Dental radiology: ageing changes in permanent teeth of beagle dogs

J. P. Morgan and T. Miyabayashi

Department of Radiological Sciences and the Laboratory for Energy-Related Health Research, School of Veterinary Medicine, University of California, Davis, CA 95616

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ABSTRACT

Radiographic interpretation of dental or periodontal disease is dependent in part on an understanding of ageing changes. A progressively ageing colony of healthy beagle dogs (120 to 3759 days) was studied by use of high-detail radiographs made following the death of the dog. Morphological features whose radiographic appearance was found to be especially age-dependent were: root canal size, both vertical and horizontal alveolar bone resorption, visualisation of the lamina dura dentis, and detection of hypercementosis. Understanding of these ageing changes is necessary to avoid over-diagnosis of disease.

INTRODUCTION

To correctly interpret a dental radiograph, a knowledge of normal morphology of both bony tissues and teeth is important. Wide structural variations are dependent on age as much as on usage. All anatomic features are not demonstrable radiographically on every radiograph. Other radiographic studies of beagle dogs have covered a period of post natal tooth development from 21 to 239 days (Bartley and others 1970), whereas others have reported tooth development of mongrel dogs (Mellanby 1929). Reports dealing with radiographic techniques are more common (Zontine 1974, 1975, Emily 1986, Lavelle 1987). This report describes ageing changes associated with the permanent dentition of beagle dogs. Some of these changes are more correctly considered developmental, whereas others are degenerative in nature (Dahlberg 1964). However, all are characterised by radiographically demonstrable change with age following eruption of permanent dentition (Gustafson 1950).

Presence of calculus (Rosenberg and others 1966, Sorenson and others 1980) or tartar as well as clinically important degenerative changes of soft tissues, such as gingivitis/periodontitis, could not be evaluated radiographically. Sexual dimorphism has been described in canine teeth (Lorber and others 1979) but was not evaluated in this study.

MATERIALS AND METHODS

A group of beagle dogs including both sexes was studied radiographically to determine rates of skeletal maturation (Bartley and others 1970). This material was added to an older group including both sexes so that ages extended from 120 days to 3759 days (10 years). Deciduous teeth had all exfoliated by 155 $\pm$ 7 days of age as previously reported (Shabesta and others 1967). Eruption of permanent dentition began at 115 $\pm$ 6 days and was complete by 175 $\pm$ 11 days as previously reported (Arnall 1961, Bell 1965, Bartley and others 1970). All dogs were from the same closed colony and were maintained in 3 m $\times$ 4 m wire pens. They were fed an adequate diet throughout life (Wolf and others 1966, Wolf 1973) and received prophylactic and therapeutic medical attention by a professional staff on a regular and emergency basis. At the time of the dog's death, lateral radiographs were made of the maxillae and mandibles, using XTL-2 Therapy Localisation Film (Kodak), which is a non-screen film. A 30-inch focal-film distance was used with a machine setting of 400 mAs, using a 100 mA station that

Table 1. Ages of dogs studied

Age (days)		
120	258	1423
135	270	1533
139	300	1825
156	330	2153
178	390	2591
191	485	3066
196	510	3358
198	570	3504
203	600	3577
226	766	3759
231	1168	
238	1387	

permitted use of the small focal spot. Dependent on the size of the specimen, kVp settings were in the range of 50 to 60. Film processing was done in the Kodak M-4B automatic processor that was converted to a one-and-a-half-minute processing cycle. Ages of the 34 dogs studied were tabulated (Table 1). Because of limitations imposed by use of lateral views only, changes involving incisors were not thoroughly evaluated.

RESULTS

Components of the teeth and supporting tissues included enamel that was seen uncommonly as a dense radio-opaque line on occlusal surfaces covering the coronal portion of the tooth and tapering to a fine edge at the cervical margin of the tooth. Dentin exhibited almost the same degree of radiopacity as enamel, and these two tissues accounted for the largest portion of hard structures of teeth. Cementum normally formed a thin covering on the root's surface. These three tissues could not be separated radiographically because of their similar density. The pulp chamber and pulp canal were seen as a continuous radiolucent pattern in the tooth's centre because of their soft tissue composition and extended from the coronal portion of the root apex.

The lamina dura dentis is a non-specific term that refers to the alveolar socket's bony wall and is continuous with the alveolar crest, making a sharp angle to it. It appeared as a dense line parallel to the root and was separated from the tooth by the radiolucent periodontal ligament. Cancellous bone filled the interdental and interradicular spaces with a lace-like trabecular pattern. Lamellar bone forming alveoli of the lower teeth was more clearly evaluated radiographically than bone around the upper teeth. The radiographically discernible mandibular canal, mental foramina, and an easily identified ventral cortex were unique in the mandible. All anatomical structures were more easily studied in the mandible than in the maxilla, primarily because of the ease in identifying bone tissue surrounding the lower teeth and the absence of superimposed tooth roots (Fig 1).

Root chamber and canal

The root chamber and canal of permanent teeth were clearly identified radiographically in young dogs and underwent a pattern of ageing change that resulted in their near disappearance. The root canal had its largest diameter following dental eruption and occupied the majority of the cross section of the root. At that time, walls of the developing root quickly tapered to a knife-edge appearance. An approximation of maximum size of the root canal varied with each tooth and was determined at a point one-half the distance from the bifurcation of the roots to the root apex in selected premolar and molar teeth and at the dentinoenamel junction in canine teeth. Percentages of the root occupied by the canal near the time of eruption were: (1) 80 per cent in both upper and lower canine teeth, (2) 75 per cent in the caudal root of the upper fourth premolar, (3) 66 per cent in the caudal root of the lower fourth premolar, and (4) 70 per cent in the cranial root of the lower first molar. These measurements decreased rapidly until they all became less than 10 per cent by two to three years of age (Fig 2). Ratios of root canal width to root width were plotted (Fig 3).

Root apex

The root apex was more easily evaluated in the lower arcade. Following exfoliation of deciduous teeth, roots of some lower premolars and molars appeared to extend into the mandibular canal. In canine teeth, narrowing of apical foramina was obvious at 191 days and the foramina appeared closed at 270 to 300 days. Apices of caudal roots of fourth premolar teeth and cranial roots of lower first molar teeth were selected for evaluation

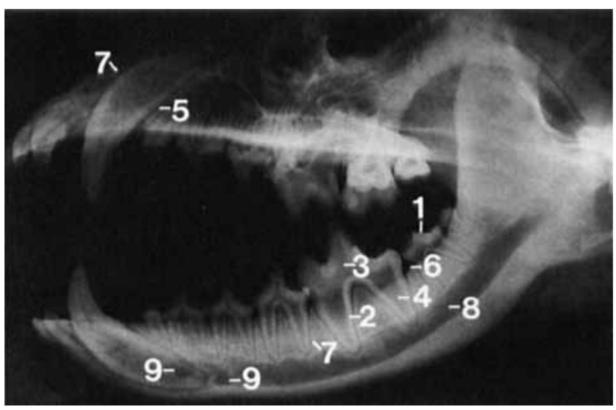

FIG 1. Lateral radiograph made at 258 days of age shows anatomical features of teeth and supporting structures: enamel (1), dentin (2), root chamber (3), root canal (4), periodontal ligament space (5), cortical bone creating the alveolar crest (6), lamina dura dentis (7), mandibular canal (8), and mental foramina (9)

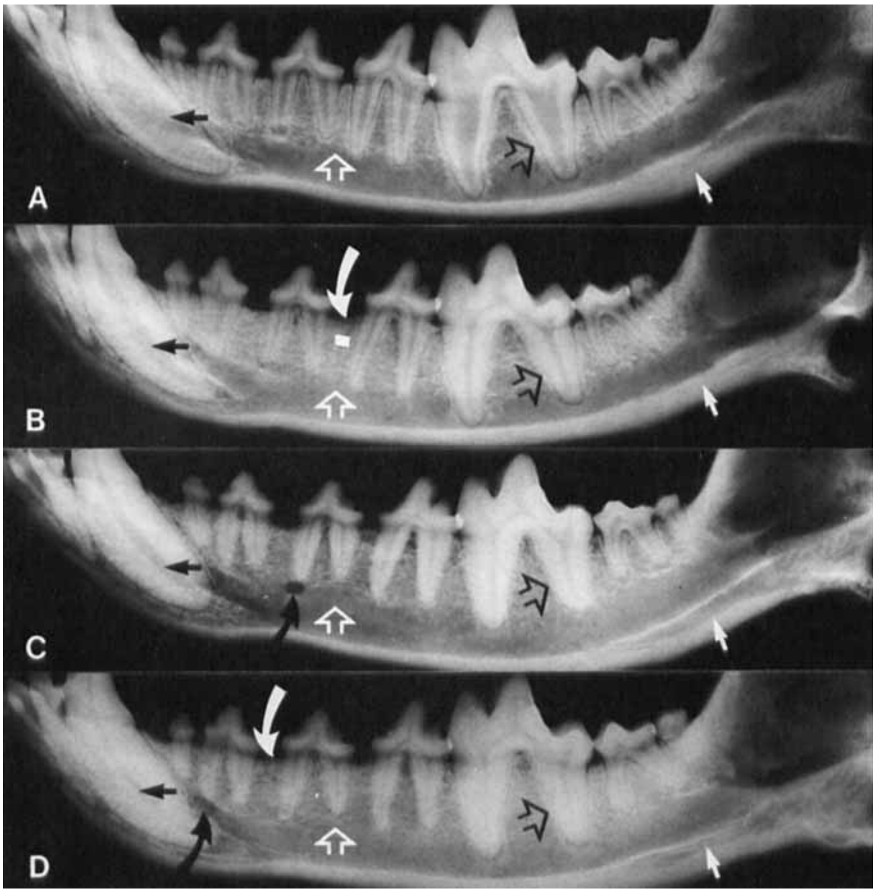

FIG 2. Lateral radiographs made at 270 days of age (A), 485 days of age (B), 766 days of age (C), and at 1423 days of age (D) show marked ageing changes. Note changes in the root chambers and root canals (straight black arrows), variation in location and appearance of the mental foramina (curved black arrows), changing character of the mandibular cortex (straight white arrows), wavy appearance of the alveolar crest indicating horizontal bone loss (curved white arrows), variation in appearance of the lamina dura (open black arrows), and change in appearance of the mandibular canal and the relationship of the apical lamina dura to the mandibular canal (open white arrows)

because of their prominence radiographically but remained difficult to evaluate because of less obvious lucent foramina. However, the apices appeared closed by 196 to 226 days of age (Fig 4). Measurements of the width of apical foramina and time of closure were recorded (Fig 5).

Attrition

Reduction in cusp height and consequent flattening of occlusal planes occurred with severe attrition, resulting in tooth shortening. Attrition of occlusal surfaces of lower fourth premolars and first and second molars was severe in two dogs at the ages of 1825 days and 2153 days (five years) (Fig 6). Attrition of canine teeth suggested a more abnormal occlusal pattern and was seen earliest at 485 days (one year) and later in other dogs at 1533, 3066, and 3577 days (four to nine years) (Fig 7).

Idiopathic resorption of roots

Resorption of the roots as indicated radiographically by increased lucency in the apical region was noted uncommonly (Fig 8).

Hypercementosis or cemental hyperplasia

Hypercementosis was characterised by deposition of excessive amounts of secondary cementum on root surfaces causing a generalised root thickening or prominent bulbous apical enlargement. Persistence of a lucent periodontal membrane surrounding the area of hypercementosis made its detection easier. Hypercementosis appeared to be an uncommon ageing change in the group studied (Fig 8).

Mental foramina

Mental foramina are openings of the mental canals and inconsistently appeared as two oval or round radiolucencies in the premolar region of the mandible. The location of the rostral foramen ranged between an area ventral to the root of pre-

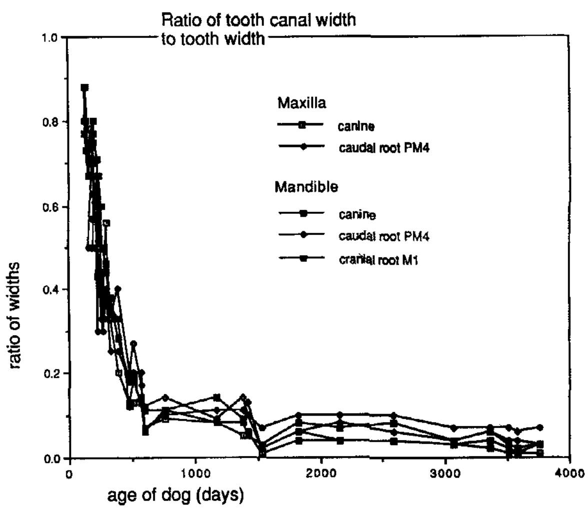

FIG 3. Ratio of root canal width to tooth width determined by age of dog

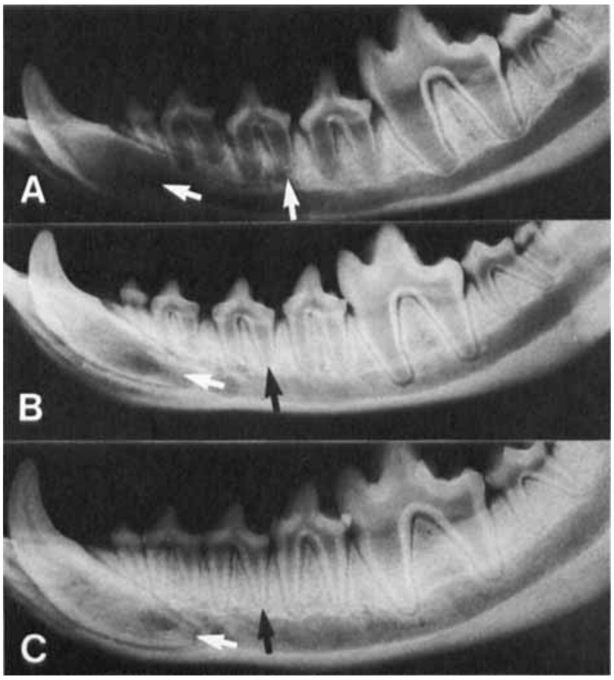

FIG 4. Lateral radiographs made at 178 days of age (A), 198 days of age (B) and 270 days of age (C) show changes in appearance of the root apex (arrows) and change in appearance of the mandibular canal

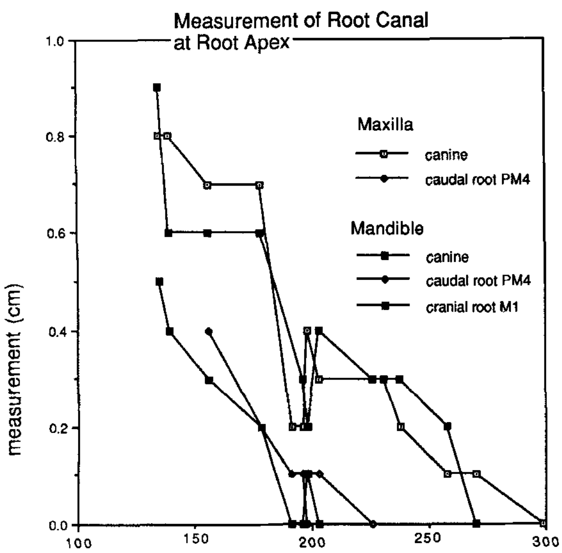

FIG 5. Measurement of root canal at root apex determined by age of dog

molar 1 and the rostral root of premolar 2. The location of the caudal foramen extended from the roots of premolars 2 and 3 and an area ventral to the bifurcation of the roots of premolar 3. The rostral foramina was usually identified at all ages, whereas the caudal foramina often were not seen in dogs over four years of age (Figs 2 and 9).

Mandibular cortex

Width of the ventral cortex of the mandible varied from 10 to 25 per cent of the dorsoventral measurement of the mandible but was not age-related. However, the character of the bony tissue within

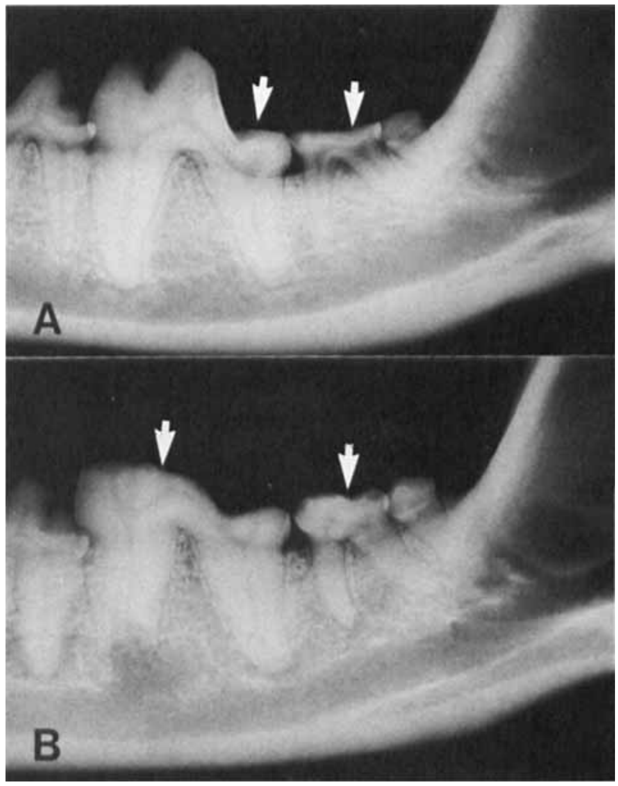

FIG 6. Lateral radiographs made at 1825 days of age (five years) (A) and at 3577 days of age (nine years) (B) show attrition of lower fourth premolars and first and second molars (arrows). Note the change in appearance of the mandibular cortex

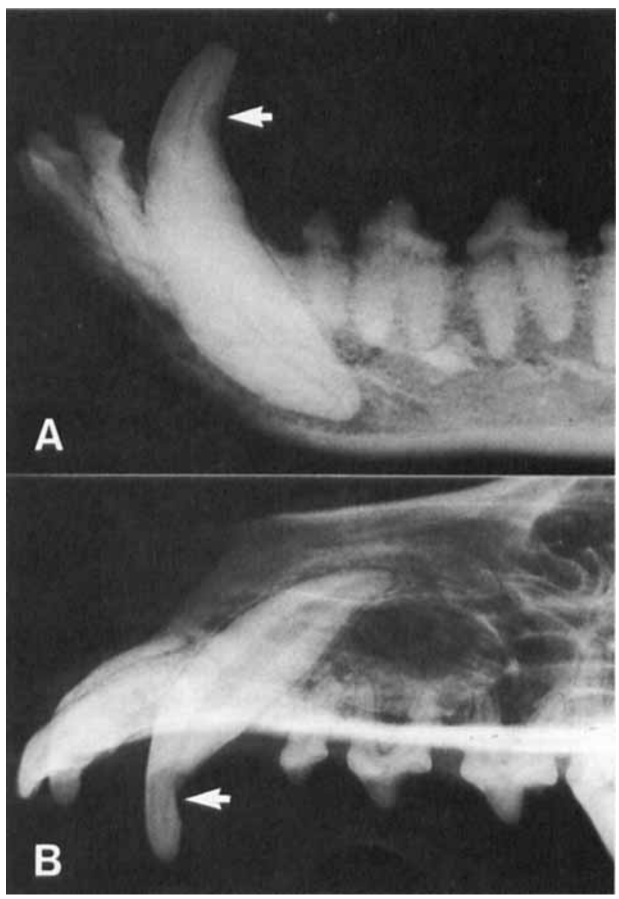

FIG 7. Lateral radiographs made at 485 days of age (one year) (A) and at 3577 days of age (nine years) (B) show attrition of canine teeth (arrows)

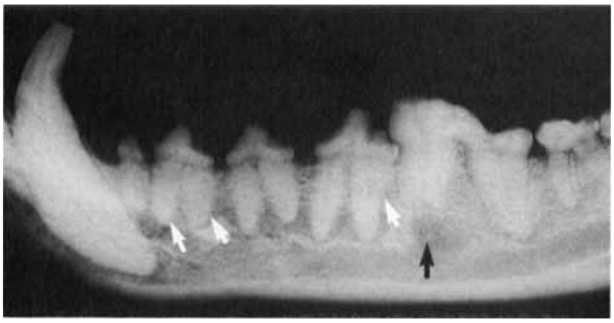

FIG 8. Lateral radiographs made at 3577 days of age (nine years) show root resorption (black arrow) and extensive hypercementosis (white arrows)

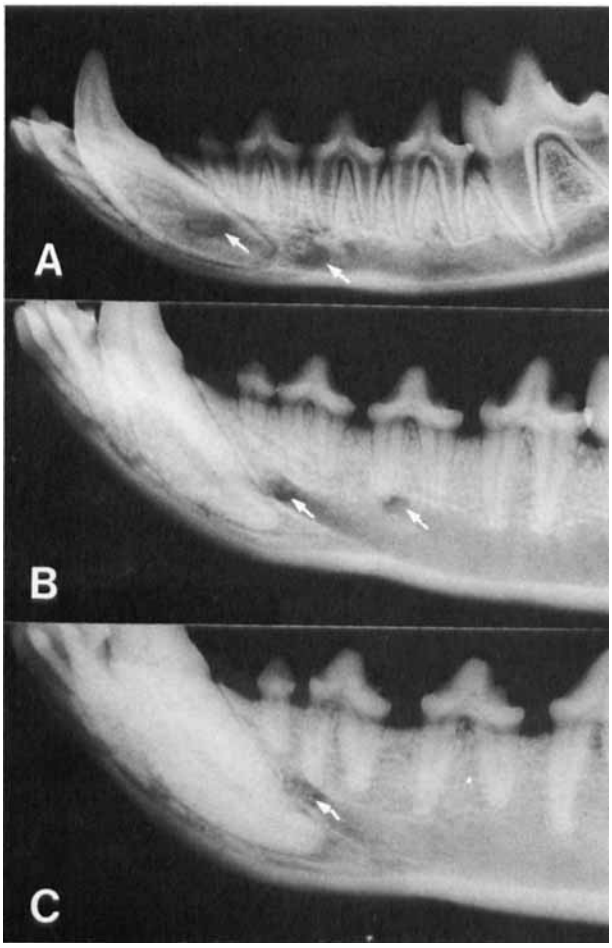

FIG 9. Lateral radiographs made at 231 days of age (A), 600 days of age (B), and 1423 days of age (three years) (C) show varying locations and appearances of mental foramina (arrows). Note the pattern of closure of the apical foramina of the canine teeth and the appearance of the lamina dura

the ventral cortex changed consistently with age. In younger dogs to an age of 300 days, the cortex was composed of uniformly dense bone. By 600 days, a lucency suggesting replacement of the compact bone by cancellous bone was found within the cortex ventral to the last molar. This lucency remained throughout life in most dogs but varied in size and prominence (Figs 2, 6 and 10).

Alveolar bone

The trabecular pattern of interradicular and interdental bone remained delicate in form and did not form a distinct trabecular pattern until about 196 days or approximately 20 days after completion of eruption of permanent dentition. At that age, normal alveolar bone had a defined trabecular pattern with a sharply identified margin and extended between teeth in a pyramidal shape (Fig 11). The gingival margin of alveolar processes that extended between the cementoenamel junctions of adjacent teeth was readily apparent radiographically and is referred to as the alveolar crest. Size of the interdental space determined whether the crest was flattened or pointed (Fig 2).

Regressive changes in the alveolar crest were common by the age of one year but it was difficult to determine the degree of regression because of the absence of an easily defined cementoenamel junction. Alveolar crests receded with age and showed two patterns of resorption, horizontal or vertical. Blunting of alveolar crests due to bone resorption led to creation of a wavy appearance of this otherwise straight line, and was first noted at 270 days of age involving the region of the lower premolars and molars. A part of the wavy appearance was due to a 'cupping out' of interdental alveolar bone. Similar changes were first noted in the maxilla at 485 days (one year) and probably were detected later because of less accurate evaluation of these teeth. After 600 days (one year), maxillae and mandibles both had alveolar crests with a wavy appearance as well as definite vertical bone removal (Fig 2). Vertical bony resorption began at the junction between the alveolar crest and the tooth neck and

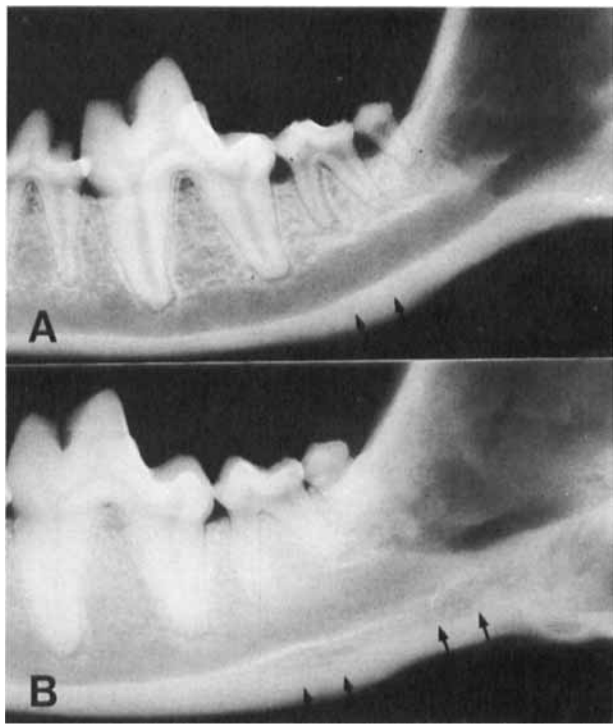

FIG 10. Lateral radiographs made at 570 days of age (A) and at 1423 days of age (three years) (B) show the changing character of the mandibular cortex with hyperlucency developing (arrows). Note appearance of the dorsal border of the mandibular canal

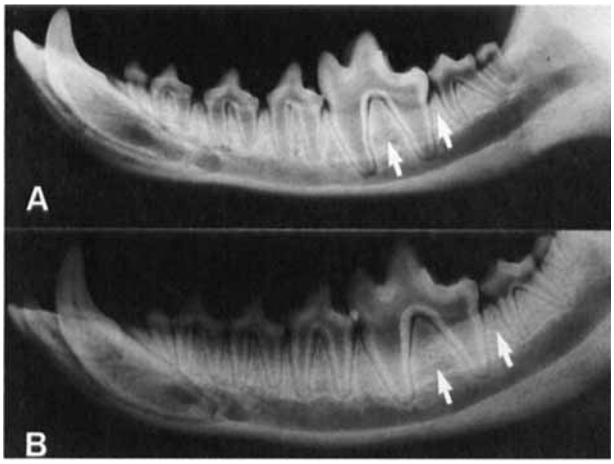

FIG 11. Lateral radiographs made at 198 days of age (A) and 258 days of age (B) show the matured character of normal interradicular and interdental bone (arrows)

extended vertically along the tooth root. Vertical loss of bone indicated creation of infra-bony pockets adjacent to the tooth root with alveolar bone forming the lateral walls. Vertical loss was more difficult to detect around upper first molar teeth because of the overlying third root (Fig 12).

Lamina dura dentis

The radiographic appearance of the lamina dura dentis was age-dependent, tooth-dependent and, importantly, was influenced by an oblique X-ray beam. In young dogs, the shadow was dense, had uniform width, and was easily identified against the radiolucent periodontal membrane. With age, density decreased and width diminished resulting in more difficult evaluation. The lamina dura was noted to be persistent around the canine teeth until the age of 3504 days (nine years) because of ease of evaluation. Disappearance of the lamina dura around the caudal root of the upper and lower fourth premolars was first noted at 300 days; however, disappearance of the lamina dura around these teeth was not complete in all dogs until approximately five years of age (Figs 2, 9 and 13). The lamina dura around the cranial root of the lower first molar was first missing at 570 days (two years) and was inconsistent in appearance until over five years of age after which it was not seen. The lamina dura dentis was most clearly identified around the roots of the second and third lower molars until the oldest age (Fig 2).

The lamellar bone that formed the dorsal and ventral borders defining the mandibular canal was not seen equally well in all dogs and was age-dependent. Both canal borders were readily identified until the age of 300 days (Figs 1, 2, 4, 11 and 13). The dorsal border became indistinct in appearance and was not identified radiographically after the age of 1387 days (three years) (Figs 2, 10, 12 and 13). There was a tendency to overdiagnosis generalised bone loss upon evaluation of these radiographs.

The lamina dura around the apex of the roots of the fourth lower premolars and first lower molars was located dorsal to the mandibular canal until about 200 days. After this age, tooth movement placed the apices of the second, third, fourth premolars, and first molar in close contact or actually within the canal. As a result, the apical lamina dura was difficult to evaluate and appeared to be missing (Figs 2 and 13).

DISCUSSION

Radiographic evaluation of the teeth in this study is known to have limitations because there is only a single lateral projection available for examination. For examination of the incisors, an additional open-mouth projection is needed. Another problem is that only the radio-opaque tissues can be studied, which means that changes in the soft tissues associated with gingivitis/periodontitis are not evaluated. These limitations in radiographic examinations have been discussed (Theilade 1960).

Failure to develop a thickened, easily identified enamel layer is another limitation in diagnosis. The thin character of the enamel layer is consistent with minimal food mastication in the dog and has been reported earlier (Lawson and

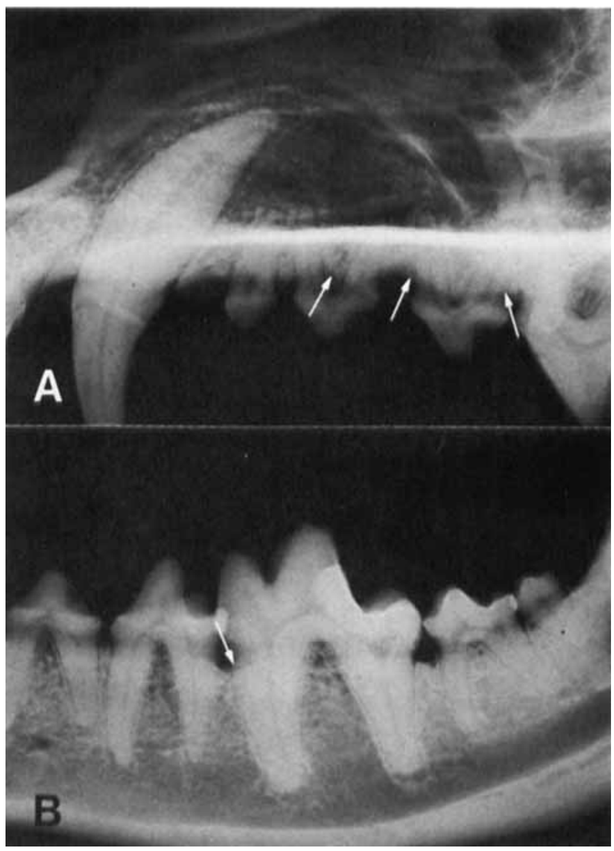

FIG 12. Lateral radiographs made at 1825 days of age (five years) (a) and 3358 days of age (nine years) (b) show vertical bone regression (arrows). Note the appearance of the dorsal border of the mandibular canal

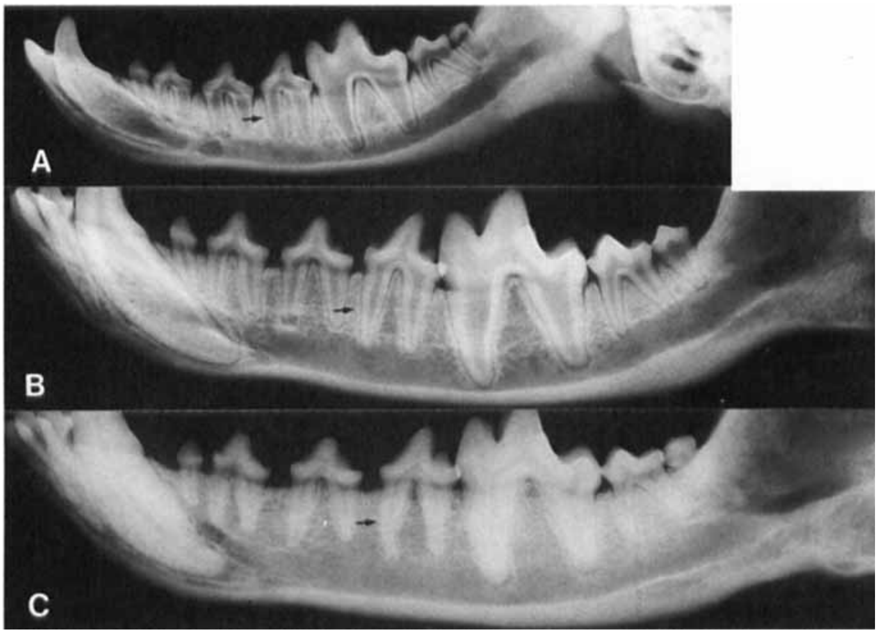

FIG 13. Lateral radiographs made at 198 days of age (A), 270 days of age (B), and 1423 days of age (three years) (C) show change in appearance of the mandibular canal and the relationship between the canal and roots of the teeth. Note the appearance of the lamina dura (arrows) and the dorsal border of the mandibular canal and the relationship of the apical lamina dura to the mandibular canal

others 1960). The dentinoenamel junction (amelodentinal junction) lacked scalloping as seen in herbivores and man, making identification difficult in the dog (Lawson and others 1960). This means that measurements using this junction as a reference point are difficult. In addition, the cementum could not be separated from the dentin radiographically. It became obvious that any separation of the hard tissues of the teeth was nearly impossible radiographically and that the tissue of origin of changes noted radiographically might be difficult to determine. Hypercementosis, however, appeared to be an exception and the new tissue seen around the roots was clearly from the cemental layer. Because of the lucency of the pulp chamber and pulp canal, changes in their size and shape were more easily identified. Changes in the appearance of the root chamber and canal have been described earlier (Zontine 1974, Tholen 1987). From this study, it appears this is a predictable change and can be used to determine a dog's age accurately to the age of two to three years after which the change is slower and could not be used as accurately in the determination of the dog's age.

An understanding of the radiographic appearance of the root apex is important because of the possibility of misdiagnosing a destructive periapical lesion. The closure of the apices was closely age-dependent, as has been suggested, and its appearance can be anticipated (Zontine 1974). However, roots of permanent teeth may undergo idiopathic resorption that can be considered to be analogous to remodeling that occurs in repair of bone (Lee 1985) and occurs secondarily to many processes (Zontine 1974, Morton 1978). Resorption may occur externally from periodontal tissue or internally from the pulp chamber or canal. If external resorption becomes extensive, it results in radiographically detectable tooth shortening and an indistinct appearance to the root that is easily misdiagnosed as an apical/periapical abscess. If mental foramina are projected over the apices of canine or premolar teeth, they also mimic destructive changes that are assumed to be associated with periapical disease. The location of the ventral mandibular cortex strongly influences the appearance of the apices of teeth; in the older dog, the apices rest dorsal to the ventral cortex within the lucent mandibular canal. These findings only suggest some of the reasons for over-diagnosis of apical changes radiographically.

Attrition is the physiological wearing away of a tooth as a result of tooth-to-tooth contact occurring during mastication. This occurs normally on the occlusal surface of the maxillary first and second molars and the mandibular first, second, and third molars (Colmery and Frost 1986). Exposure of dentinal tubules and subsequent irritation of odontoblastic processes results in formation of secondary dentin that aids in protecting the pulp from further injury. Even though these dogs were kept on gravel and were often noted to chew on stones, there was a low frequency of attrition. It may be that other features influence attrition, such as grinding of the teeth as occurs in man (bruxism). Attrition of the canine teeth may be due to a different cause than attrition of the molar teeth.

Of major interest in dental radiology is the determination of the character of the periodontal space. The appearance of this space is influenced by changes in the cementum as well as in the surrounding alveolar bone. Because this was a radiographic study, it was not possible to compare alveolar regression patterns with plaque accumulation as has been done in studies primarily concerned with periodontal disease (Lindhe and others 1973). The relationship of horizontal loss of the alveolar ridge to the presence of periodontitis should be made carefully because of the possible influence of an oblique X-ray beam during radiography. The early finding of a wavy appearance of the alveolar crest possibly reflected early periodontal disease in the dogs that advanced at the expense of horizontal loss of the alveolar crest. The bone tissue surrounding the roots contributes to the visualisation of the periodontal space. The lamina dura dentis (hard layer) is a non-specific radiographic term describing the more dense bony tissue that forms a plate of bone adjacent to the roots. Linear changes in this bone parallel to the roots are seen as well as those involving the alveolar crest. Loss of density of the vertical bone was an early finding characterising vertical disease. Thickness and density of the lamina dura varied with the amount of occlusal stress to which the tooth was subjected. It is important to realise that the regressive changes in the alveolar crest and vertical loss of bone were common by the age of one year as has been suggested before (Lee 1985), but at an age much earlier than suggested by others (Gad 1968, Sorenson and others 1980). Hypercementosis affected the appearance of the periodontal ligament but was an uncommon finding in this study until an older age. It is suggested that the entire dentition be evaluated to determine changes in character of the periodontal space and that the appearance of the lamina dura dentis around all teeth be evaluated in diagnosis of systemic disease. A marked difference around one tooth can be used only in the determination of focal disease.

CONCLUSIONS

It was evident from this study that ageing strongly influenced interpretation of dental radiograph. Most important were changes in size of the radiolucent root canal and closure of the apex of the tooth. Both vertical and horizontal alveolar bone resorption appeared to occur early in life, as did disappearance of the lamina dura dentis. Hypercementosis in concert with the disappearing lamina dura made detection of the periodical lagment space difficult and created a pattern in which the tooth root appeared to blend with the surrounding alveolar bone.

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