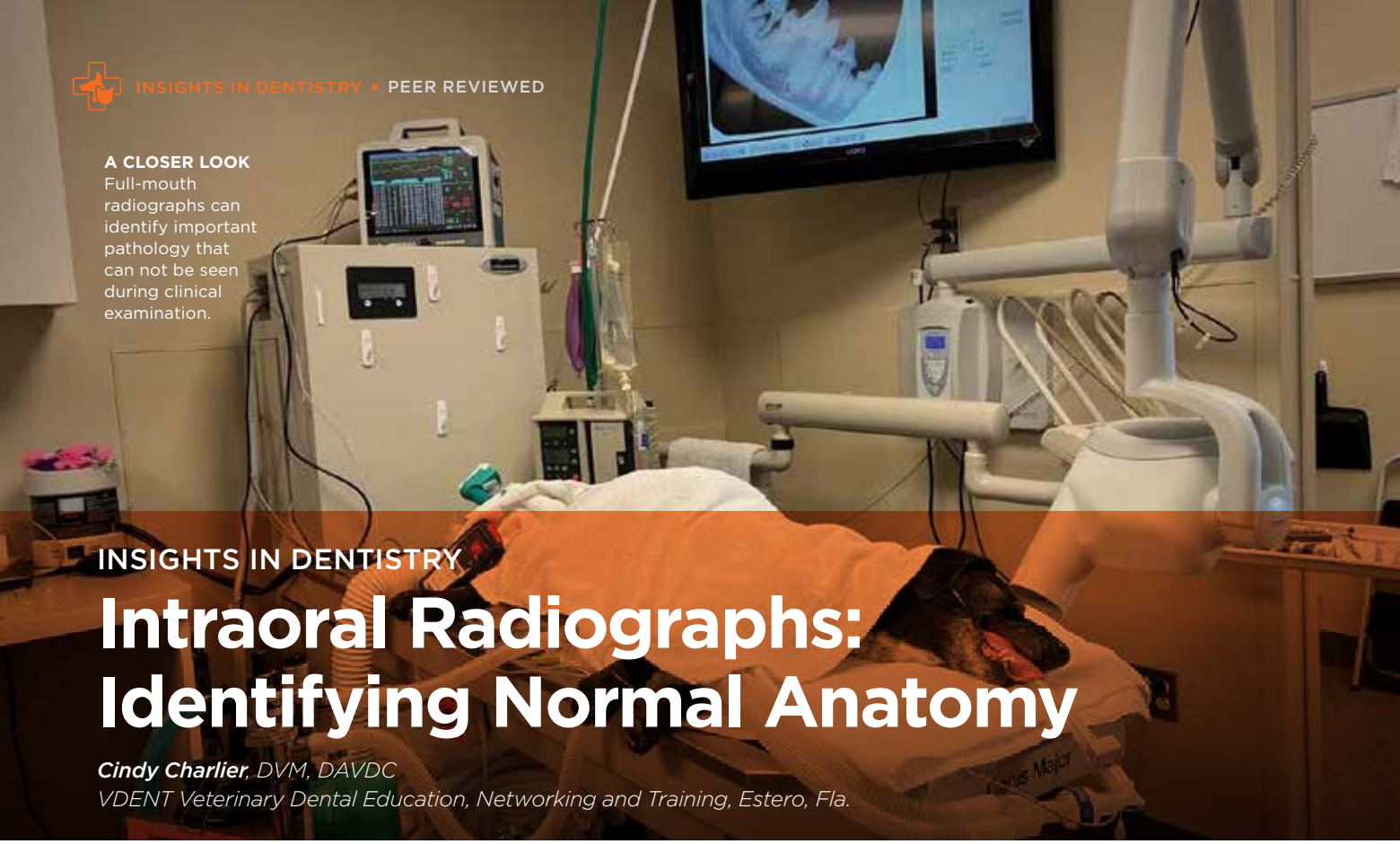

A CLOSER LOOK
Full-mouth radiographs can identify important pathology that can not be seen during clinical examination.

INSIGHTS IN DENTISTRY

Intraoral Radiographs: Identifying Normal Anatomy

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Full-mouth intraoral radiographs are an essential part of the evaluation of oral health. Combined with extraoral and intraoral examinations of an anesthetized patient, intraoral radiographs provide information needed to diagnose and treat oral disease. As with any skill in veterinary medicine, interpreting intraoral radiographs improves with time and experience. To appreciate abnormal, you first need to understand normal. This article explains why full-mouth radiographs should be taken for every dentistry patient and later reviews:

- normal radiographic dental anatomy
- criteria for diagnostic radiographs
- steps for reading an intraoral radiograph
- radiographic tooth development in pediatric patients
- normal anatomic structures that may be misinterpreted as pathology

By the end of this article, general practitioners should be able to appreciate the benefits of full-mouth radiographs and know how to recognize normal anatomic structures on intraoral radiographs of dogs and cats.

WHY TAKE FULL-MOUTH RADIOGRAPHS?

To determine the full extent of oral disease and develop a treatment plan for your patients, an oral examination and full-mouth radiography performed with the patient under general anesthesia are required. Not including full-mouth radiographs as the standard of care for every

BOX 1 Research Findings on the Diagnostic Yield of Full-Mouth Radiographs[1,2]

Radiographs of teeth *without* clinically visible lesions

- Clinically important findings were identified in 27.8% of dogs and 41.7% of cats.
- Tooth resorption lesions missed on clinical examination were diagnosed for 8.7% of cats.

Radiographs of teeth *with* clinically visible lesions

- Clinically essential information was identified in 32.2% of cats, and additional information was identified in 53.9% of cats.
- Clinically essential information was identified in 22.6% of dogs, and additional information was identified in 50% of dogs.

TABLE 1 Components of Teeth and Their Supporting Structures

COMPONENT	DEFINITION	RADIOGRAPHIC APPEARANCE
Enamel	Covers the tooth crown and is the densest material in the tooth	May be visible on some teeth as a thin radiopaque (white) line
Cementum	Outermost layer of the tooth root	Same radiodensity as bone and dentin and normally cannot be seen on radiographs
Cementoenamel junction	Area where the enamel and cementum meet, sometimes referred to as the neck of the tooth	Not applicable
Pulp cavity	Contains blood vessels, nerves, and lymph tissue and is located in the center of the tooth	Radiolucent (dark) structure in the center of the tooth
Dentin	Forms the majority of the mature tooth	Less dense than enamel
Periodontal ligament space	Thin space between the tooth root and the lamina dura	Radiolucent space of uniform width around the entire tooth root
Lamina dura	Dense compact bone lining the alveolus	Visible as a thin radiopaque line
Alveolar bone	Bone that encases and supports the tooth structure	Typical cancellous bone radiopacity
Alveolar margin	Most coronal portion of the alveolar bone	Relatively horizontal and positioned 1–2 mm apical to the cementoenamel junction
Furcation	Area of a multirooted tooth where the roots diverge	Not applicable
Interradicular bone	Bone between the roots of a tooth	Typical cancellous bone radiopacity
Interproximal bone	Bone between teeth	Typical cancellous bone radiopacity
Mandibular canal	Area of uniform width in the mandible parallel to the ventral border of the mandible	Radiolucent

dentistry patient could result in sending patients out the door with undiagnosed, untreated, painful oral disease. Research confirms that the diagnostic yield of full-mouth radiographs is high and that routine use of full-mouth radiographs is justifiable (**BOX 1**).[1,2]

Use of intraoral radiographs is supported by the American Veterinary Medical Association (AVMA) and the American Animal Hospital Association (AAHA). After a 2015 review of cases of jaw fractures and retained tooth roots, the AVMA professional liability newsletter stated that it would be difficult to defend complications resulting from dentistry procedures if the veterinarian did not have access to dental radiographs.[3] The AAHA Guidelines Task Force strongly recommends obtaining full-mouth intraoral dental radiographs for all dentistry patients.[4]

TOOTH ANATOMY

For proper evaluation of intraoral radiographs, knowledge of normal anatomy of the tooth, the mandible, and the maxilla is essential. Recognizing pathology requires familiarity with normal dental anatomy (**FIGURE 1**). The radiographic components of the tooth and its supporting structures are provided in **TABLE 1**.

CRITERIA FOR DIAGNOSTIC RADIOGRAPHS

Criteria

A diagnostic radiograph must include the following anatomic landmarks (**FIGURES 2–4**):

- The level of alveolar bone (alveolar margin)

FIGURE 1. Radiograph of the right mandibular first molar (409) in a dog. Cementoenamel junction **(orange arrows)**; dentin **(black asterisk)**; pulp cavity **(blue arrow)**; periodontal ligament space **(yellow arrow)**; lamina dura **(white arrow)**; mandibular canal **(yellow asterisk)**; ventral cortex of the mandible **(orange asterisk)**; interradicular bone **(blue asterisk)**; interproximal bone **(white asterisk)**.

- The periodontal ligament space
- The entire tooth root, including 2 to 3 mm around the apex of each root
- As much of the crown as possible

Both roots of the same tooth do not need to appear on the same radiograph, nor do the entire crown and root(s). Obtaining a diagnostic image of 1 tooth may require 2 radiographs (e.g., the mandibular first molar in a larger dog [**FIGURE 5**]). Similarly, 2 radiographic images of a canine tooth in a dog may be required: 1 image of the coronal portion of the root showing the level of alveolar bone to evaluate presence/absence of periodontal disease and 1 image of the most apical portion of the tooth root and the periapical area to evaluate presence/absence of endodontic disease (**FIGURE 6**).

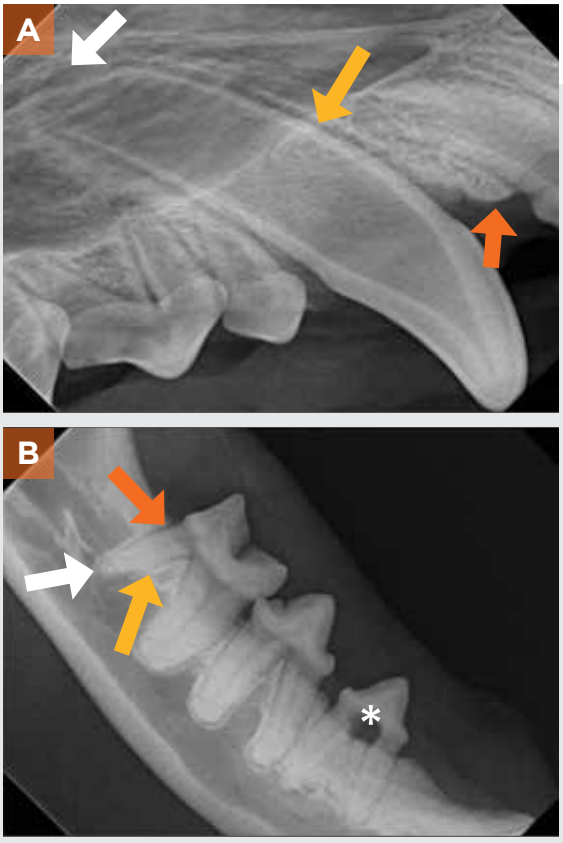

FIGURE 2. Diagnostic dental radiograph in a dog and cat. Alveolar bone margin **(orange arrows)**, periodontal ligament space **(yellow arrows)**, 2–3 mm around the apex **(white arrows)**. **(A)** Right maxillary canine tooth (104) in a young dog. Note the wide pulp cavity and open apex consistent with a developing tooth in a young dog. **(B)** Right mandibular third and fourth premolars and first molar (407, 408, 409) in a cat. Note tooth resorption at the furcation of 407 **(white asterisk)**.

Two radiographic views are also needed for complete evaluation of the maxillary canine teeth in dogs and cats (**FIGURE 7**). The occlusal view is useful for comparing the pulp cavity sizes of the maxillary canine teeth and examining the buccal aspects of the teeth for signs of periodontitis. Lateral views of the right and left maxillary canine teeth are required for accurately

FIGURE 3. Diagnostic radiograph of the left mandibular first molar (309) in a dog. The alveolar bone margin, periodontal ligament space, and 2–3 mm around the apex of each tooth root are visible. The entire crown is not visible.

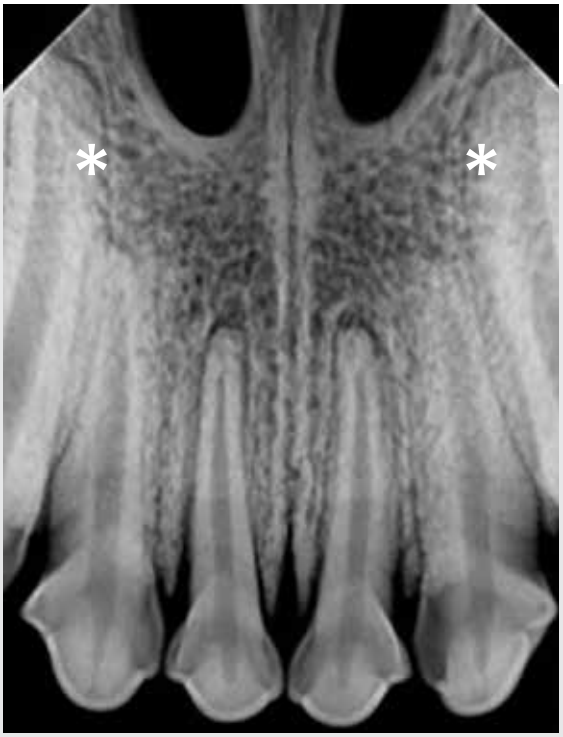

FIGURE 4. Diagnostic radiograph of the right and left maxillary first and second incisors (101, 102, 201, 202) in a dog. Nondiagnostic radiograph for the right and left maxillary third incisors (103 and 203) **(white asterisks)**.

TABLE 2 Clues for Determining Whether an Image Is of the Maxillary or Mandibular Arcade

MAXILLA	MANDIBLE
▪ Three-rooted teeth	▪ Mandibular canal (radiolucent)
▪ Palatine fissures	▪ Ventral cortex of the mandible (radiopaque)
▪ Thin radiopaque line overlying the maxillary canine tooth and premolars	▪ Air on either side of the mandible
▪ Zygomatic arch	▪ Mandibular symphysis

evaluating the periapical region without superimposition on the maxillary premolar teeth and for evaluating periodontal status at the mesial and distal aspects of the canine teeth.[5] The palatal side of maxillary canine teeth cannot be fully evaluated with radiographs; evaluating the maxillary canine tooth for periodontal disease on the palatal side requires use of a periodontal probe.

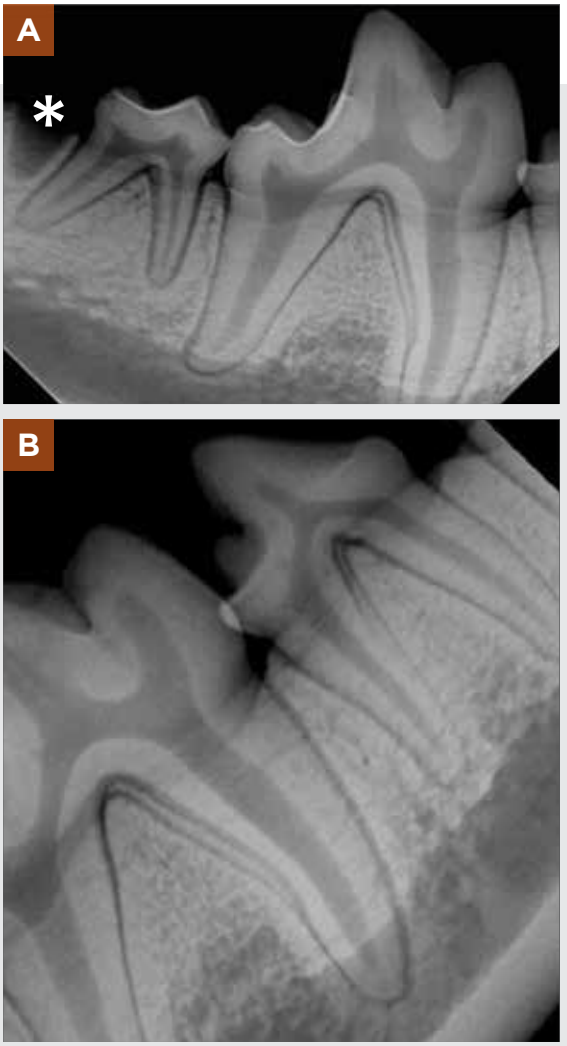

FIGURE 5. Diagnostic radiographs of mandibular molars in a dog; 2 images of the mandibular first molar are often needed for larger dogs. **(A)** Right mandibular first molar distal root (409), mandibular second molar (410), and third molar (411). Note: 411 has been removed **(white asterisk)**. **(B)** Right mandibular fourth premolar distal root (408) and right mandibular first molar mesial root (409).

Viewing

Some veterinary software programs will label the image with the tooth number(s) as they are exposed and will orient them correctly on the computer screen. If images are not labeled and correctly oriented by the software, certain clues will help determine whether the image is of the maxillary or mandibular arcade (**TABLE 2**).

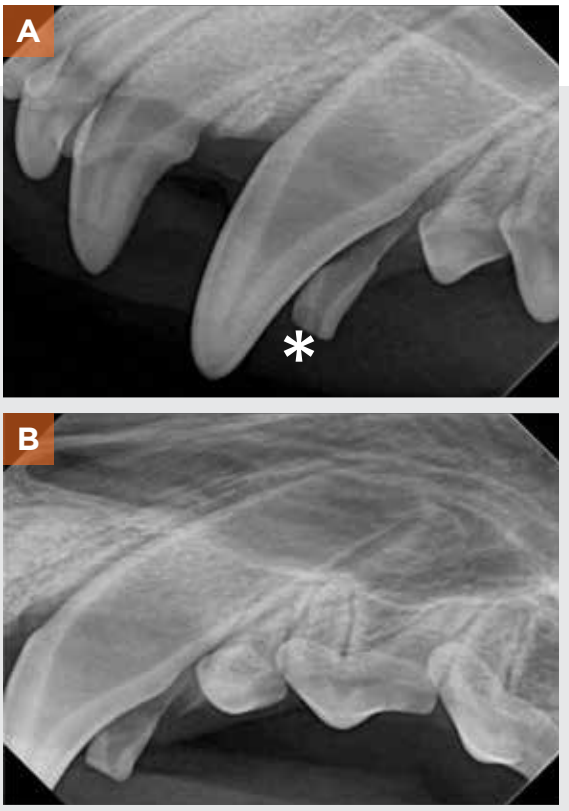

FIGURE 6. Two views of the canine tooth in a young dog. **(A)** Left maxillary canine tooth (204), showing the crown and most coronal portion of the root. Note the persistent deciduous left maxillary canine tooth (604) **(white asterisk)**. **(B)** Additional view showing the apical portion of the root and the periapical area. Note the wide pulp cavity and open apex consistent with an immature tooth in a young dog.

When viewing intraoral radiographs, orient the image the same way each time (just as you would do with thoracic or abdominal radiographs). If the tooth on the image is a maxillary tooth, then the radiograph should be rotated so the crowns of the teeth point downward (in their natural position) on the computer screen. If the tooth on the image is a mandibular tooth, then the radiograph should be rotated so the crowns of the teeth point upward. After determining if the tooth is in the maxilla or the mandible and orienting the radiograph accordingly, ask yourself whether the radiograph is of the right or left side of the mouth. If the rostral mandibular or maxillary premolars or molars are toward the right side of the radiograph, then you are looking at the right maxillary or mandibular premolars and molars. If the rostral teeth are located toward the left side of the radiograph, then you are looking at the left mandibular or maxillary premolars and molars (**FIGURE 8**). When viewing incisors, the right maxillary or mandibular incisors are on the left side of the image and the left maxillary or mandibular incisors are on the right side of the image (similar to a ventrodorsal abdominal or thoracic radiograph) (**FIGURE 9**).

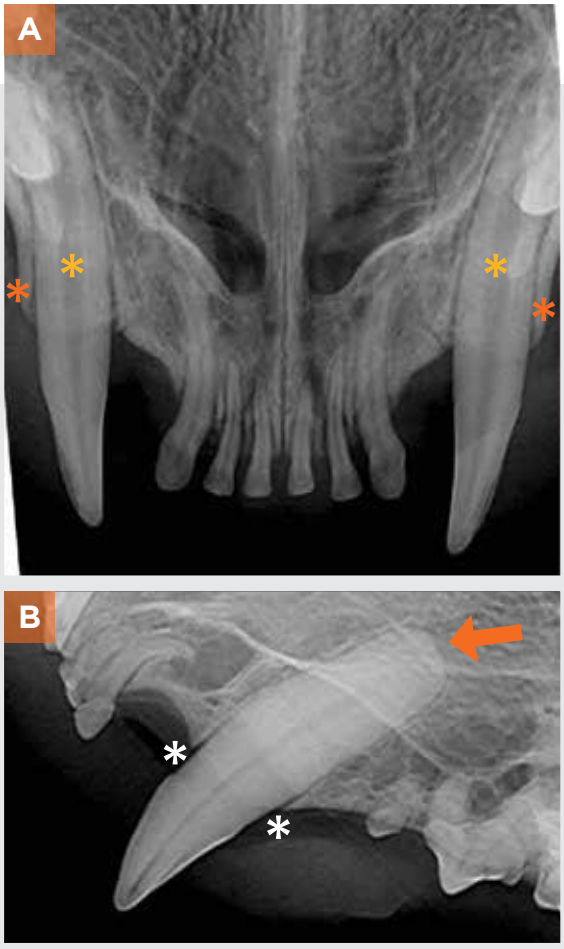

FIGURE 7. Radiographs of maxillary canine teeth in a cat. **(A)** The occlusal view of the maxillary canine teeth is useful for evaluating the pulp cavity size **(yellow asterisks)** and buccal bone **(orange asterisks)**. The apical portion of the maxillary canine teeth is superimposed on the maxillary premolars and cannot be evaluated. **(B)** Lateral view of the left maxillary canine tooth (204) is required for evaluating the mesial and distal alveolar bone margins **(white asterisks)** and periapical area **(orange arrow)**.

The number of full-mouth radiographs needed to see all the teeth, including the level of alveolar bone and the periapical area around each tooth root, can vary with patient size (the larger the patient, the more images usually needed). Mount full-mouth radiographs so that the patient's right maxilla and right mandible are on the viewer's left side and the patient's left maxilla and left mandible are on the right side (**FIGURE 10**).

STEPS FOR READING AN INTRAORAL RADIOGRAPH

Every time you read an intraoral radiograph, follow the same steps in the same order, just as you do for thoracic or abdominal radiographs.

1. Evaluate the level of alveolar bone around each tooth; alveolar bone should be 1 to 2 mm apical to the cementoenamel junction.
2. Follow the periodontal ligament space around each root, pausing at the apex to evaluate the periapical area. The periodontal ligament space should be of uniform width around the entire tooth root.
3. Evaluate the size of the pulp cavity of each tooth. The pulp cavity size should be consistent with the age of the patient and with the contralateral tooth.

FIGURE 8. Radiograph of mandibular premolars and molar in a cat. The rostral teeth are toward the left. This radiograph shows the left mandibular third and fourth premolars and first molar (307, 308, 309).

4. Look at all the bone and soft tissue visible on the radiograph; additional pathology may be present in these tissues.

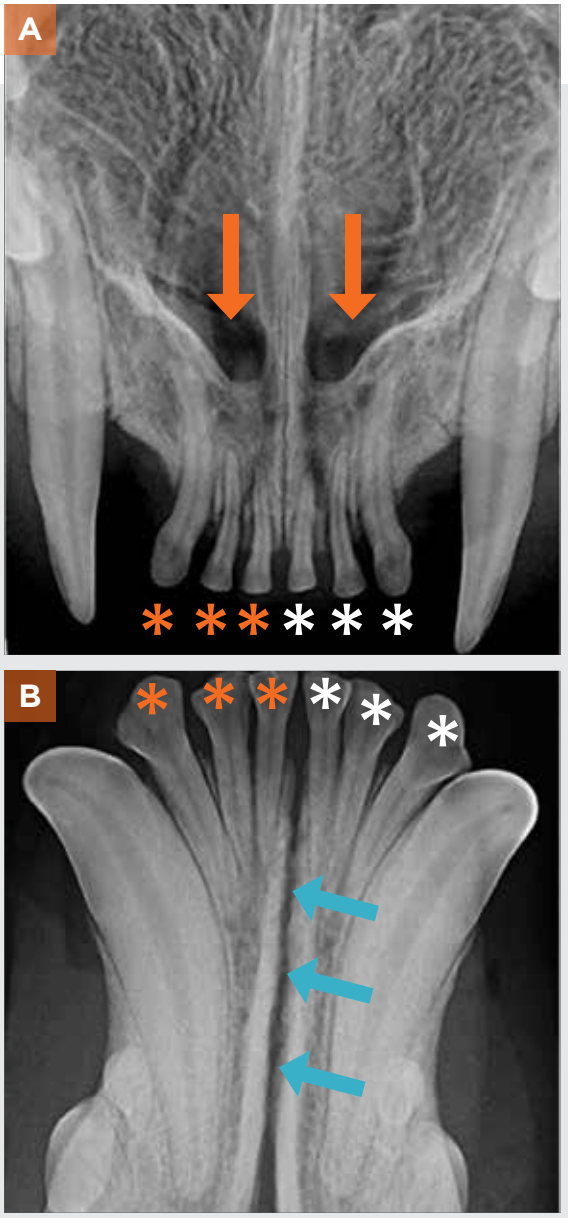

FIGURE 9. Radiographs of incisors in a cat and dog. **(A)** Maxillary incisors in a cat. The right maxillary incisors (101, 102, 103) are on the left side of the radiograph **(orange asterisks)**, and the left maxillary incisors (201, 202, 203) are on the right **(white asterisks)**. The palatine fissures are the symmetrical radiolucent structures **(orange arrows)** distal to the maxillary incisors. **(B)** Mandibular incisors in a dog. The right mandibular incisors (401, 402, 403) are on the left **(orange asterisks)**, and the left mandibular incisors (301, 302, 303) are on the right **(white asterisks)**. The fibrocartilaginous mandibular symphysis joins the 2 mandibles and appears as a radiolucent line between the central incisors **(blue arrows)**.

If you are not sure of the significance of a radiographic finding, take another view or look at the radiograph of the contralateral tooth. Remember that normal anatomy can sometimes mimic pathology.

RADIOGRAPHS OF PEDIATRIC PATIENTS

Deciduous Dentition

Interpreting intraoral radiographs of pediatric patients can be challenging because of the presence of deciduous teeth and permanent tooth buds. The permanent maxillary canine teeth erupt mesial to the deciduous maxillary canine teeth. All other permanent teeth erupt lingual or palatal to their deciduous tooth counterparts. There are no deciduous precursors for the permanent first premolar or molars. In dogs, the maxilla and mandible have 3 deciduous premolars: the second, third, and fourth premolars, named for the teeth that succeed them in the jaw rather than their function or anatomy. The deciduous maxillary third premolar is anatomically similar to the permanent maxillary fourth premolar. The deciduous maxillary fourth premolar is anatomically similar to the permanent maxillary first molar (3 roots and a large occlusal surface). The deciduous mandibular fourth premolar has the function and morphology of a molar but is replaced by the permanent fourth premolar (**FIGURE 11**).[6]

Permanent Tooth Development

At the time of permanent tooth eruption, the apex is incomplete, the pulp cavity is wide, and the primary dentin layer is thin. As the tooth develops, the apex closes and secondary dentin is produced by odontoblasts within the pulp cavity. Apical closure occurs by 7 to 9.5 months of age in dogs[7] and 7 to 11 months in cats.[8] As the dog or cat continues to mature, the pulp cavity continues to get smaller as the thickness of the secondary dentin layer increases (**FIGURE 12**).

Why is the tooth development process important? Radiographs of a tooth in a mature dog or cat should show a small pulp cavity and a thick layer of dentin. In a mature dog or cat, if the radiograph of a tooth shows a large pulp cavity and a narrow layer of dentin, development of that tooth has arrested and the tooth is nonvital. When the tooth dies, the pulp cavity of that tooth stays the same size for the rest of the animal's life.

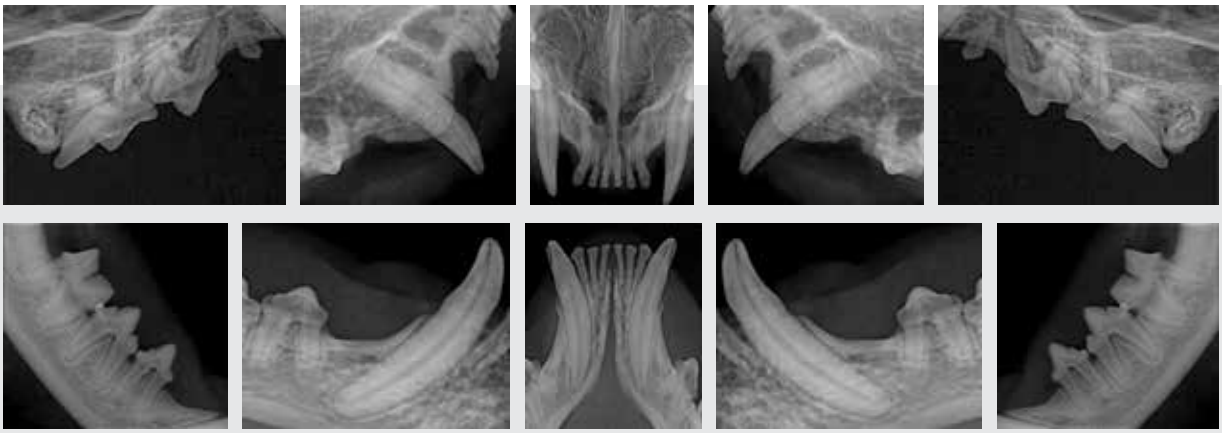

FIGURE 10. Full mouth radiographs of a cat.

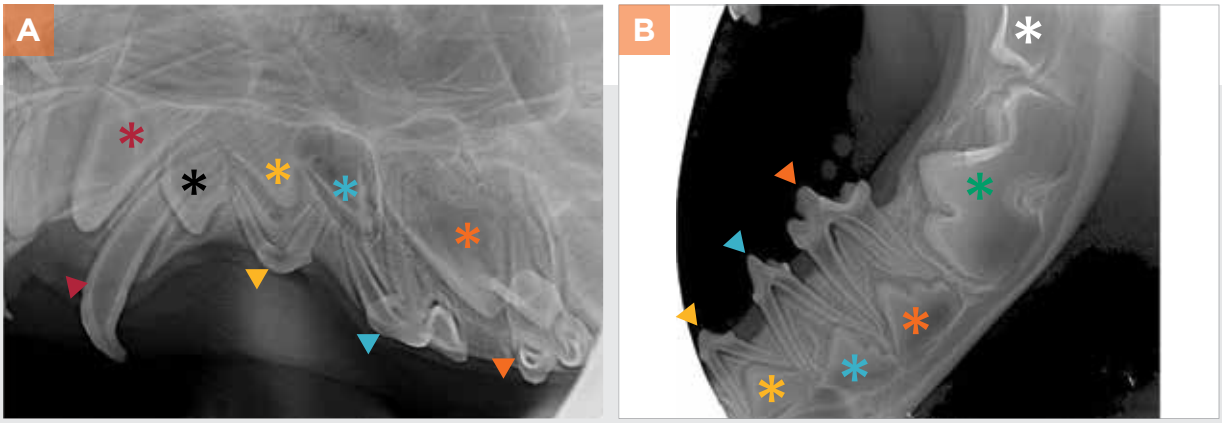

FIGURE 11. Deciduous and permanent teeth in a young dog. Note: There are no deciduous precursors for the first premolar or molar teeth. **(A)** Left maxilla. Permanent tooth buds **(asterisks)**: left maxillary canine (204) **(red)**; first premolar (205) **(black)**; second premolar (206) **(yellow)**; third premolar (207) **(blue)**; and fourth premolar (208) **(orange)**. Note: the permanent left maxillary first and second molar teeth (209, 210) are not visible in this radiograph. Deciduous teeth **(arrowheads)**: left maxillary canine (604) **(red)**; second premolar (606) **(yellow)**; third premolar (607) **(blue)**; and fourth premolar (608) **(orange)**. **(B)** Left mandible. Permanent teeth **(asterisks)**: left mandibular second premolar (306) **(yellow)**; third premolar (307) **(blue)**; fourth molar (308) **(orange)**; first molar (309) **(green)**; and second molar (310) **(white)**. Note: the permanent mandibular first premolar and third molar teeth are not visible in this radiograph. Deciduous teeth **(arrowheads)**: second premolar (706) **(yellow)**; third premolar (707) **(blue)**; fourth premolar (708) **(orange)**.

NORMAL ANATOMY THAT MAY MIMIC PATHOLOGY

Two "White Lines" in the Maxilla

For dogs, 2 radiopaque lines appear on radiographs of the maxillary canine and premolar teeth: the junction of the vertical body of the maxilla and its palatine process and the maxillary conchal crest. These normal anatomic structures can mimic the lamina dura and interfere with interpretation of apical structures.

- The junction of the vertical body of the maxilla and its palatine process is visualized as a radiopaque line that crosses the midroot of the maxillary canine tooth and continues caudally and is apical to the roots of the maxillary premolars.
- The maxillary conchal crest is seen as a radiopaque line that begins just mesial to the root of the canine tooth and continues caudally to reach the level of the third premolar. Because of its location close to the apex of the maxillary canine tooth, it is difficult to change its location by changing angulation of the x-ray beam (**FIGURE 13A**).[9]

For cats, the 2 lines are also formed by the junction of the vertical body of the maxilla and its palatine process and the conchal crest.

- The vertical body of the maxilla and its palatine process is visualized as a radiopaque line that crosses the middle third of the maxillary canine tooth root.
- The conchal crest appears as a radiopaque line that

begins just mesial to the root apex and ends at the third premolar. Because of the anatomic location of these 2 structures close to the apex of the maxillary canine tooth, the linear opacities always appear close to the tooth root (**FIGURE 13B**).[10]

Chevron

A chevron artifact is a very regular chevron-shaped radiolucency commonly associated with the maxillary incisors and canine teeth in dogs (**FIGURE 14**); radiographically, it looks similar to lesions of endodontic origin. This effect is created by trabecular bone and vascular channels around the apices, contrasted with the dense compact bone of the alveolar walls and incisive bone.[11]

In general, periapical lesions associated with endodontic disease will be more circular or irregularly shaped lucencies and the periodontal ligament space will not be visible around the root tip. The root tip of an endodontically diseased tooth may exhibit signs of apical root resorption.

Summation

Other lucencies and opacities are created by the summation effect of superimposed structures, projecting overlying anatomy in a way that makes the structure appear to be associated with a tooth root or its supporting bone.[11] Summation of the mandibular first molar apices superimposed over the mandibular canal can be confused as an endodontic lesion (**FIGURE 15**). **BOX 2** lists clues for differentiating summation of normal structures from pathology.

FIGURE 12. Development of left maxillary canine tooth (204) in the cat. **(A)** Immature tooth with wide pulp cavity, thin dentin layer, and open apex. **(B)** Maturing tooth, smaller pulp cavity, thicker dentin layer, and closed apex. **(C)** Mature tooth, small pulp cavity, thick dentin layer, and closed apex.

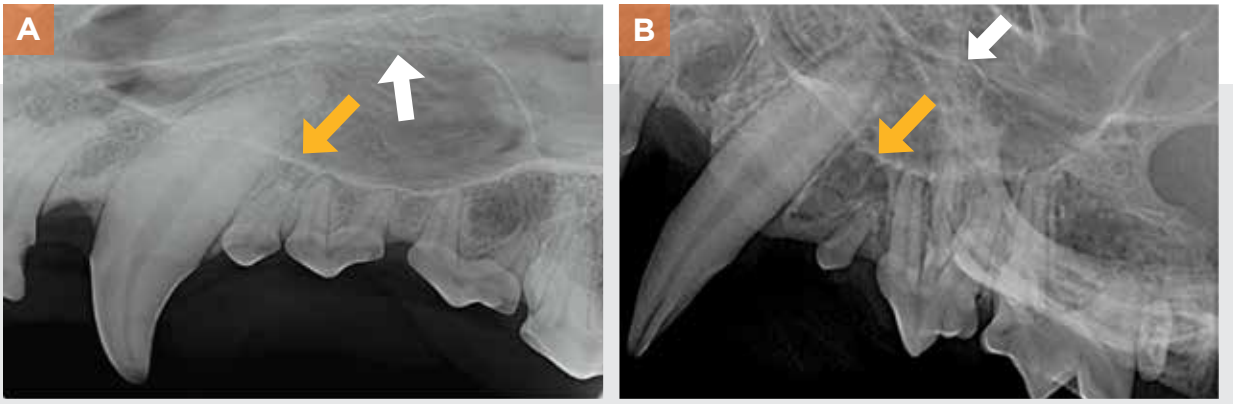

FIGURE 13. Radiographs of maxillary canine teeth in a dog and cat, showing linear opacities (white lines). **(A)** Left maxillary canine tooth (204) in a dog. Conchal crest **(white arrow)**, junction of the vertical body of the maxilla and its palatine process **(yellow arrow)**. **(B)** Left maxillary tooth (204) in a cat. Conchal crest **(white arrow)**, junction of the vertical body of the maxilla and its palatine process **(yellow arrow)**. Note: the teeth are slightly elongated, and the left maxillary third premolar (207) has a supernumerary (additional) root. The zygomatic arch is the radiopaque structure superimposed on the roots of 207, 208, and 209.

BOX 2 Clues for Determining Whether a Periapical Lucency Is Normal Anatomy or Pathology

- Look at the clinical appearance of the tooth.
- Compare the radiograph with one of the contralateral tooth.
- Move the x-ray tube head. If the lucency is periapical pathology, it will remain adjacent to the apex of the tooth regardless of the tube head position. If the lucency results from summation, it will appear to move away from the apex of the tooth with a tube head shift.
- Draw imaginary lines that extend the periodontal ligament space apically. If the lucency is within the extension lines, it is probably normal anatomy. If it is irregularly shaped and extends beyond the extension lines, it probably represents periapical pathology.

FIGURE 14. Chevron lucencies associated with right maxillary incisors (101, 102, 103). Note the regular shape of the lucency and the intact lamina dura around the apex of the tooth **(arrows)**.

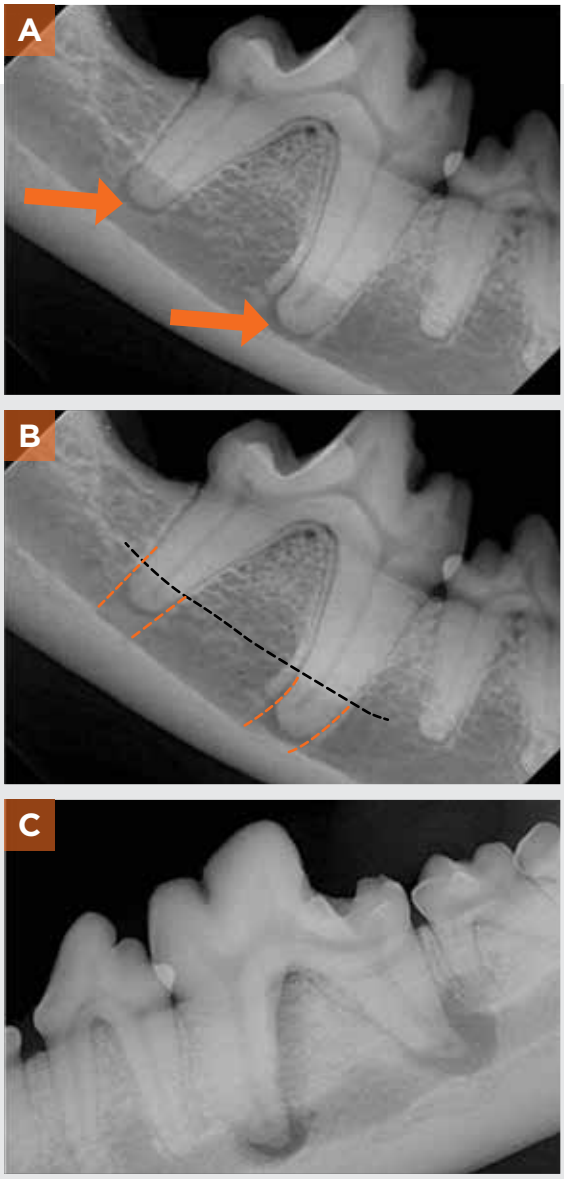

FIGURE 15. Radiographs showing periapical lucencies in a dog. **(A)** Right mandibular first molar (409) showing the summation effect resulting from superimposition of the apex of the tooth roots over the mandibular canal **(arrows)**. **(B) Black dashed line** indicates the dorsal border of the mandibular canal. **Orange dashed lines** indicate the periodontal ligament extension lines. The lucency is contained within the extension lines and therefore is probably the result of superimposition of the apices over the mandibular canal. **(C)** Left mandibular first molar (309). The periapical lucency is irregular in shape, wider than the root tip, and extends beyond the extension lines of the periodontal ligament space. There is evidence of apical root resorption. These findings are consistent with endodontic disease and are not the result of superimposition of the apices of 309 on the mandibular canal.

Far left: courtesy Chanda Miles, DVM, DAVDC. Opposite radiographs: courtesy Chanda Miles, DVM, DAVDC.

When in doubt, consult with a board-certified veterinary dentist or take follow-up radiographs in 3 to 6 months to evaluate changes in the appearance of the periapical lucency.

Foramina

- The caudal and middle mental foramina may be mistaken for periapical pathology associated with the rostral mandibular premolars.
- In the dog, the middle mental foramen is ventral to the mesial root of the second premolar and the caudal mental foramen is ventral to the mandibular third premolar (**FIGURE 16**).
- In the cat, the middle mental foramen is in the interdental space between the mandibular canine tooth and third premolar and the caudal mental foramen is ventral to the mandibular third premolar (**FIGURE 17**). To distinguish between a foramen and a periapical radiolucency, change the angle of the tube head when obtaining the radiograph. The foramen will move relative to the root as the angle of the tube head is changed. If the lucency remains associated with the apex of the tooth, then it is periapical pathology.

Radicular Groove of Mandibular First Molar

- The periodontal ligament space on the distal aspect of the mesial root of the mandibular first molar in a dog may appear as a double line or shadow. This double line represents the radicular groove (**FIGURE 18**).[6] Incorrectly interpreting this normal anatomic structure may lead you to believe that there are 2 mesial roots in the first molar.

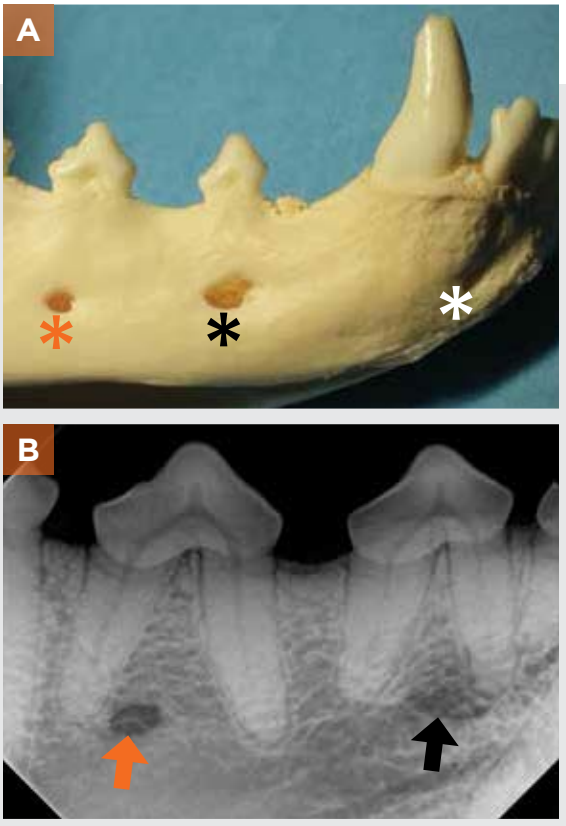

FIGURE 16. Mental foramina of the dog. **(A)** Rostral mandible of a dog skull, showing the location of the rostral **(white asterisk)**, middle **(black asterisk)**, and caudal **(orange asterisk)** mental foramina. The mandibular first premolar is missing. **(B)** Radiograph of right mandibular premolars, showing the middle mental foramen ventral to the mesial root of the mandibular second premolar (406) **(black arrow)** and caudal mental foramen ventral to the mandibular third premolar (407) **(orange arrow)**.

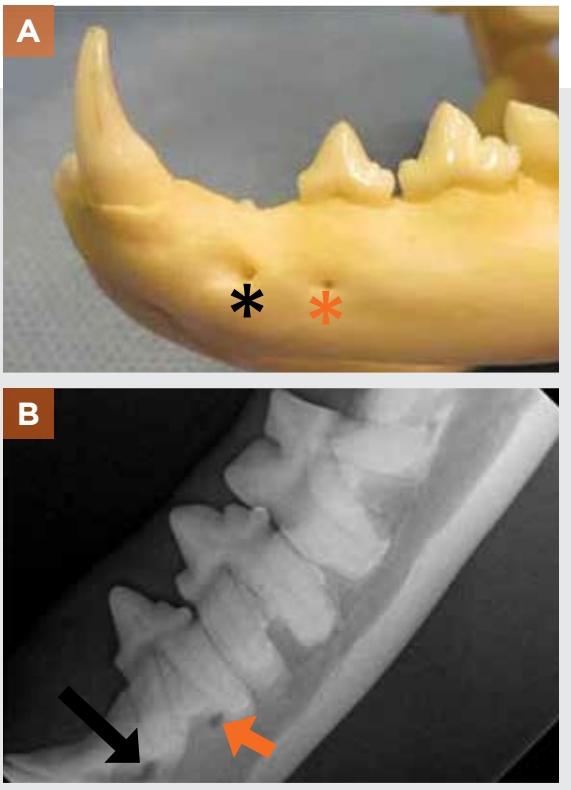

FIGURE 17. Mental foramina of the cat. **(A)** Rostral mandible of cat skull, showing the location of the middle **(black asterisk)** and caudal **(orange asterisk)** mental foramina. **(B)** Radiograph of left mandibular premolars showing the middle mental foramen in the interdental space between the left mandibular canine (304) and third premolar teeth (307) **(black arrow)** and the caudal mental foramen ventral to the mandibular third premolar (307) **(orange arrow)**.

CONCLUSIONS

To obtain essential information for determining appropriate treatment for each tooth in each patient, full-mouth radiographs are required.

As with most things in veterinary medicine, the first step in learning how to interpret intraoral radiographs is becoming familiar with normal dental anatomy. Radiographs are 2-dimensional, and superimposed structures may cause misinterpretation of normal anatomy as pathology. The second step in learning how to interpret intraoral radiographs is understanding radiographic findings associated with oral diseases. To read about pathology seen on intraoral radiographs, see "Intraoral Radiographs: Identifying Common Pathology" in the July/August 2022 issue of *Today's Veterinary Practice*. The more intraoral radiographs you read, the more disease you will find and the more you will believe in the value of full-mouth intraoral radiographs for every dentistry patient.

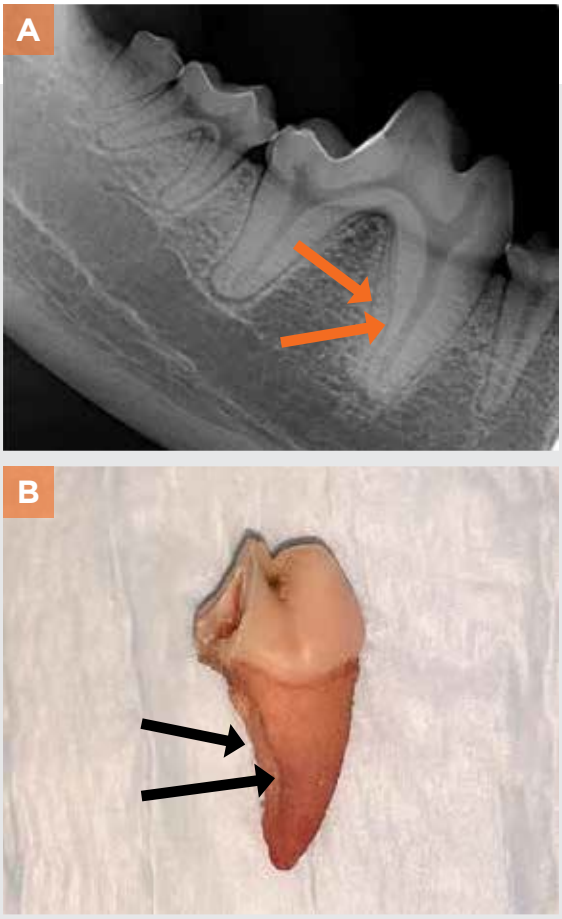

FIGURE 18. Radicular groove in a dog. **(A)** Radiograph showing double line resulting from the radicular groove on the distal side of the mesial root of the right mandibular first molar (409) **(orange arrows)**. **(B)** Extracted mesial root of the right mandibular first molar, with the radicular groove visible on the distal side of the mesial root. **Black arrows** point to the edges of the radicular groove that cause the double line seen in **(A)**.

Author's note: Special thanks to the veterinary nurses who obtained these radiographs and are an integral part of the oral healthcare team. TVP

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