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Molar eruption and identification of the eastern grey kangaroo (*Macropus giganteus*) at different ages

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ABSTRACT. To treat dental disorders and estimate age, it is important that veterinarians understand teeth eruption sequence for the animal in question. Few dental images of the eastern grey kangaroo have been published. In the present study, radiographic imagings of 29 kangaroos, ranging in age from 12 months to 10 years 9 months, was used to surveil the replacement of premolars and the eruption of molars. These images revealed eruption patterns in five stages, while the second and third deciduous premolars were shed non-systematically. Furthermore, the third premolars and fourth molars erupted in the mandible earlier than in the maxilla, which may contribute to the frequency of mandibular dental disorders.

KEY WORDS: *Macropus giganteus*, mandibular, maxillary, radiographic image, replacement

To enable the treatment of dental disorders and estimate the age of macropods, it is important to understand teeth eruption sequence. In *Macropus giganteus*, a previous study reported the dental formula: I3/ 1, C0/ 0, P2/ 2 and M4/ 4; however, the process of molar replacement at each age was not described [9]. In addition, another study reported that a fifth molar occasionally presents as a supernumerary tooth [4]. Few images of kangaroo teeth at different ages have been published; therefore, further study is required to clarify various aspects of the dentition in this particular macropod.

Dental disorders are one of the most common diseases in captive macropods [14]. Lesions can develop because of various bacterial infections [8, 10], the etiologies of which are multifactorial and include dental calculus, retained post-functional molars, variation in environment, cold weather, and overcrowded captive populations [1, 7, 8, 12]. Dental disorders are frequently documented in Eastern grey kangaroos (*Macropus giganteus*) at the Kanazawa Zoological Gardens (Yokohama, Japan). These animals tended to be younger than 4 years of age, and the primary lesion (55 of 58 dental disorder cases) was mandibular according to 258 clinical case studies involving 200 kangaroos [2]. To treat such conditions, it is important to understand teeth eruption sequences at each stage of the animal's life. However, dental identification has not been well described for the Eastern grey kangaroo, especially in specimens younger than 5 to 6 years of age, which is when premolar replacement and molar eruption occur [11].

The aim of the present study, therefore, was to examine the process of premolar replacement and molar eruption in the Eastern grey kangaroo, and to clarify the dentition at each developmental age. To achieve this, we analyzed radiographic images and compared them with those published in a previous report [5].

The Eastern grey kangaroos housed at the Kanazawa Zoological Gardens originated from the Currumbin Wildlife Sanctuary (Queensland, Australia) in 1986, and have been bred and kept at the facility since then. In the present study, 29 animals (10 male, 19 female; age range: 12 months to 10 years 9 months) were examined at this facility (Table 1). Radiographic images of the heads of 27 of 29 kangaroos were obtained under manual restraint; multiple images of 9 animals were captured (Table 1). The following four radiographic planes were used: lateral, ventral-dorsal, left angle (45°), and right angle (45°). Two of the 29 kangaroos died before examination: a female 1 year 1 month of age (No. 28), which died 3 months after emergence from the pouch; and a male, 2 years 2 months of age (No. 29). Their skulls were examined and the mandibles were separated from the skull before radiography was performed. Radiography of the maxilla was performed at an angle of 45°. The left and right parts of the mandibles were divided, and radiography was performed laterally in one of the mandibles.

Identification schemas of kangaroo teeth reported in the literature have been inconsistent [3, 6, 9]. However, Luckett [5] illustrated dP3-P3 relationships by ontogenetic assessment of dental homologies, and Kierdorf *et al*. [3] adapted the observations

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Table 1. Radiographic images were reviewed in eastern grey kangaroos (*Macropus giganteus*). The identification number is given in the left columns

No.	Sex	Age[a)]	Number of frequency[b)]
1	M	1y1m	1
2	F	12m−1y2m	4
3	F	1y1m−1y2m	2
4	M	1y8m	1
5	F	1y11m	1
6	F	1y11m	1
7	F	1y12m	1
8	M	2y1m	1
9	F	2y1m−2y2m	2
10	M	2y3m	1
11	F	2y4m	1
12	F	2y6m	1
13	F	2y10m	1
14	F	2y5m−3y1m	3
15	M	3y1m	1
16	M	3y3m−3y8m	11
17	F	4y2m	1
18	F	4y2m−4y4m	2
19	F	4y4m	1
20	F	4y7m−5y1m	11
21	M	4y8m−5y3m	15
22	F	4y9m−5y6m	7
23	F	5y2m	1
24	M	7y4m	1
25	F	8y5m	1
26	F	9y9m	1
27	M	10y9m	1

m: month; y: year. a) When the radiographic image was taken. b) The frequency of imaging at a given age. Interval is 2 weeks or 1 months. In No. 14, it is 3 months.

by Luckett and provided clearer images. Accordingly, teeth identification schema of the 29 kangaroos in the present study was annotated in accordance with the report by Kierdorf *et al*. [3].

The process of identifying teeth according radiographic imaging data is as follows. First, whether third premolars ($P^3/_3$) was embedded in the bone, could be confirmed that third deciduous premolars (dP^3) was under P^3 in the maxilla and dP_3 was over P_3 in the mandible. At some point, when $dP^2/_2$ and/or $dP^3/_3$ were shed, and molar ($M^4/_4$) had not clearly emerged, it became difficult to distinguish between $dP^3/_3$ and $M^1/_1$. In these cases, the root of $M^1/_1$ was clear, while that of $dP^3/_3$ was not. Second, when $P^3/_3$ emerged, it could be confirmed that $P^3/_3$ was smaller than $M^1/_1$. Third, when $M^4/_4$ had emerged, molars from $M^1/_1$ to $M^4/_4$ were identifiable.

In one of the kangaroos (No. 28), both sides of $dP^2/_2$, $dP^3/_3$ and a $M^1/_1$ had erupted, and both sides of $P^3/_3$ and $M^2/_2$ were embedded in the maxilla and mandible (Fig. 1a and 1b). In the other animal (No. 29), both sides of $M^2/_2$ had moved horizontally and erupted in both the maxilla and mandible, and both sides of $M^3/_3$ had emerged at the posterior region of the both maxilla and mandible (Fig. 1c and 1d). These observations corresponded with those of the live kangaroos younger than 2 years 5 months of age.

Radiographic observations from the live kangaroos are summarized in Table 2. $P^3/_3$ vertically erupted from 2 years 10 months of age. However, the ages at which $dP^2/_2$ and $dP^3/_3$ were shed and $P^3/_3$ erupted, even between left and right sides, were variable among the individual kangaroos. $P^3/_3$ usually erupted until 5 years of age; a representative example (No. 16) is shown in Fig. 2a and 2b. In the mandible, P_3 first emerged and progressed to replace dP_3, although dP_2 had already been shed in some kangaroos by then. Subsequently, dP_2 and dP_3 were sequentially shed and P_3 erupted. Thereafter, in the maxilla, dP^2 had been shed in many cases, and P^3 had dropped down and replaced dP^3. In addition, $M^4/_4$ emerged at the back of the bone.

Finally, $M^4/_4$ erupted, and all teeth had emerged by the time the kangaroos were approximately 5 years of age (Fig. 2c). M_4 erupted in the mandible, and then M^4 in the maxilla. The $P^3/_3$ and $M^1/_1$ in both the maxilla and mandible were sequentially shed from 7 years 4 months of age (Fig. 2d and Table 2).

The present study revealed the process of tooth replacement and eruption in the Eastern grey kangaroo at various ages. In summary, the sequence of eruption of the permanent teeth was M1-M2-M3-P3-M4 (occasionally, M1-M2-P3-M3-M4) in the

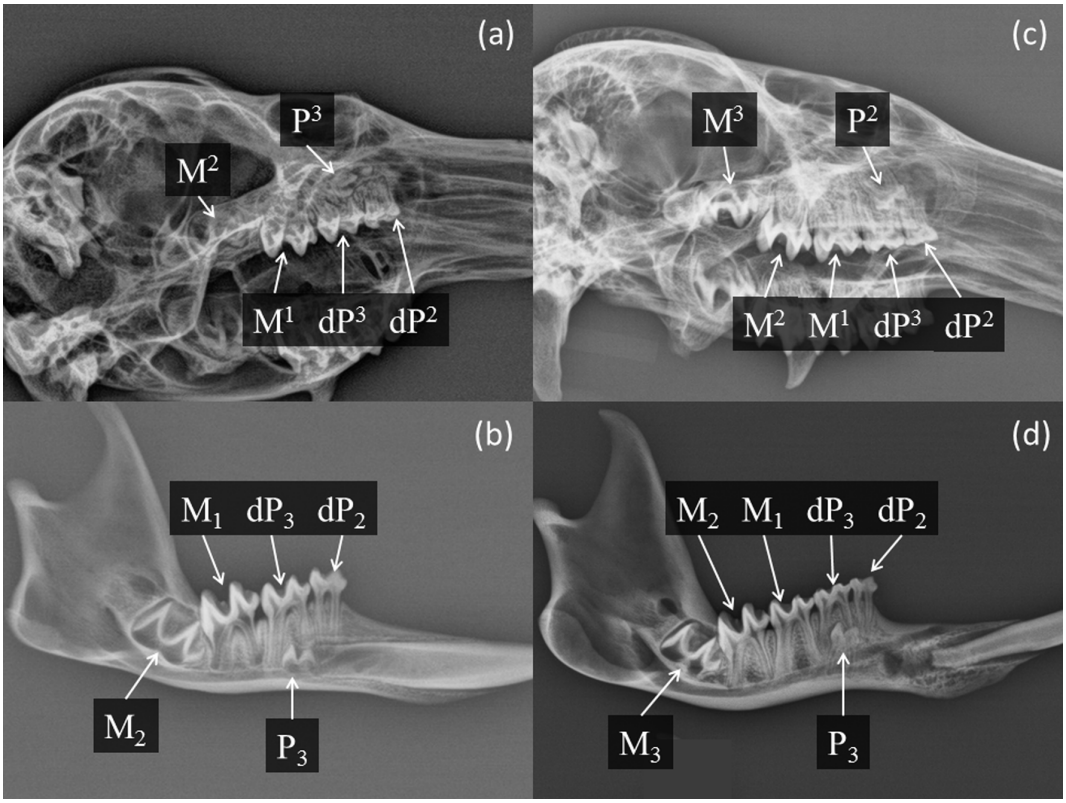

Fig. 1. Radiographic images of the skull of the eastern grey kangaroo (*Macropus giganteus*). (a) The cranium and (b) mandible of the skull of a female eastern grey kangaroo that died at 1 year 1 month of age (No. 28). (c) The cranium and (d) mandible of the skull of a male eastern grey kangaroo that died at 2 years 2 months of age (No. 29). $M^2/_2$ had moved horizontally and erupted, and $M^3/_3$ emerged by 2 years of age.

Table 2. Stage of tooth eruption in the mandible and maxilla of the Eastern grey kangaroo (*Macropus giganteus*)

Age	Number of		Maxilla							Mandible						
	Individuals[a)]	Samples[b)]	dP^2	dP^3	P^3	M^1	M^2	M^3	M^4	dP_2	dP_3	P_3	M_1	M_2	M_3	M_4
12m−1y2m	3	7	○	○	△	○	−/△ R: 5/2 L: 5/2			○	○	△	○	- / △ R: 5/2 L: 5/2		
1y8m−2y10m	11	13	○/▽/− R: 4/8/1 L: 5/8/0	○/ − R: 13/0 L: 11/2	△/○ R: 12/1 L: 11/2	○	○	△		○/ − R: 12/1 L: 12/1	○/ △/ − R: 4/7/2 L: 4/9/0	△/○ R: 11/2 L: 13/0	○	○	- /△ R: 2/11 L: 2/11	
3y1m−4y4m	6	17	-	○/− R: 6/11 L: 13/4	△/○/− R: 0/15/2 L: 11/3/3	○	○	○	−/△ R: 1/16 L: 2/15	○/ − R: 0/17 L: 5/12	▽ / − R: 0/17 L: 5/12	△/ ○/ − R: 0/15/2 L: 6/11/0	○	○	○	- /△ R: 2/15 L: 2/15
4y7m −5y6m	4	34	-	-	○	○	○	○	△/○ R: 19/15 L: 19/15	-	-	○	○	○	○	○
7y4m−10y9m	4	4	-	-	-	○/ − R: 2/2 L: 2/2	○	○	○	-	-	-	○ / − R: 2/2 L: 2/2	○	○	○

○: erupted; △: emerged in the bone (not erupted); ▽: sheding; -: absent. a) The number of the examined kangaroos. b) The frequency of imaging. m: month; y: year; R: right side; L: left side. No.14 was categorized in both 1y8m−2y10m and 3y1m−4y4m.

maxilla and mandible. In addition, the present study presented radiographic images of both the maxilla and mandible. These images may be useful for the identification of teeth, especially during treatment. Previous studies have presented only a few images to describe identification of the teeth [3, 6, 13], or depicted tooth replacement and eruption processes only in the maxilla, and have not described the ages associated with each stage in the process [9]. These studies have provided approximate information to identify teeth and the process of tooth replacement and eruption. However, for clinical use, it is important to gain a graphic understanding

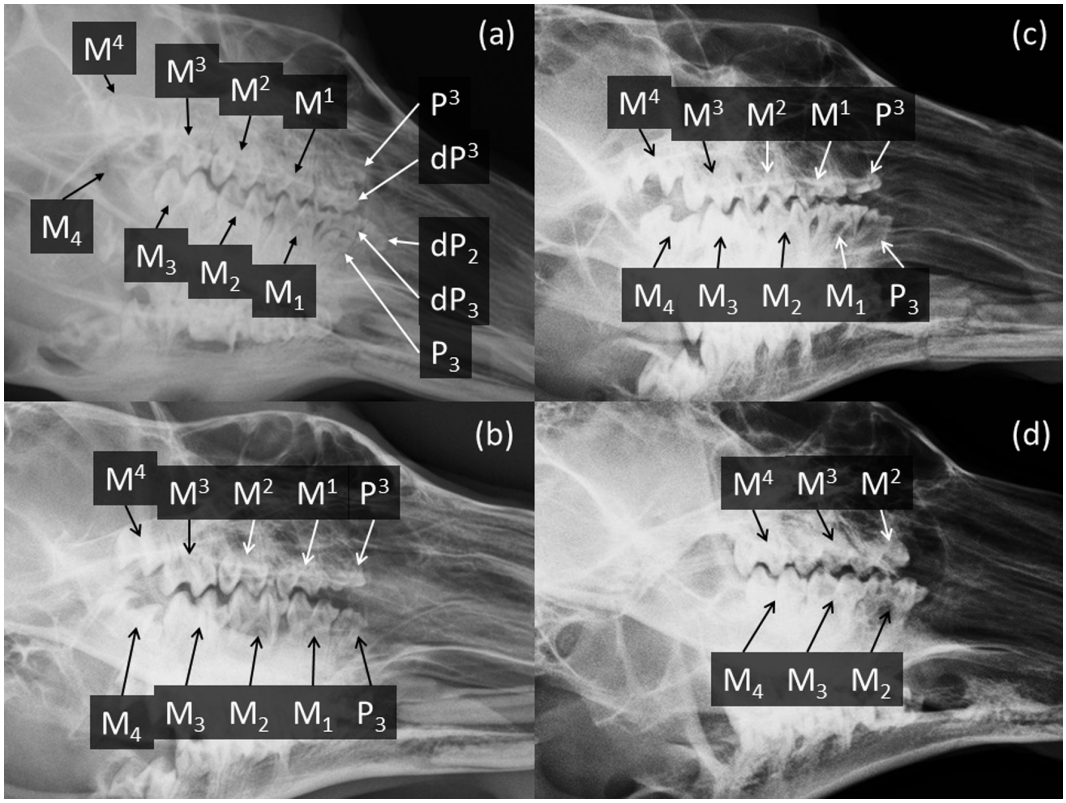

Fig. 2. Radiographic images of the skull of the male eastern grey kangaroo (*Macropus giganteus*). (a) The skull of a male eastern grey kangaroo (No. 16) at 3 years 3 months of age, and (b) 4 years 4 months of age. In the maxilla, dP^3 was replaced by P^3; in the mandible, P_3 overlapped and replaced dP_3 after dP_2 and dP_3 were shed. Vestiges of $M^4/_4$ are shown in (a) and emerged in (b). (c) The skull of a female eastern grey kangaroo at 4 years 8 months of age (No. 20). $M^4/_4$ had erupted and M_4 eruption in the mandible was earlier than that in the maxilla. (d) The skull of a male eastern grey kangaroo at 9 years 9 months of age (No. 26). $P^3/_3$ and $M^1/_1$ were shed.

of identification of the teeth, in addition to the replacement and eruption process at each age. Therefore, the results of this study may add to the current knowledge base.

The replacement of $dP^2/_2$ and $dP^3/_3$ by $P^3/_3$ in both the maxilla and mandible was variable, even between left and right sides, among individual kangaroos. In the mandible, P_3 generally overlapped dP_3 before dP_2 and dP_3 were shed. However, in some cases, dP_2 was shed first and dP_3 was replaced by P_3, or dP_2 remained after P_3 erupted. In contrast, in the maxilla, dP^2 was shed before dP^3 was replaced by P^3. In most cases, replacement occurred in the mandible earlier than in the maxilla. The reason for this is unclear and, therefore, further studies are required.

We have documented that dental disorders are common in Eastern grey kangaroos (mainly in specimens younger than 4 years of age), and the main lesions are mandibular [2]. Although these dental disorders are caused by various bacterial infections, *Fusobacterium necrophorum* infection is believed to be the principal etiology [14], while molar replacement and eruption are also considered to be causative. The main symptom is swelling in the mandible. In our experience, mucosal swelling is frequently observed, and osteomyelitis is occasionally confirmed through radiography.

The present study revealed that replacement of dP_2 and dP_3 with P_3, and the eruption of M_4, occurred earlier in the mandible than the maxilla. However, the length of the mandibular arch may not be adequate for the erupted tooth and, consequently, teeth in the mandible may show crowding. Therefore, because of limited space, inflammation may be easily induced when P_3 or M_4 erupts.

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