but rather complementary to CT.

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