Crown Structure of the Maxillary Molars in the Japanese Shrew Mole, *Urotrichus talpoides* (Insectivora, Talpidae)

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Summary: The maxillary first and second molars (M^1 and M^2) in the Japanese shrew mole, *Urotrichus talpoides*, were investigated using an odontometrical approach. The mesiodistal crown diameter was larger in M^1 than in M^2 , while the buccolingual diameter of M^1 was nearly equal to that of M^2 . M^2 was more compressed mesiodistally than M^1 . M^1 had a large distal triangle on the styler shelf. The mesial triangle of M^2 was slightly larger than the distal triangle. Despite being smaller than M^1 , M^2 was less variable than M^1 in terms of size. The distal triangle of M^1 and the mesial triangle of M^2 were well developed, and thus this area, which corresponds to the inflection point of the maxillary dental arch, was most likely the center of an occlusal function.

The Japanese shrew mole (*Urotrichus talpoides*) is an insectivora that is native to Japan. The maxillary molars display a dilambdodont pattern when viewed from an occlusal surface. In other words, the paracone, metacone, and the three styler cusps (buccal styles) are connected by a W-shaped crista (ectoloph), which forms the buccal styler shelf. This shelf is divided into two parts: the mesial and distal triangles. The shape of these triangles is species-specific, and depends on the molar type (Sakai and Hanamura, 1969, 1973). Therefore, the structure of the dilambdodont molar can be used to express the quantitative changes in these triangles. The present study investigated the differences in the maxillary first and second molars (M^1 and M^2) in *Urotrichus talpoides* using an odontometrical approach. Special attention was paid to the structure of the triangles on the buccal styler shelf.

Materials and Methods

Seventy skulls of *Urotrichus talpoides* housed at the Second Department of Anatomy, School of Dentistry, Aichi-Gakuin University were measured

using a measure scope (Nikon, Japan), calibrated to 0.001 mm. These materials were selected under the condition that wear was not visible under a stereo microscope. The crown dimensions measured (Fig. 1) were the buccal and lingual mesiodistal diameters (BMD and LMD), the mesial and distal buccolingual diameters (MBL and DBL), the dimensions of the triangles on the styler shelf (mesiobuccal mesiodistal diameter, MBMD; mesio-buccal buccolingual diameter, MBBL; distobuccal mesiodistal diameter, DBMD; distobuccal buccolingual diameter, DBBL), and the buccolingual diameter of the protocone (MLBL). The standard used for measurements obtained outside the crown (BMD, LMD, MBL and DBL) was that of Hanamura *et al.* (1990).

The crown area were calculated as follows:

$$\text{Crown area (CrA)} = \frac{\text{BMD} + \text{LMD}}{2} \times \frac{\text{MBL} + \text{DBL}}{2}$$

$$\text{Area of the protocone (PrA)} = \text{LMD} \times \text{MLBL}$$

Area of the triangles on the styler shelf:

$$\text{Mesial triangle area (MtriA)} = \frac{\text{MBMD} \times \text{MBBL}}{2}$$

Fig. 1. Measurement of crown dimensions on the maxillary molars in *Urotrichus talpoides*.

Mesiodistal diameters

BMD: buccal mesiodistal diameter

LMD: lingual mesiodistal diameter

MBMD: mesiobuccal mesiodistal diameter

DBMD: distobuccal mesiodistal diameter

Buccolingual diameters

MBL: mesial buccolingual diameter

DBL: distal buccolingual diameter

MBBL: mesiobuccal buccolingual diameter

DBBL: distobuccal buccolingual diameter

MLBL: mesiolingual buccolingual diameter

$$\text{Distal triangle area (DtriA)} = \frac{\text{DBMD} \times \text{DBBL}}{2}$$

The crown indices were calculated as follows:

$$\text{Crown index (Cr index)} = \frac{\text{BL}}{\text{MD}} \times 100$$

For MD and BL, the largest diameters for each direction are used: MD is the BMD, and BL is the larger of MBL and DBL.

Mesiodistal diameter index (MD index)

$$= \frac{\text{LMD}}{\text{BMD}} \times 100$$

Buccolingual diameter index (BL index)

$$= \frac{\text{DBL}}{\text{MBL}} \times 100$$

The crown area indices were calculated as follows:

$$\text{Protocone are index (PrA index)} = \frac{\text{PrA}}{\text{CrA}} \times 100$$

$$\text{Mesial triangle index (MtriA index)} = \frac{\text{MtriA}}{\text{CrA}} \times 100$$

$$\text{Distal triangle index (DtriA index)} = \frac{\text{DtriA}}{\text{CrA}} \times 100$$

Individual relationships within the molar series were observed, and the size reduction of molar teeth was analyzed quantitatively according to the reduction index described by Fujita (1950). This index represents the size of the more reduced tooth (M^2) relative to less reduced tooth (M^1) as a percent. The molar size sequence (MSS) was determined for each crown dimension. When the reduction index of M^2 was less than 1%, the MSS was $M^1 = M^2$ for the purposes of calculation (Kondo *et al.*, 1994).

Preliminary results revealed that molar size displayed no significant sexual dimorphism. In addition, for half the samples, the sexuality was obscure. For these reasons the data for both sexes were combined.

Descriptive statistical analysis, including distribution parameters was performed using JMP statistical software (SAS Institute Inc., Ver. 3.1.6) on a personal computer. Differences between measurements were analyzed using the student's t-test when the distribution was normal, and a nonparametric test (Wilcoxon's signed-rank test) for the remaining

cases. Statistical significance was established at the $P < 0.05$ or $P < 0.01$ level.

Results

Figure 2 shows an SEM micrograph of the max-

illary molars from an occlusal view. Tables 1, 2 and 3 show the results of basic statistical analysis of crown dimensions and indices. Table 4 shows the reduction indices, and Table 5 shows the MSS in the crown dimensions.

Although M^1 was larger than M^2 for most of the crown dimensions, the MBBL, LMD and MBL were

Fig. 2. SEM micrograph of maxillary molars from an occlusal view in *Urotrichus talpoides*.

Table 1. Basic statistics of crown dimensions, and results of a t-test between M^1 and M^2 (mm)

	M^1				M^2				t-test
	N	mean	SD	CV	N	mean	SD	CV	
BMD	67	2.099	0.109	5.195	68	1.829	0.079	4.334	★
LMD	67	1.213	0.063	5.160	68	1.287	0.070	5.412	★
MBL	67	1.827	0.086	4.717	68	1.898	0.085	4.454	★
DBL	67	1.935	0.126	6.511	68	1.497	0.075	5.033	★
MBMD	67	0.992	0.071	7.190	68	0.970	0.051	5.230	☆
MBBL	67	1.059	0.080	7.600	68	1.232	0.065	5.267	★
DBMD	67	1.140	0.085	7.419	68	0.866	0.054	6.287	★
DBBL	67	1.517	0.093	6.162	68	1.155	0.072	6.231	★
MLBL	67	0.757	0.047	6.160	68	0.676	0.052	7.651	★

★: $P < 0.01$, ☆: $P < 0.05$

Table 2. Basic statistics of crown areas, and results of a t-test between M^1 and M^2 (mm²)

	M^1				M^2				t-test
	N	mean	SD	CV	N	mean	SD	CV	
CrA	67	3.115	0.214	6.883	68	2.646	0.168	6.332	★
PrA	67	0.918	0.084	9.159	68	0.870	0.082	9.399	★
MtriA	67	0.525	0.057	10.843	68	0.598	0.052	8.624	★
DtriA	67	0.864	0.075	8.729	68	0.500	0.049	9.790	★

★: $P < 0.01$

Table 3. Basic statistics of crown indices, and results of Wilcoxon-test between M¹ and M² (%)

	M ¹			M ²			Wilcoxon-test
	N	mean	SD	N	mean	SD	
Cr index	67	92.49	8.18	68	103.90	5.86	★
MD index	67	57.89	3.56	68	70.45	4.11	★
BL index	67	105.96	5.77	68	78.96	3.87	★
PrA index	67	29.51	2.20	68	32.88	2.48	★
MtriA index	67	16.86	1.28	68	22.62	1.62	★
DtriA index	67	27.76	1.80	68	18.90	1.33	★

★: P < 0.01

significantly larger in M² than in M¹ (P < 0.01) and the reduction index of MBBL was the largest of all dimensions (116.72%). The smallest difference between M¹ and M² was noted in the MBMD. The reduction index was 98.27%, and the MSS showed that M¹ > M² in 48.48% of cases, while M¹ < M² in 34.85%. With respect to crown area, the MtriA was larger in M² than in M¹. The other areas were larger in M¹ than in M². In particular, the DtriA

was small in M², and the reduction index was 57.94%.

The crown proportion was compared using the crown indices. The crown index was significantly larger in M² than in M¹ (P < 0.01). The BL of M² was larger than that of M¹. The MD index was larger in M² than in M¹, while the BL index was larger in M¹ than in M². Therefore, the mesial and lingual parts of M¹ were less developed than those of M². The crown area indices showed the PrA was larger in M² than in M¹. The MtriA index was also larger in M² than in M¹, while the DtriA index was larger in M¹. These results again demonstrated that the mesial part of M¹ was less developed than that of M².

Comparison of the coefficients of variation (CV) showed that M¹ varied more than M² in size with the exception of the protocone size (LMD, MLBL). In particular, the variability of the region on the stylar shelf in M¹ were large.

Figure 3 shows a schematic representation of the crown in the molars. The MD was larger in M¹ than in M², while the BL of M¹ was nearly equal to that of M². M² was more compressed mesiodistally than M¹. As for the triangles on the stylar shelf, M¹ had a large distal triangle. M² had a slightly larger mesial triangle than the distal triangle.

Table 4. Reduction indices of the crown dimensions in M² (%)

	N	mean	SD
BMD	66	87.40	5.59
LMD	66	106.28	8.03
MBL	66	103.74	4.85
DBL	66	77.26	4.56
MBMD	66	98.27	8.50
MBBL	66	116.72	10.27
DBMD	66	76.21	7.12
DBBL	66	76.09	5.54
MLBL	66	89.20	7.26
CrA	66	84.87	5.61
MtriA	66	114.77	14.66
DtriA	66	57.94	6.40
PrA	66	94.79	10.28

Table 5. Molar Size Sequences (MSS) in the crown dimensions

	M ¹ > M ²		M ¹ = M ²		M ¹ < M ²	
	N	%	N	%	N	%
BMD	64	96.97	2	3.03	0	0.00
LMD	10	15.15	5	7.58	51	77.27
MBL	8	12.12	12	18.18	46	69.70
DBL	66	100.00	0	0.00	0	0.00
MBMD	32	48.48	11	16.67	23	34.85
MBBL	1	1.52	2	3.03	63	95.45
DBMD	66	100.00	0	0.00	0	0.00
DBBL	66	100.00	0	0.00	0	0.00
MLBL	59	89.39	3	4.55	4	6.06

Fig. 3. Schematic representation of maxillary molars in *Urotrichus talpoides*.

Discussion

Although many descriptive studies of dilambdodont molars have been published, little is known about their quantitative structure. The dentition of Talpidae has been described in detail by Sakai and Hanamura (1973). M^1 has a well developed distobuccal region, but a poorly developed mesio-buccal region. M^2 differs from M^1 in the poor development of the distobuccal region, and M^2 is more reduced mesiodistally. Sakai (1981) has reported the statistics of molar size and crown indices in *Urotrichus talpoides*. Although the method he used to measure molar dimensions differed from ours, and thus his results cannot be directly compared to ours, his finding that M^1 was larger mesiodistally than M^2 , and smaller buccolingually, agreed with the results of the present study.

An odontometrical study of dilambdodont molars has been performed in other species, such as, *Suncus murinus* (Soricidae) (Hanamura *et al.*, 1990) and *Tupaia glis* (Scandentia) (Kondo *et al.*, 1994). In both species M^1 has a larger MD than M^2 , while M^2 has a larger BL than M^1 . M^1 has a larger DBL than MBL, and M^2 has a larger MBL than DBL. These findings are also in agreement with those of the present study. It is likely that M^2 is compressed mesiodistally, but prolonged buccolingually in comparison with M^1 . The mesiobuccal region of M^1 is less developed than M^2 .

These structures in the dilambdodont molars

seem to be closely related to the proportional differences between the mesial and distal triangles on the styler shelf. In the present study the MtriA was larger in M^2 than in M^1 , while the DtriA was larger in M^1 than in M^2 . M^2 had the slightly larger mesial triangle than distal one, but the difference between the two triangles was smaller in M^2 than in M^1 . These proportional differences between M^1 and M^2 are in agreement with those found for *Suncus murinus* and *Tupaia glis* above.

Sakai (1981), analyzing regional differences in *Urotrichus*, concluded that the least size variability was found in M^2 , which agrees with the results of the present study. Similar findings in *Tupaia* have been reported by Kondo *et al.* (1994), and in Indriidae (Primates) by Gingerich and Ryan (1979). An association between early formation and low morphological variability in M^1 was noted by Gingerich (1974). In the case of *Urotrichus*, *Tupaia* and Indriidae, M^2 is less variable than M^1 despite developing later, and thus the ontogenetic explanation is not always accurate. Another hypothesis has proposed that variability is related to occlusal complexity (Gingerich and Schoeninger, 1979).

Kondo *et al.* (1994) concluded that the occlusal function in the molar field concentrated at the inflection point of the maxillary dental arch in *Tupaia*. The maxillary arch curve is pear shaped in *Tupaia*. The arch width generally increases from I^1 to M^1 , and decreases from M^2 to M^3 . The inflection point of the arch curve corresponds to the area

between the distal half of M^1 and the mesial half of M^2 . In this area the molars are well-developed buccolingually. This configuration was also found in *Urotrichus*. Because the distal triangle of M^1 and the mesial triangle of M^2 are well developed, this area is most likely the center of an occlusal function. The variability of crown dimensions did not differ greatly within M^2 , while the dimensions of the stylar shelf were clearly variable in M^1 . Although large, the distal triangle of M^1 was not stable. The protocone region was less variable in M^1 . The protocone is closely related to opposition, whereas the ectoloph is related to the shearing in an occlusion. Thus, the functional structure of M^1 appears to differ from that of M^2 . The crown shape of M^2 seems to indicate an occlusal function due to the stability of M^2 . Therefore, M^2 has a stable crown structure despite its size small.

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