

Morphology of Deciduous Canines in Asian Apes



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Abstract

The aim of this study was to determine the morphology and sexual dimorphism of the deciduous canines of Asian apes (*Hylobates lar* and *Pongo pygmaeus*). The lingual view of the maxillary deciduous canines of gibbons showed a triangular pyramidal shape with a strong mesiodistal symmetry. The center of the crown had a median lingual ridge. This feature differed from that of the other great apes. In the mandible, the crown was distorted to a square shape having the heel-like protrusion of the distal crown base. The maxillary deciduous canines of the orangutan were roughly pyramidal lingually. The lingual ridge was a thick, broad ridge. It ran from the crown apex along the mesial groove to just before the cervical ridge. The mandibular canines had a distorted square shape due to the heel-like protrusion of the distal crown base. Characteristic of the deciduous teeth was that the ridges were highly expanded and very well developed. Sex differences in tooth size were not significant for gibbons, but were significant for orangutans.

Keywords: Deciduous canine; Crown morphology; Tooth size; Sexual dimorphism; Asian apes

Introduction

The divergence of Old World monkeys (Cercopithecoidea) and apes (Hominoidea) is thought to have occurred during the Oligocene [1]. The two extant apes in Asia are the small ape, the gibbon, and the great ape, the orangutan. Their origins are thought to be older than those of African apes, with gibbons and orangutans diverging from the hominoid group between 16 and 20 million years ago, with gibbons diverging before orangutans [2]. Asian apes are a lineage that followed its own evolutionary path and is considered primitive [2,3].

The most striking feature of the gibbon dentition, which distinguishes them from other hominids except humans, is the lack of sexual dimorphism in canine size and shape [4]. The majority of canine studies have focused on size in relation to sexual dimorphism and fewer studies have examined morphology in detail [5-11]. This is due to the prejudice that canines have a single, conical morphology and have been less variable than other teeth, resulting in little attention being paid to canine morphology in anthropoids [4, 12-14].

Recently, sexual dimorphism was found to occur not only in size, but also in morphology and surface relief in bonobo canines [12] and significant sexual differences in shape and size were

found in gibbon canines, which were previously thought to have little sexual dimorphism [13]. There have been several reports on the deciduous teeth of great apes [1,6,15,16]. However, few have described the morphology of the canines in detail, and there have been no reports on the morphology and the size of the deciduous canines of the Asian apes. This study focused on the morphology and size of the deciduous canines of Asian gibbons (*Hylobates lar*) and orangutans (*Pongo pygmaeus*), with the aim of comparing interspecific differences and sexual dimorphism between the two species.

Materials and Methods

The materials consist of deciduous canines obtained from bleached skulls of gibbons and orangutans from the collections of the Research Centre for Human Behaviour and Evolution, Kyoto University; the Laboratory of Physical Anthropology, Kyoto University; the Museum Zoologicum Bogoriense, Bogor; and the Japan Monkey Centre. The deciduous canines selected for study were fully erupted from the alveolus. Impressions of the deciduous canines were taken with silicone impression material (Provil: Heraeus Kulzer GmbH) and hard plaster casts were made. Photographs were taken from the occlusal view, with the crown axis aligned with the optical axis of the camera, and from

the lingual view, with the crown axis perpendicular to the optical axis of the camera. Tooth sizes (mesiodistal and labiolingual diameters) were measured on the model using digital calipers (1/100 mm, Digimatic: Mitutoyo Co.).

The maxillary deciduous canines were measured according to previous methods [4,6,8,17]. The mandibular deciduous canines were measured using the following method, as they were found to be slightly rotated [17]. The mesiodistal diameter (MD) of the crown was recorded as the distance between the most prominent points of the mesial and distal parts of the crown on a line drawn perpendicular to the mesiodistal axis of the crown as viewed from the occlusal plane. This method is the same as the previous method [16]. The labiolingual diameter (LL) was the distance measured perpendicular to the mesiodistal diameter. Crown area (MD×LL) and crown index (LL/MD×100) were calculated from the measurements. The percentage of sex dimorphism in crown measurements was calculated using the formula [(male mean - female mean) / female mean × 100] [18-21]. Student's t-test ($P < 0.05$, $P < 0.01$) was used to assess the significance of differences

in means.

Results

Maxilla

The maxillary and mandibular deciduous canines of a male and a female gibbons (*Hylobates lar*) are shown in Figures 1 and 2. Occlusally, the male contour was elliptical and highly labiolingually symmetrical. The lingual view showed a pyramidal triangle and was mesiodistally symmetrical. The mesial and distal shoulders were approximately 1/4 of the crown height from the cervical line. The median lingual ridge was well developed and was a broad, thick ridge that descended vertically from the cusp tip in the center of the crown, bisecting the lingual fossa mesially and distally, and merging with the cervical ridge to form a tubercular bulge. The groove running mesial to the median lingual ridge was moderately deep and interrupted by the mesial marginal ridge. The distolingual fossa was wider and deeper than the mesial one. The cervical ridge was broad and highly inflated at the tubercular bulge.

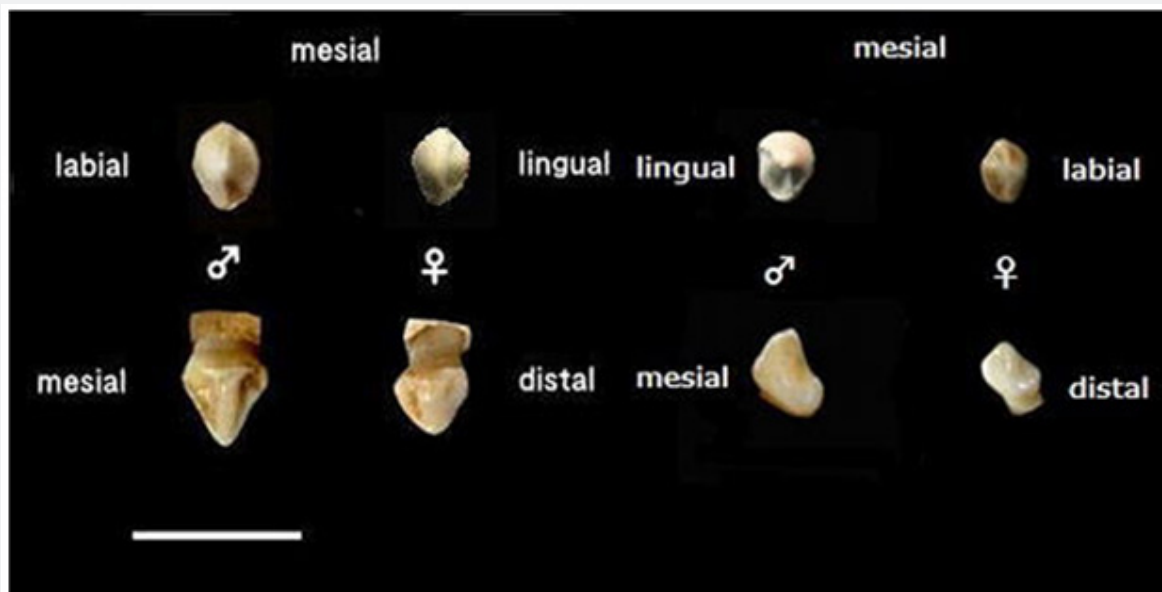


Figure 1: View of occlusal and lingual aspects of deciduous canines of a male (no. 532) and a female (no. 4706) gibbons. Left is maxilla and right is mandible. Scale 10 mm.

The crown morphology of the females was distorted triangular and the symmetry was weaker than that of the males. The female was characterized by a slightly smaller crown size, a more rounded tooth surface than the male, a more distally inclined crown, and a cervical ridge that more sloped from mesial to distal toward the root. The mesial shoulder was approximately 1/4 of the crown height from the cervical line. The cervical ridge was well developed and highly swollen. These characteristics varied slightly among individuals.

Mandible

When viewed occlusally, the male had an ellipsoid shape. Its mesiolabial margin was highly convex and its lingual margin was loosely convex. Lingually, the males had a distorted square shape having a heel-like protrusion of the distal crown base and were long mesiodistally. The mesial crest was straight and the distal crest was loosely concave. The mesial shoulder was approximately 1/2 of the crown height from the cervical line and the distal

shoulder was 1/3. The lingual ridge was a broad, rounded ridge running obliquely downward from the tip, joining the cervical ridge at its base. The distolingual groove running between this ridge and the distal crest was deep and ended in the distolingual fovea. The cervical ridge was broad and strongly inflated, running downward from the mesial shoulder, then turning and rising in a V-shape to the distal shoulder.

Females were morphologically similar to males. Characteristic features of females were that the tooth surfaces were rounder than those of males, the mesial shoulder was approximately 2/3 of the crown height from the cervical line and the distal shoulder was 1/3 of the crown height, and the height of tooth apex was lower than in males.

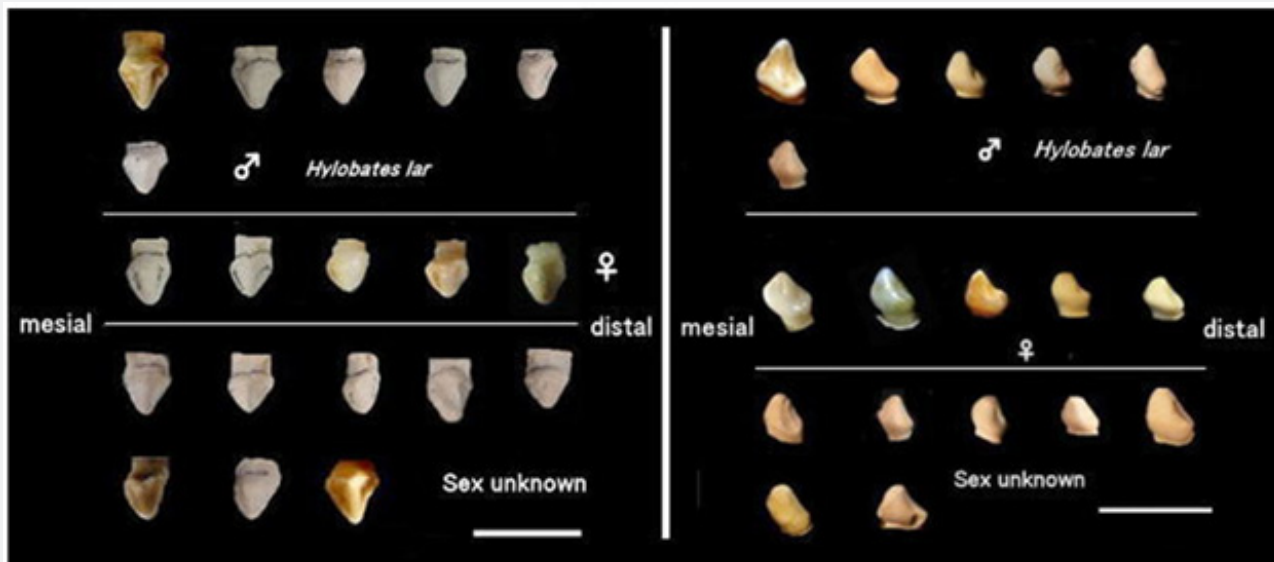


Figure 2: View of lingual aspects of deciduous canines of males, females, and sex unknown of gibbons. Left is maxilla and right is mandible. Scale 10 mm.

Maxilla

The occlusal surface of male orangutans (*Pongo pygmaeus*) was elliptical, with a strongly convex labial margin and a straight lingual margin. The lingual aspect was roughly pyramidal with the distal base protruding outward. The cusp tip was located mesially. The mesial and distal cristae were straight. The mesial groove was interrupted by the mesial marginal ridge and then continued along the inner side of this ridge. The mesial shoulder was located apical to more than 1/3 of the crown height and the distal shoulder was 1/5 of the crown height. The lingual ridge was a thick, broad ridge. It ran from the crown apex along the mesial groove to just before the cervical ridge. The central groove crossed and bisected the cervical ridge. The distolingual fossa was wide. The cervical ridge was well developed, thick and rounded. The cervical line was concave towards the root.

The female crown was similar in outline to the male. The differences were that the females were smaller, the cervical ridge was not as strongly developed as in the males, and the crown surface phenology was softer and more rounded. The mesial and distal shoulders were located approximately 1/5 of the height of the crown (Figure 3).

Mandible

The occlusal view of the mandibular deciduous canines in males was elliptical. The labial margin of the mesial half was strongly convex. The lingual view was longitudinally distorted square with the heel-like protrusion of the distal crown base. The mesial crest was straight and the distal crest was slightly concave. The mesial shoulder was at 1/2 to 2/3 of the crown height and the distal shoulder was at 1/3 to 1/4 of the crown height. The mesial groove was shallow and was interrupted by the mesial marginal ridge and then flowed down distally along this ridge. The lingual ridge was a thick, rounded ridge that descended distally from the apex to the cervical ridge. The groove between this ridge and the distal crest formed a deeply depressed distolingual fossa. The cervical ridges of both sexes were broad and strongly inflated, running obliquely downward from the base of the mesial shoulder to the lowest part of the marginal ridge, then turning and rising in a V-shape to the base of the distal shoulder.

The contour of the female crown was similar to that of the male. The difference was that the female crown was smaller and the phenology of the crown surface was slightly rounded. The mesial shoulder was located at approximately 3/5 of the crown height and the distal shoulder at 1/4. Both gibbons and orangutans

showed individual variation in the morphology of their maxillary and mandibular canines, but the approximate shape of the crown,

the position of the shoulder and the degree of development of the cervical ridge were stable (Figures 2 and 4).

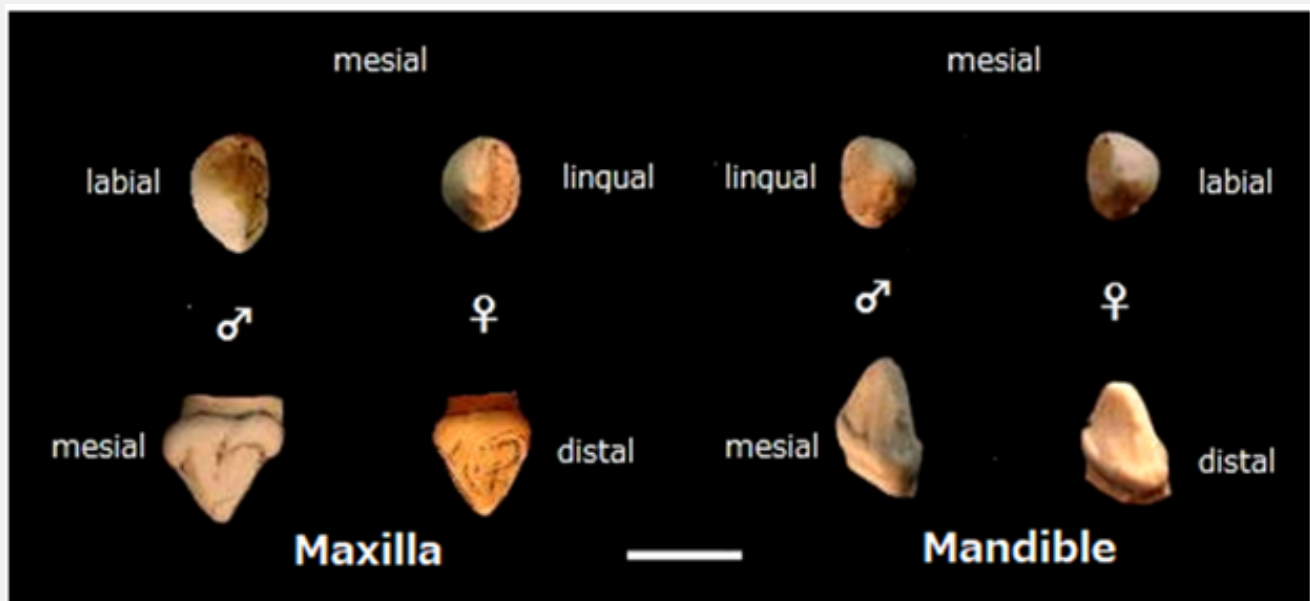


Figure 3: View of occlusal and lingual aspects of deciduous canines of a male (No. 6648) and a female (No. 6658) orangutans. Left is maxilla and right is mandible. Scale 10 mm.

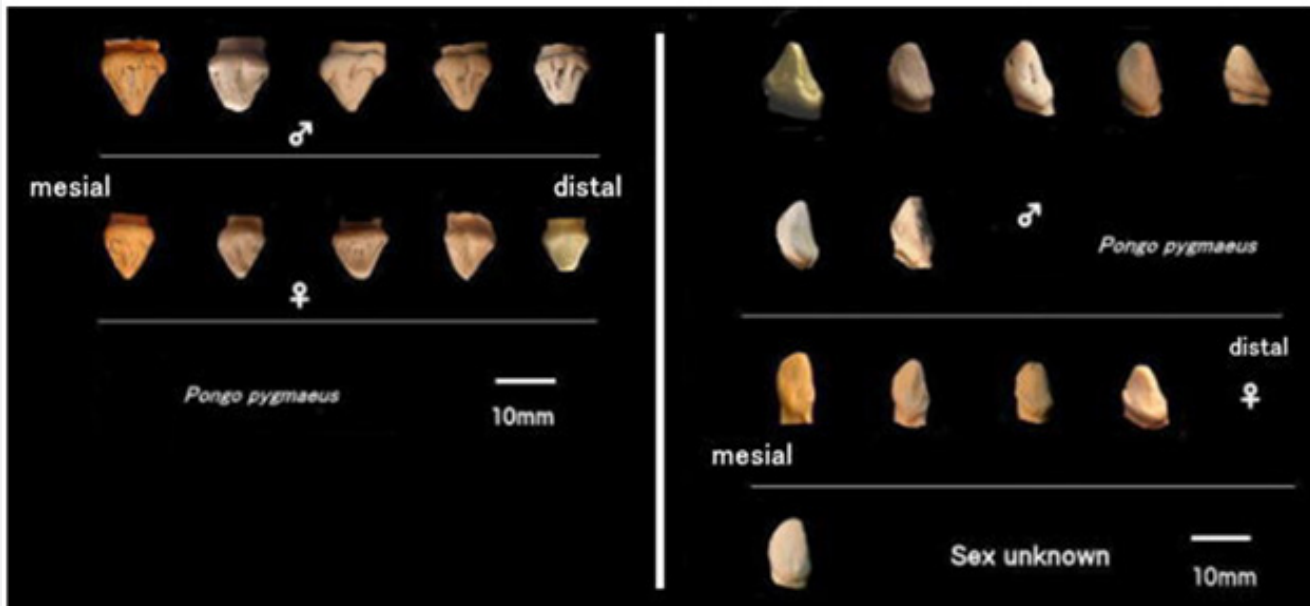


Figure 4: View of lingual aspects of deciduous canines of males, females, and sex unknown of orangutans. Left is maxilla and right is mandible. Scale 10 mm.

Numerical analysis

Table 1 shows the results of basic statistics for the mesiodistal crown diameter; labiolingual diameter; crown area and crown index of the maxillary and mandibular deciduous canines of male

and female gibbons. In both sexes, the maxilla showed higher values than the mandible for mesiodistal and labiolingual crown diameters, and crown area. However, the crown index was higher in the mandible.

Table 2 shows the percentage sex dimorphism and t-values of maxillary and mandibular deciduous canines in gibbons. Sex differences tended to be more pronounced in labiolingual diameter than in mesiodistal diameter, and in mandible than in maxilla. However, there were no significant sex differences in the mean values for any of the items (Table 2).

Table 3 shows the basic statistics for the orangutan maxilla and mandible. For both sexes, the maxilla had higher values than the mandible for mesiodistal crown diameter, labiolingual

diameter and crown area. However, the crown index was higher in the mandible.

Table 4 shows the results of significance tests of mean differences for orangutans. The percentages of sex differences were significantly greater for males for mesiodistal and labiolingual diameters and crown area in both jaws of the deciduous canines. However, there were no significant sex differences for the crown index.

Table 1: Basic statistics of male and female maxillary and mandibular deciduous canines in gibbons.

	Measurement	Male	Female	Sex unknown	Sex combined
Maxilla	Mesiodistal d	4.31 (0.44, 6)	4.27 (0.20, 6)	4.75 (0.24, 9)	4.49 (0.37, 21)
	Labiolingual d	3.39 (0.33, 6)	3.32 (0.15, 6)	3.51 (0.22, 9)	3.42 (0.24, 21)
	Crown area	14.71 (2.85, 6)	14.18 (1.10, 6)	16.67 (1.45, 9)	15.39 (2.12, 21)
	Crown index	78.72 (3.98, 6)	77.64 (3.73, 6)	73.99 (5.24, 9)	76.43 (4.93, 21)
Mandible	Mesiodistal d	3.64 (0.50, 6)	3.54 (0.14, 5)	3.82 (0.55, 7)	3.68 (0.44, 18)
	Labiolingual d	2.91 (0.29, 6)	2.82 (0.20, 5)	3.05 (0.38, 7)	2.94 (0.31, 18)
	Crown area	10.71 (2.51, 6)	10.00 (0.72, 5)	11.79 (3.04, 7)	10.93 (2.41, 18)
	Crown index	80.46 (4.75, 6)	79.80 (6.72, 5)	80.22 (6.39, 7)	80.19 (5.63, 18)

Means (standard deviation, number of samples).

Table 2: Significance tests for sex differences in gibbons.

		% sexual dimorphism	t value (df)	Significant test
Maxilla	Mesiodistal d.	0.98%	0.1953(10)	ns
	Labiolingual d.	2.06%	0.4965(10)	ns
	Crown area	3.76%	0.4305(10)	ns
	Crown index	1.39%	0.4820(10)	ns
Mandible	Mesiodistal d.	2.66%	0.4093(9)	ns
	Labiolingual d.	3.16%	0.5905(9)	ns
	Crown area	7.03%	0.6018(9)	ns
	Crown index	0.82%	0.1898(9)	ns

df: degree of freedom, ns: not significant

Table 3: Basic statistics of male and female maxillary and mandibular deciduous canines in orangutans.

	Measurement	Male	Female	Sex unknown	Sex combined
Maxilla	Mesiodistal d.	10.68 (0.57, 6)	8.49 (0.69, 5)		9.68 (1.29, 11)
	Labiolingual d.	7.76 (0.63, 6)	6.79 (0.71, 5)		7.32 (0.81, 11)
	Crown area	82.98 (9.56, 6)	57.81 (8.83, 5)		71.54 (15.80, 11)
	Crown index	72.70 (5.01, 6)	80.20 (8.32, 5)		76.11 (7.45, 11)
Mandible	Mesiodistal	8.14 (0.64, 7)	7.09 (0.53, 7)	9.03 (0.31, 3)	7.87 (0.93, 17)
	Labiolingual	7.11 (0.50, 7)	6.41 (0.42, 7)	7.14 (0.14, 3)	6.83 (0.55, 17)
	Crown area	58.15 (8.15, 7)	45.52 (5.48, 7)	79.04 (4.45, 3)	54.11 (9.85, 17)
	Crown index	87.46 (3.88, 7)	90.62 (6.19, 7)	64.72 (1.02, 3)	87.28 (6.72, 17)

Means (standard deviation, number of samples).

Table 4: Significance tests for sex differences in orangutans.

	Maxilla	% of sexual dimorphism	t value (d.f.)	Significant test
Maxilla	Mesiodistal d.	25.82%	5.6567 (9)	**
	Labiolingual d.	14.25%	2.3747 (9)	*
	Crown area	43.54%	4.5351 (9)	**
	Crown index	-9.35%	-1.7641 (9)	ns
Mandible	Mesiodistal	14.89%	3.3638 (12)	**
	Labiolingual	11.01%	2.8659 (12)	*
	Crown area	27.75%	3.4020 (12)	**
	Crown index	-3.49%	-1.1461 (12)	ns

df: degree of freedom, ns; not significant, *: $P < 0.05$, **: $P < 0.01$

Discussion

Deciduous teeth are more conserved than permanent teeth, and primitive features tend to remain in deciduous teeth when they are not found in permanent teeth [22-24]. In addition, there is little sex difference in the size of deciduous teeth compared to permanent teeth [25]. Few studies have been conducted on the deciduous teeth of great apes due to difficulties in sex determination and small numbers of individuals [1,6,15,16]. According to Smith et al. [26], who studied the timing of primary tooth development in great apes, most primates, including gibbons, have teeth at birth and almost all primary teeth erupt within two weeks of birth. Only great apes and humans do not develop teeth until after one month of age. Gorillas and chimpanzees begin to erupt at about 1.5 and 3 months of age, respectively, and take about 1 year to complete eruption. Orangutans erupt relatively late, at about 4 months of age, and take about 1 year to complete their dentition. Only humans take the longest (over 7 months) from birth to eruption of the first tooth, with the primary dentition taking 2-3 years to complete.

There are differences in the life histories of great apes and humans: great apes wean later, reproduce earlier, and have longer birth intervals, whereas humans wean earlier, have longer juveniles, later first reproduction, shorter birth intervals, and longer lifespans [27].

The morphology of canines in gibbons and orangutans

The crown shape in the lingual view of maxillary canines of the gibbon was similar to that of other great apes, with the crown of males forming a pyramidal triangle. Females had an essentially similar shape, but the crown tended to slope distally. In contrast, the morphological anatomy of the lingual surface differed considerably from that of the deciduous canines of other great apes.

The most striking features of the maxillary deciduous canines were the position and orientation of the lingual ridge. The lingual ridge of the canines and deciduous canines of the great apes runs

from the apex of the crown to the marginal ridge along the mesial groove [12-14]. In the deciduous canines of gibbons, however, it descends from the apex down the middle of the crown to join the cervical ridge, with a nodular bulge at the confluence. Ward et al. [28] referred to this ridge as the median lingual ridge. In this study, this ridge is referred to as the median lingual ridge or central ridge, which is restricted to the maxillary deciduous canines of gibbons. This feature was found only in gibbons and not in great apes.

The deciduous teeth of orangutans had a morphology similar to that of other great apes [16]. The characteristic feature was that the ridges were highly expanded and very well developed. This tendency was particularly pronounced in males. In the lingual view of the mandibular canines, both gibbons and orangutans resembled the mandibular canine morphology of other great apes [16], with a distorted square crown outline. However, in gibbons, the position of the mesial shoulder was more toward the apex, and the angle of the mesial shoulder was more right-angled or acute. In the permanent and deciduous canines of great apes, the angle of the mesial shoulder was more blunt [16].

Crown size and sex differences

Sex hormones have been reported to be responsible for sex differences in the size of human permanent teeth [29,30]. An examination of the sex difference in the size of primary teeth in a number of human populations revealed wide variation. It has been reported that the top tooth types showing strong sexual dimorphism in mesiodistal crown diameter were the first primary molar in the maxilla and the first primary incisor in the mandible [30]. Among permanent teeth, canines are always the most sexually dimorphic. However, in the primary dentition, primary canines are not necessarily the most sexually dimorphic. The most striking feature of gibbon canines was the lack of sexual dimorphism in permanent teeth. Deciduous tooth size differed little between males and females. Notwithstanding, closer examination of permanent canines revealed that males were slightly larger than females and that especially there were

large differences in crown height. Unfortunately, due to the wear of the apical, it was not possible to accurately measure the crown height [1,3,13,31,32]. Gibbons had the smallest deciduous teeth of any ape, and there were no significant sex differences in tooth size (MD and LL) in either the maxilla or mandible. The deciduous teeth of chimpanzees and bonobos also lacked extreme sexual dimorphism [13,17]. This is the consensus of researchers who have measured the deciduous teeth of other great apes [1,15,17]. However, in the present study, significant sex differences were found in gorilla deciduous canines [16], and significant sex differences were also found in orangutan deciduous canines in mesiodistal and labiolingual crown diameters.

Gil-Donoso et al. [25] found that in humans, permanent canines are influenced by sex hormones, but in deciduous canines, hard tissue calcification begins between 15 and 18 weeks after fertilization and ends around the ninth month of postnatal life. They concluded that the effects of sex hormones on primary teeth are limited and that there are no significant sex differences in primary teeth. They reported that sex differences are unlikely to occur in human primary teeth. Kinzey [22], who studied the relationship between eruption order and canine size, found that in chimpanzees, gorillas, and orangutans with large canines, the order of eruption of primary teeth was di1, di2, dm1, dm2, and dc; in humans with small canines and gibbons with large canines, it was di1, di2, dm1, dc, dm2 [22,31]. Schultz (1944) noted that eruption order in the great apes represents a newly acquired specialization and that the sequence of eruption in man and gibbon is the original condition. He noted that there was no apparent relationship between the order of eruption and the size of the deciduous canines [22].

Mortzou & Andrews [33] described a strong sexual dimorphism in the deciduous teeth of *Griphopithecus* from Paşalar, Turkey. They attributed this to the fact that the species was more sexually dimorphic than chimpanzees. If so, the marked sexual dimorphism in orangutan deciduous canines in the present study may be due to the strong sexual dimorphism in permanent canines in this species, which may also have revealed marked differences in deciduous canines. This is because both gorillas and orangutans show stronger sexual dimorphism in their permanent canines than chimpanzees [14,34].

There are several reports on the size of human primary canines, which are significantly larger in boys [35-40]. The degree of dimorphism in human permanent canines was fairly weaker than in gorillas and orangutans. Despite the small but significant proportion of sex differences in human maxillary canines, the emergence of significant sex differences in deciduous canines was difficult to understand. Further investigation would be required [41].

Conclusion

The aim of this study was to determine the morphology of

the deciduous canine and the sexual dimorphism in Asian apes. The occlusal view of the maxillary deciduous canines of gibbons was long and elliptical mesiodistally, while the lingual view was more pyramidal triangular, and was highly symmetrical mesiodistally. The median lingual ridge was well developed and descends vertically from the apex in the center of the crown, joining the cervical ridge at the base to form a tubercular bulge. The females were similar in morphology to those of the males, but the crowns were more distally inclined and less symmetrical. The mandibular canines were distorted into square shape with the heel-like prominence of the distal crown base in the lingual view. The occlusal aspect of orangutan maxillary deciduous canines was elliptical, while the lingual aspect was pyramidal triangular. The phenotype of tooth surface morphology was weaker in females than in males. The mandibular deciduous canines were elliptical in shape from the occlusal view. The lingual view showed a distorted square shape due to the heel-like prominence of the distal tooth crown base. There were significant sex differences in size. Sex differences in deciduous canine size were not significant in gibbons, but were significant in orangutans.

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