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Dental Anomalies in Four Mole Species of the Genus *Mogera* (Insectivora, Talpidae) from Japan

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Abstract Dental anomaly was examined in four species of Japanese moles of the genus *Mogera* collected from several localities. Any anomalies were observed when more than 30 specimens were considered in each locality. The frequency of dental anomalies varied 1.6% to 17.5 % among localities. Among species, observed anomalies were the highest in *M. tokudae* besides its smallest sample number (N=57) and the lowest in *M. imaizumii* (1.8%). Observed dental anomalies were categorized as absent, supernumerary, and connate teeth, and most of them were found on the premolar region. Tooth absence was observed on first and second premolars in all four species. The supernumerary teeth were observed only in Kagawa population of *M. wogura*. Most of them were single additional tooth, but one specimen had three excessive teeth positioned lingually on the right upper jaw side. Only one case with supernumerary canines in both upper jaw sides, was reported at first in talpid species. The connate teeth were not frequent but seen in *M. tokudae* and *M. wogura*. Our results indicate that there are interspecific and local differences of dentition, possibly controlled by a genetic system.

Key words : *Mogera*, supernumerary teeth, oligodonty, connate teeth, dental formula.

Introduction

Dental anomaly of Japanese Talpidae was not well studied (for example, see Miyao, 1972). Imaizumi and Kubota (1978) reported about the variation of tooth number in two species of shrew-moles, *Dymecodon pilirostris* and *Urotrichus talpoides*, based on the large number of specimens. On the mole species, dental anomaly was not examined in detail, though only preliminary description about dental anomaly was achieved in three species of Japanese *Mogera* (Abe *et al.*, 1991). According to Abe *et al.* (1991), dental anomaly of Japanese mole species were very rare, and they situated this fact to certificate the new genus, *Nesoscaptor*, with different tooth number from Uotsuri Island, Ryukyu, Japan. After that, Motokawa *et al.* (2001) described the dental variation in Taiwanese ally of Japanese moles and the Taiwanese mole, *M.*

Table 1. Interspecific comparison among four species of *Mogera*.

Species	N	Anormal specimens observed	Jaw sides examined	Anomaly tooth		
				Upper	Lower	Total
M. etigo	71	6 8.45%	142	7	5	12 8.45%
M. tokudae	57	10 17.54%	114	13	7	20 17.54%
M. imaizumii	331	6 1.81%	662	5	1	6 0.91%
M. wogura	684	44 6.43%	1368	35	16	51 3.73%
Total	1143	66 5.77%	2286	60	29	89 3.89%

insularis, showed greater frequency of dental number. They considered *Nesoscaptor* is a junior synonym of *Mogera* based on their observation.

Seen in these cases, dental anomaly of Talpidae has a special interest because genera of this group were mostly defined by their dental formula. Dental variations among mole genera are seen in the incisor and premolar rows, whereas no congenital anomaly of teeth in number was observed in some rodents (for example Sone *et al.*, 2004). In this paper, we examined dental anomaly of four species of Japanese moles collected from several localities.

Materials and Methods

The total of 2,286 jaw sides (1,143 skulls) of four species of *Mogera* from nine localities (prefectures) from Japan were examined under the dissection microscope. The prefecture less than 30 specimens were basically excluded to the examinations, because of not enough sample size. On the context of *M. etigo* and *M. tokudae*, their distribution areas are confined in Niigata Prefecture, therefore described as “Echigo” and “Sado”, respectively. The “Kyushu” population is gathered with Kagoshima, Miyazaki, Kumamoto, Nagasaki Prefectures because of each small specimen number. Specimens were deposited in the National Museum of Nature and Science (NSMT-M) and the personal collections of Mr. Satoshi Kawaguchi (#) and the first author (SIK). Detailed information of specimen number of each species is shown in Table 1.

Normal dentition of *Mogera* was previously described in Sakai and Hanamura (1973) and dental formula as I3/2, C1/1, P4/4, M3/3＝42 (I: incisor, C: canine, P: premolar and M: molar). In this study, we focused on the absent and supernumerary teeth as anomalies in the tooth number, and on the connate tooth as anomalies in the morphology. Since we did not make X-ray observations, the category of absent tooth may includes both congenital and postnatal tooth losses, and also does not exclude the possibility of the existence of embedded teeth (Natsume *et al*., 2005). Obvious tooth losses after birth were excluded in our external observations when the remains of roots or alveoli were observed on the surface of the jaws. A supernumerary tooth was defined as an extra tooth with independent roots seen from surface observations. When two teeth shared the same root, they were considered as a connate tooth (Miles and Grigson, 1990). Abnormal tooth positions were identified based on the occlusal relationships between the upper and lower tooth rows, and were supplemented by observations of the tooth morphology when several anomalies were observed on both jaws.

Results

Dental anomalies were observed in the 66 specimens (5.8%) in the *Mogera* species. In *M.*

Table 2. Frequencies of absent teeth in four species of *Mogera*.

Species	Locality	N	Anormal specimens observed	Teeth examined	P^1	P^2	P_2	Total
M. etigo	Echigo	71	6	142		7	5	12
			8.45%			4.93%	3.52%	8.45%
M. tokudae	Sado Isl.	57	9	114	1	12	6	19
			15.79%		0.88%	10.53%	5.26%	16.67%
M. imaizumii	Kanagawa	185	3	370		2	1	3
			1.62%		0.54%	0.27%	0.81%	
	Tokyo	109	2	218		2		2
			1.83%			0.92%		0.92%
	Miyagi	37	1	74		1		1
			2.70%			1.35%		1.35%
M. *wogura*	Kyushu	66	2	132			2	2
			3.03%				1.52%	1.52%
	Hiroshima	50	3	100			4	4
			6.00%				4.00%	4.00%
	Aichi	108	1	216		2		2
			0.93%			0.93%		0.93%
	Kagawa	460	13	920	10	4	1	15
			2.83%		1.09%	0.43%	0.11%	1.63%
Total		1143	40	2286	11	30	19	60
			3.42%		0.48%	1.31%	0.83%	2.62%

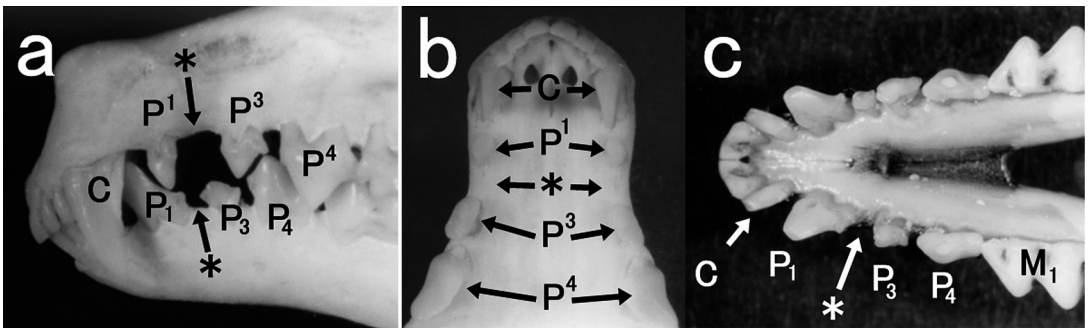

Fig. 1. Three examples of absent teeth (asterisks) in *Mogera tokudae*. — a, Left upper and lower second premolars (NSMT-M 15643); b, right and left upper second premolars (NSMT-M 15644); c, left lower premolar (NSMT-M 29606).

tokudae, the frequency was highest (17.5%) and followed by *M. etigo* (8.5%), *M. wogura* (6.4%) and *M. imaizumii* (1.8%). All anomalies were observed on the position of premolar rows, besides one specimen from Kagawa carrying symmetrical canines in lingual sides (#889). In each species, they were located twice frequently on the upper jaw than lower jaw (Table 1).

Sixty absent teeth were observed in 40 specimens of four species (Table 2). Half of them (30 cases) were located on the upper second premolar (Fig. 1a, b) and less frequently on lower second premolar (19 cases, Fig. 1c) and upper first premolar (11 cases). The frequencies of moles from Sado Island (*M. tokudae*) and Echigo Plain (*M. etigo*) showed relatively high values. In *M. wogura*, the occurrence and position of absent teeth were variable among populations.

The supernumerary teeth were exclusively observed in Kagawa population of *M. wogura* (Table 3). One case (#889) was observed on the lingual sides of both upper canines. These teeth were sickle-shaped sharp and weak teeth, comparative to the normal canine (Fig. 2a). Most su-

Table 3. Frequencies of supernumerary teeth observed in *M. wogura* from Kagawa Prefecture.

Species	Locality	N	Anormal specimens observed	Teeth examined	C^1	P^1	P^2	P^3	P_2	Total
M. wogura	Kagawa	460	13 2.83%	920	2 0.22%	12 1.30%	2 0.22%	1 0.11%	2 0.22%	19 2.07%
Total		1143*	13 1.14%	2286*	2 0.09%	12 0.52%	2 0.09%	1 0.04%	2 0.09%	19 0.83%

* : Specimen number including all examined localities.

pernumerary teeth were observed on distal position of the upper first premolar (12 cases, Fig. 2b), and other positions were rare (one or two cases in distal position of upper second, third and lower second premolars, Fig. 2c and Table 3). One individual (#967) carried three supernumerary premolars on the lingual side of right upper premolar row. These teeth included one premolariform tooth and two undeveloped conical teeth in confused state (Fig. 3).

Total of seven connate teeth were observed in *M. wogura* and *M. tokudae* (Table 4). The positions were evenly scattered in upper first and fourth premolars and lower third and fourth premolars, but rather larger unicuspids tend to carry this anomaly (Fig. 4). It is notable that connate teeth in upper jaw and lower third premolar were only observed in *M. wogura* from Kagawa. Moreover two specimens (#894 and #934, Fig. 5 a and b, respectively) collected in Kagawa showed unique combination of missing in lower second premolar and connation of third premolar.

Discussion

It had discussed that the dental anomalies of the Japanese mole, genus *Mogera*, is quite rare. Abe *et al.* (1991) described that only 13 of 458 (2.8%) specimens had absent, excess, or fused teeth in the upper and lower premolar regions. In their report, examined samples were gathered from all around the Japanese Islands, and each sample from the localities was a few in number. Motokawa *et al.* (2001) showed 4.3% of the Taiwanese mole, *M. insularis* had reduced dentition, but only 23 specimens had been examined. Therefore, we could not evaluate enough both the occurrence rate within each population and local variation of dental anomalies.

The case study of dental anomalies based on the observation of enough samples was conducted by Ueda (1959), who examined the tooth anomaly of 119 specimens of *M. wogura* collected from Hiroshima Prefecture. He showed one case (0.9%) of supernumerary tooth between upper second and third premolars. On the other hand, seven cases of absent teeth (5.84%) on the position of upper second and lower second premolars (misidentified as “first premolars” in Ueda, 1959) were occurred in his samples. Moreover, two third of the specimens showed symmetrical tooth losses in both jaw sides.

In this study, 50 specimens of *M. wogura* from Hiroshima Prefecture were considered, and about 6% of specimens carried tooth absence. This percentage value is similar to the previous study (Ueda, 1959), but symmetrical tooth losses were observed only one of three specimens. In other localities, Kagawa and Kyushu population showed the high number of dental anomalies, and supernumerary teeth, especially, were seen only in the Kagawa population. Thus it assumes that the western population of *M. wogura* exhibits highly variable dentition. In species level, *M. tokudae* has highest occurrence of missing teeth and this may be caused by their isolated small population sizes, namely founder effect and random genetic drift in the island effects.

The body size of the mole is changeable in accord with the Bergman’s rule, thus the size of

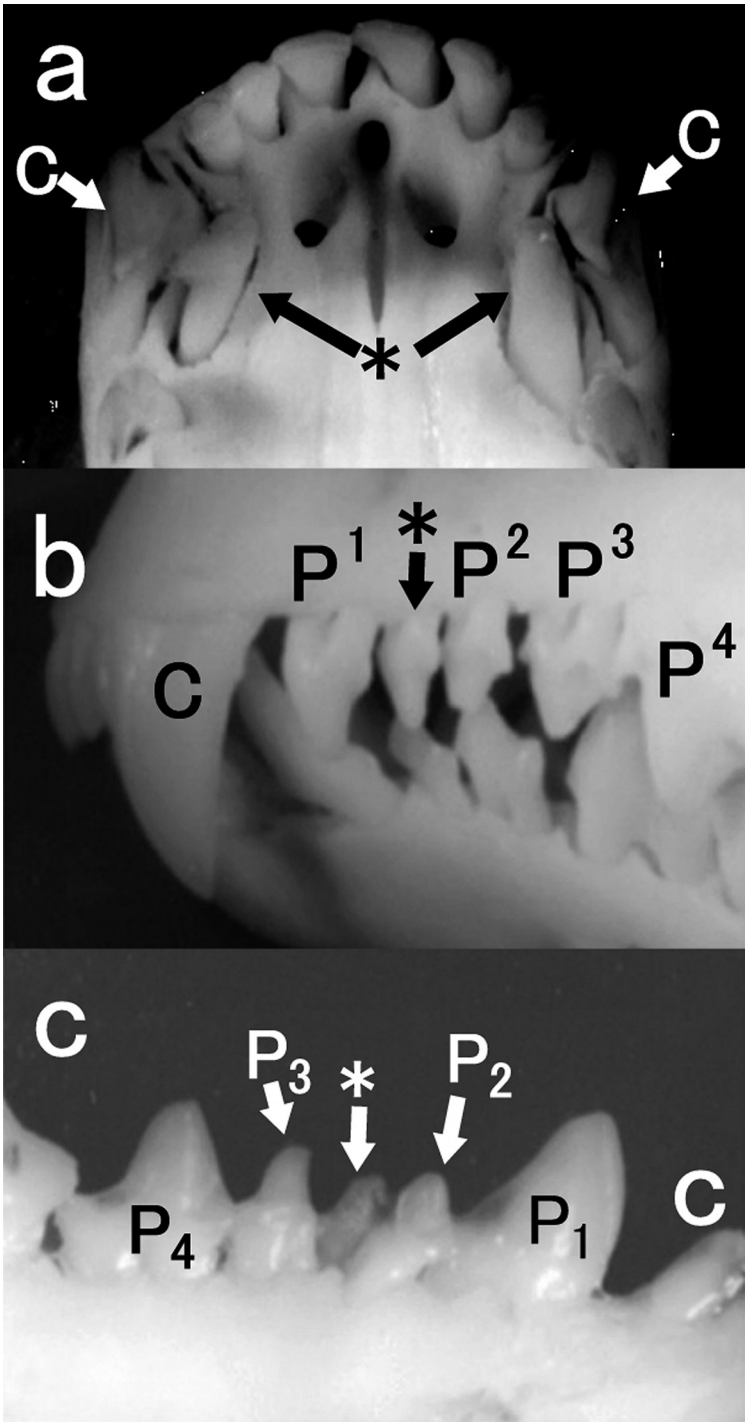

Fig. 2. Three examples of supernumerary teeth (asterisks) in *Mogera wogura*. — a, Symmetrically occurred supernumerary canines in the lingual positions of upper normal canines (# 889); b, supernumerary tooth between left upper first and second premolars (# 486); c, supernumerary tooth between left lower second and third premolars (# 909).

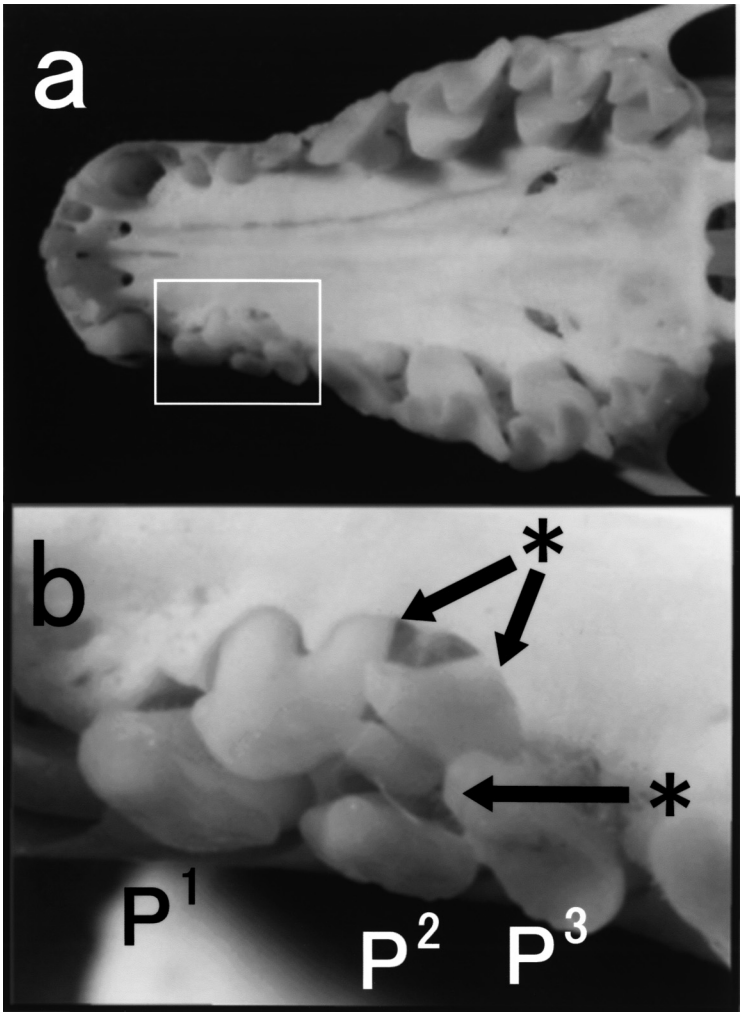

Fig. 3. Three supernumerary teeth erupted in the lingual position of first to third upper premolars (# 967) in *M. wogura*. Inset in 3a was magnified in 3b.

M. wogura varies from the smallest in Kyushu population to the largest in Nagoya Castle population (Koyasu and Oda, 2009). Chugoku and Shikoku populations are middle size of them (Abe, 1967). In our results, missing teeth of *M. wogura* were observed more in western small populations (Kyushu, Hiroshima and Kagawa: 2.83–6.00%) than large eastern population (Aichi: 0.93%) (Table 2). Natori and Shigehara (1997) examined the relationship between palate size and missing teeth of the house musk shrew, *Suncus murinus*, and discussed that upper third premolar frequently missed in small sized population. Although their conclusion was partially denied (Jogahara *et al.*, 2007), on the context of *Mogera* in our report, frequent observation of missing teeth is fit with the decreased size of the jaw in the western populations. This is also in the case on two closely related species from Niigata Prefecture, i.e. small-sized *M. tokudae* had higher percentage of dental anomaly than *M. etigo* (Table 1).

It is generally considered that the position of the absent and supernumerary teeth are centered on the terminal position of cheek teeth (mesial of first premolar and distal of third molar) accord-

Table 4. Frequencies of connate teeth observed in *M. tokudae* and *M. wogura*.

Species	Locality	N	Anormal specimens observed	Teeth examined	P^1	P^4	P_3	P_4	Total
M. tokudae	Sado Isl.	57	1 1.75%	114				1 0.88%	1 0.88%
M. wogura	Aichi	108	2 1.85%	216				2 0.93%	2 0.93%
	Kagawa	460	4 0.87%	920	1 0.11%	1 0.11%	2 0.22%		4 0.43%
Total		1143* 0.87%	7 0.61%	2286*	1 0.04%	1 0.04%	2 0.09%	3 0.13%	7 0.31%

* : Specimen number including all examined localities.

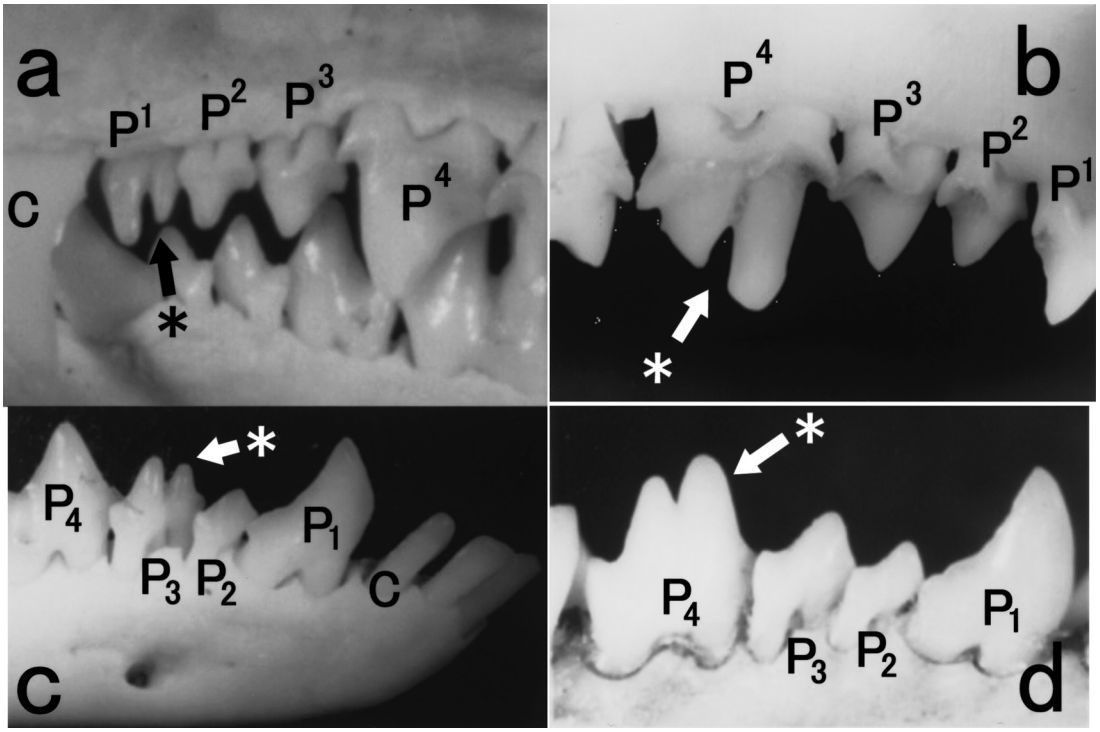

Fig. 4. Four examples of connate teeth observed in *M. wogura*. — a, Upper first premolar (# 896); b, upper fourth premolar (# 822); c, lower third premolar (# 867); d, lower fourth premolar (SIK 0324).

ing to the terminal reduction and addition theory, established by Fujita (1995) and progressed by Koyasu (1993). However, tooth absence on the lower jaw was only observed in second premolar position (19 of total 60 absent teeth, Table 2). This is well explained because lower first premolar is large and functional tooth for the moles to catch their prays. By the way, it is difficult to explain by the terminal reduction theory that losses of upper second premolar (30 of 60) were higher than the first one (11 of 60) (Table 2). Tooth size of upper second premolar is smaller than the first one (Sakai and Hanamura, 1973), thus this tooth may have degenerating trend. Similar results were obtained by other species of moles, genus *Talpa* (Stein, 1962; Yudin, 1989; Kawada *et al.*,

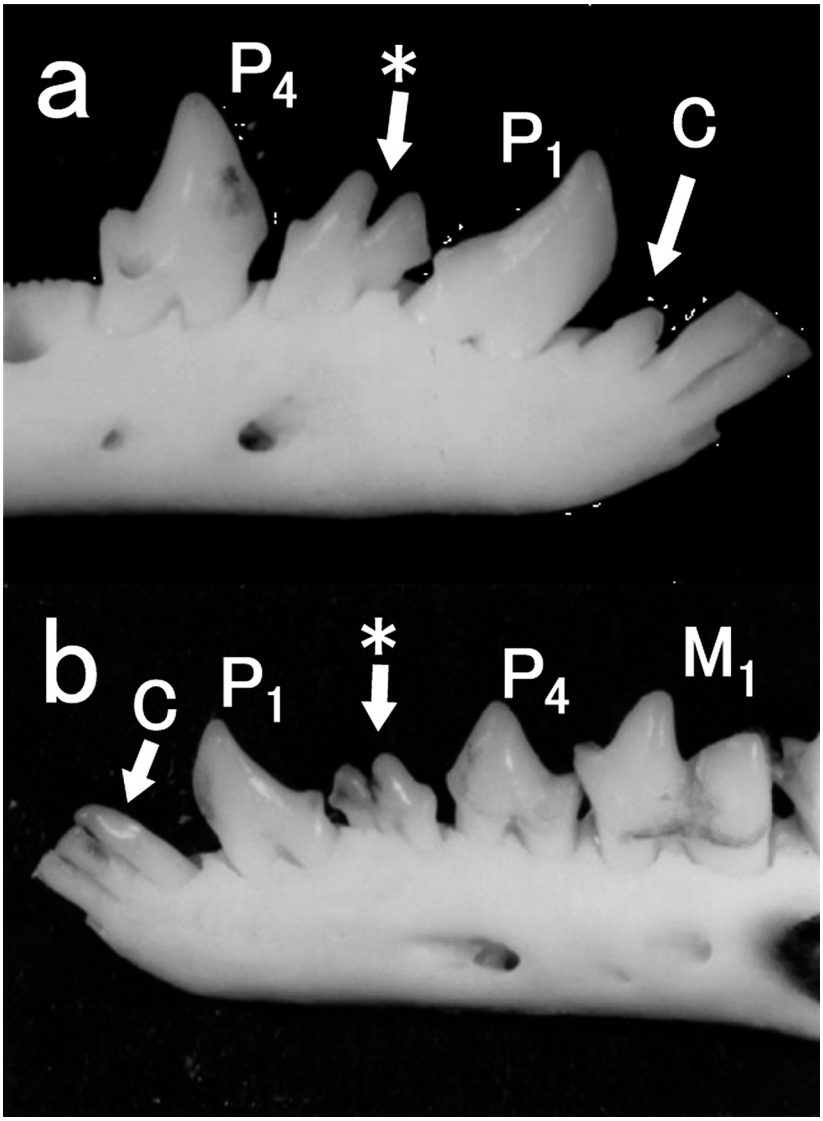

Fig. 5. Two examples of simultaneously occurred absent and connate teeth of *M. wogura* (a, # 894 and b, #934).

2006). Highly specialized dentition of the moles, genus *Parascaptor* and *Scaptochirus*, have the dentition I3/3, C1/1, P3/4, M3/3＝42 and I3/3, C1/1, P3/3, M3/3＝40, respectively (Dobson, 1883; Stroganov, 1948), and they attained the dental reduction on the upper and lower second premolars, sequentially. Moreover, due to the absence of lower incisors and the peglike premolars, tooth number is reduced to 38 in three moles from Tatvan, Turkey, and to 39 (asymmetry) in the type of *Scaptochirus davidianus*, which is now considered as *Talpa davidiana* (see Kryštufek *et al.*, 2001; reviewed in Kawada, 2005). Therefore, we conclude that the mole species have a trend to experience the dental reduction in second premolar positions, as a supportable result from our observation.

Supernumerary teeth were observed only in Kagawa Prefecture, which samples were collected in and around the Sanuki City. Extraordinary high occurrences of dental anomaly in restricted locations were reported in the Augsburg Zoo of

Gernamy (Stein, 1962) and Bryatia District of Russia (Kawada *et al.*, 2006). They were discussed that the dental instability has caused based on the genetic drift and founder effect (Miles and Grigson, 1990). The moles living in the Japanese plains have good habitat in the agricultural farms, e.g. rice field, and such environment should tend to give the moles isolated small population in comparison with the forests, where is the native habitat. These artificial modifications of the environments in history may affect the occurrence of dental anomaly in certain populations. The comparison among more localities is stressed for further evaluation.

Two rare cases of supernumerary teeth were also found in Kagawa specimens. One of them (#889) had a symmetric extra canine tooth located on each lingual side of normal canines (Fig. 2a). In the previous studies considered more than 8,000 specimens of *T. europaea*, no anomaly was found in the canine position (Stein, 1962). Thus this is conspicuously special case of supernumerary teeth in the talpine moles (also see Miyao, 1972). These extra teeth were weak sickle-shaped conical teeth. Another case was found in #967. This specimen possessed three extra teeth in the lingual side of upper first to third premolars (Fig. 3). One of these teeth had the shape resemble to the first premolar, but two were small conical teeth. Sometime milk dentition used to retain in the permanent tooth row, but we can not consider them as milk canines or premolars because their positions were lingual side of normal dentition. These specimens were considered as exceptionally abnormal specimens.

Connate tooth is thought to be formed by the fusion of normal and supernumerary tooth germs (Miles and Grigson, 1990). On the developmental mechanism, connate tooth can be regarded as a form of supernumerary tooth (Kawada *et al.*, 2006). In *T. europaea* and *T. altaica*, this kind of abnormality was frequently observed in upper third and lower fourth premolars (Stein, 1962; Kawada *et al.*, 2006). In *Mogera* species, connate teeth were observed in several positions of premolar rows (Table 4). Three connate lower fourth premolars were possessed by Sado population of *M. tokudae* and Aichi population of *M. wogura*, and it is notable that supernumerary tooth never occurred in these localities. On the other hand, connate upper first and fourth and lower third premolars were all seen in Kagawa Prefecture, where many supernumerary teeth observed (comparative in Table 3 and 4). Especially, connate upper first premolar shown in Fig. 4a is first description in all Talpidae. The supernumerary teeth were also concentrated to this position, so that rare fusion may be occurred at premolar rows.

It is obvious that occurrence of connate teeth is most frequent in lower fourth premolar of moles in previous studies (Stein, 1962; Yudin, 1989; Abe *et al.*,1991; Kawada *et al.*, 2006). It is considered that Kagawa population of *M. wogura* has unique genetic background, because of no connation in lower fourth premolar. Two cases shown in Fig. 5 are further objective to visualize the characteristics of Kagawa population. In these specimens, tooth missing and connation were simultaneously achieved (Fig. 5). The same form was reported in several specimens of *T. altaica* (Yudin, 1989; Kawada *et al.*, 2006). These cases could be also regarded as the fusion of two normal premolars.

The developmental mechanism of supernumerary teeth is questionable. In our results, most of the supernumerary teeth were observed at the position of the upper first premolar (12 of total 19 teeth). These teeth had their shape similar to normal first premolar, and are considered as the duplications of normal tooth. These features are not able to explained by Wolsan's (1984) atavism hypothesis, which the supernumerary teeth occurred as a reformation of the ancestral character. It is most probable that the splitting of the tooth germ had occurred in the early developmental stages of these specimens. Such process is considered to be under the genetic control, and because all supernumerary teeth were confined to Kagawa Prefecture, it suggests again that this population was heavily affected by the genetic drift (Miles and Grigson, 1990) as an

additional finding to Stein (1962) for *T. europaea* and Yudin (1989) for *T. altaica*.

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