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Craniometric Analysis of Two Primate Species from Sri Lanka: *Macaca sinica* and *Trachypithecus vetulus*

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Abstract

Anthropoid primates in Sri Lanka belong to the group of Old World Monkeys in the family Cercopithecidae. The more omnivorous macaques belong to the sub-family Cercopithecinae and the folivorous two langur species to Colobinae, respectively There are marked external morphological differences between the macaque species and two langur species. However, no studies have been conducted to determine the differences from their skeletal morphology. This study attempts to determine the species variation using standard craniometrical measurements. Ten macaque and purple-faced langur crania and 8 macaque and 10 langur mandibles were measured housed at the Department of Sociology and Anthropology University of Sri Jayewardenepura, at the National Museum Colombo and from a private collection. Fifteen cranial and 9 mandibular measurements were taken using a digital sliding caliper. In the cranium, there are statistically significant differences in the muzzle length, nasal breadth, nasal height, piriform height, piriform breadth and inter orbital breadth between these two species. Macaque cranium has a longer muzzle, greater upper facial height and a wider long nose than the langurs. However, the langur cranium has a wider inter orbital distance and narrow piriform aperture than the macaques. In the mandible, there are statistically significant differences between bicondyle breadth, bigonial breadth, bimental eminence breadth and height of ramus. Langur mandibles are taller and wider than macaques. When considering the teeth, both species have bilophodont teeth; nevertheless langur teeth have higher cusps than macaques. This is directly related to their dietary specialization and is used to distinguish between Cercopithecines and Colobines. These cranial and mandibular measurements and dental morphology are very important for the identification of different primate species from the bones excavated from prehistoric cave sites in Sri Lanka.

Introduction

For its small geographical size Sri Lanka is home to five primate species represented by 12 subspecies distributed throughout the country. They are the toque macaque species (*Macaca sinica*) with three sub species (*Macaca sinica sinica, Macaca sinica aurifrons, Macaca sinica opistomelas*), purple-faced leaf langur (*Trachypithecus vetulus*) with four sub species (*Trachypithecus vetulus, Trachypithecus vetulus vetulus, Trachypithecus vetulus nestor, Trachypithecus vetulus philbriki* and *Trachypithecus vetulus monticolar*), gray langur (*Semnopithecus priam*), of the two loris species *Loris tardigradus* with two sub species (*Loris tardigradus tardigradus, Loris tardigradus nycticeboides*) and *Loris lydekkarianus* is represented by *Loris lydekkerianus nordicus* and *Loris lydekkerianus grandis* (Molur *et al.* 2003, Nahallage *et al.* 2008).

The three diurnal species belong to the Infra order Catarrhini (Old World Monkeys), the name is derived from the shape of the nostrils, which are usually narrow and facing downward rather than round and facing laterally as in most New World Monkeys. In their dentition they have two premolars in each quadrant. The Cercopithecoid monkeys have several anatomical features that distinguish them from apes and humans. Most prominent are their specialized molar teeth, in which the anterior two cusps and posterior two cusps are aligned to form two ridges or lophs and called as bilophodont teeth. In cranial anatomy Old World Monkeys have relatively narrow nasal openings and narrow tooth rows compared to the apes.

Old World monkeys are divided into two sub families: the Cercopithecines or cheek-pouch monkeys and the Colobines or leaf – eating monkeys. Many of their differences are related to basic dietary adaptations. The colobines are mainly leaf and seed eaters, whereas the Cercopithecines are predominantly fruit eaters (Napier and Napier 1967; Goldstein *et al.* 1987; Smith 1983). Cercopithecines have cheek pouches, shorter guts to digest fruits (Caton 1998; Kay and Davis 1994), broader incisor teeth and molar teeth with high crowns and relatively low cusps, whereas Colobines have no cheek pouches, narrow incisors and molar teeth with high cusps (Hylander 1975;

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Kay 1975). In cranial anatomy, cercopithecines have a narrow interorbital region, and the lacrimal canal is formed by both the maxillary and lacrimal bones; in Colobines, the interorbital region is broader and the lacrimal bone completely surrounds the canal. Cercopithecines have longer snouts and shallower mandibles than do Colobines (Fleagle 1988).

When considering the evolutionary and phylogenetic relationship of the Asian Old World Monkeys, especially after separation from the hominids in early Miocene (Fleagle 1989; Stauffer *et al.* 2001), it has been observed that the ancestors of the Asian colobines and macaques diverged from one another and migrated at different times from Africa to Eurasia (Fleagle 1989). Consequently, survivors of both groups spread to Asia (Delson 1994; Delson *et al*, 2000) and have evolved independently since then (Simons 1969; Shoshani *et al.* 1996). Both of these groups have been subjected to the same environmental changes since the early Pliocene in Asia. Especially two major events that had a great impact on the biological component of Asia: the rapid uplift of the Qinghai-Tibet Plateau and the last global glaciations, 6000 years ago (Pan and Jablonski 1987). Since then they radiated throughout most of Asia, where they are now sympatrically distributed (Pan and Oxnard 2001).

In Sri Lanka, the toque macaque belongs to the subfamily Cercopithecinae and the two langur species belong to the Colobinae and they could be seen distributed sympatrically in most regions. Even though many studies have been conducted to differentiate these species based on their behavior, social structure and morphology, no studies were done to differentiate them based on their cranial or post cranial variation. Therefore the main objective of this study was to determine the species variation using cranial and dental morphology using standard craniometrical measurements. Some of the useful applications of this study are to use skeletal material to identify the different primate species found in archaeological excavation sites, to understand their distribution patterns in prehistoric periods in Sri Lanka, and to postulate the human primate relationship of early humans with respect to food and foraging patterns.

Table 1: Location of specimens

Specimen No.	Place	Part	Species
ANTH 006	UNI	Cranium and Mandible	*Trachypithecus vetulus*
T.v.p	PRI COL-1	Cranium and Mandible	*Trachypithecus vetulus*
T.v.p.	PRI COL-1	Cranium and Mandible	*Trachypithecus vetulus*
T.v	MUS	Cranium and Mandible	*Trachypithecus vetulus*
T.v.n.	MUS	Cranium and Mandible	*Trachypithecus vetulus*
T.v.	MUS	Cranium and Mandible	*Trachypithecus vetulus*
T.v.p.	MUS	Cranium and Mandible	*Trachypithecus vetulus*
T.v.n.	MUS	Cranium and Mandible	*Trachypithecus vetulus*
T.v.p.	MUS	Cranium and Mandible	*Trachypithecus vetulus*
Tv.v.	PRI COL-2	Cranium and Mandible	*Trachypithecus vetulus*
HIST 001	UNI	Cranium and Mandible	*Macaca sinica*
HIST 002	UNI	Cranium and Mandible	*Macaca sinica*
HIST 003	UNI	Cranium and Mandible	*Macaca sinica*
ANTH 003	UNI	Cranium and Mandible	*Macaca sinica*
ANTH 004	UNI	Cranium and Mandible	*Macaca sinica*
ANTH 005	UNI	Cranium and Mandible	*Macaca sinica*
M.s.a	PRI COL-1	Cranium and Mandible	*Macaca sinica*
M.s.o.(2009)	PRI COL-1	Cranium and Mandible	*Macaca sinica*
M.s.o (2010)	PRI COL-1	Cranium and Mandible	*Macaca sinica*
M.s.	MUS	Cranium and Mandible	*Macaca sinica*
HIST 005	UNI	Mandible	*Macaca sinica*
HIST 006	UNI	Mandible	*Macaca sinica*
HIST 007	UNI	Mandible	*Macaca sinica*

UNI: University, PRI COL-1: Private Collector 1, MUS: Museum, PRI COL-2: Private Collector 2

Methodology

Craniometric measurements were taken from the skulls housed at the Physical Anthropology Laboratory at the Department of Sociology and Anthropology, University of Sri Jayewardenepura and at the National Museum in Colombo and from two privet collectors. This study is focused only on the toque macaque and purple-faced leaf langur skulls. Cranial measurements were taken from 10 macaque and 10 purple-faced langur crania (Table 1). Mandibular measurements were taken from 8 macaque and 10 langur mandibles. Fifteen cranial and nine mandibular measurements were taken as shown in Table 2 and included for the analysis.

Skulls of adult monkeys were used in the study; the maturity of the specimen was assessed on the basis of third molar eruption. The craniometrical measurements were directly taken by the author on crania and mandible using a digital caliper (Mitutoyo Absolute Digimatic – Mitituyo Corporation). Measurements were taken only from the left side to avoid redundant information on symmetric structures. The data was entered into an Excel sheet and statistical analysis was performed using SPSS (version 10) package.

Results

Regarding cranial morphological variations; purple-faced leaf langurs show wide interorbital distance and their piriform apertures are long and thin, where as macaques have short interorbital distance and short and wide piriform apertures. The nasal bones of the langurs were longer compared to the short nasal bones of macaque (Fig. 1). Another important feature is the shape of the eye socket, langurs have rectangular eye sockets while macaques have rounder eye sockets. The supra orbital notch or a foramen could be clearly seen in the macaque cranium, however this feature is absent in langurs. Overall langurs have a short, upright face compared to the longer faced macaques.

Table 2. Standard cranial and mandibular measurements

Cranial Measurements		
MCB	Maximum Cranial Breadth	R euryon to L euryon
MCL	Maximum Cranial Length	glabella to opistocranium
BZB	Bi Zygomatic Breadth	between two zygia
MUZL	Muzzle Length	the distance between orbitale to alveolare (prosthion)
NB	Nasal Breadth	R alare to L alare
NH	Nasal Height	between nasion and nasospinale
PIRH	Height of Piriform Aperture	
PIRW	Width of Piriform Aperture.	
UFB	Upper Facial Breadth	between two frontomalaria temporalia
UFH	Upper Facial Height	between nasion and prosthion
IOB	Inter Orbital Breadth	between two maxillofrontalia
BOB	Bi Orbital Breadth	between R ectoconchion and L ectoconchion
OB	Orbital Breadth	between maxillofrontale and ectoconchion
PB	Palatal Breadth	between two endomolaria M2 (middle of the lingual margin of the alveolar)
PL	Palatal Length	between orale and staphylion
Mandibular Measurements		
SH	Symphysis Height	between infradentale and gnathion
BCB	Bi Condylar Breadth	between two condyla lateralia
BGB	Bi Gonial Breadth	between two gonia
BMEB	Bi Mental Breadth	between two mental eminence
MRB	Minimum Ramus Breadth	minimum distance between the anterior and posterior borders of ramus
MBL	Mandibular Body Length	straight distance from gnathion to gonion
MBH	Manibular Body Height	Height of the mandible between the M1 and M3
MBB	Mandibular Body Breadth	maximum thickness of the body at the level of second molar
HOR	Height of Ramus	between gonion and highest point of mandibular condyle

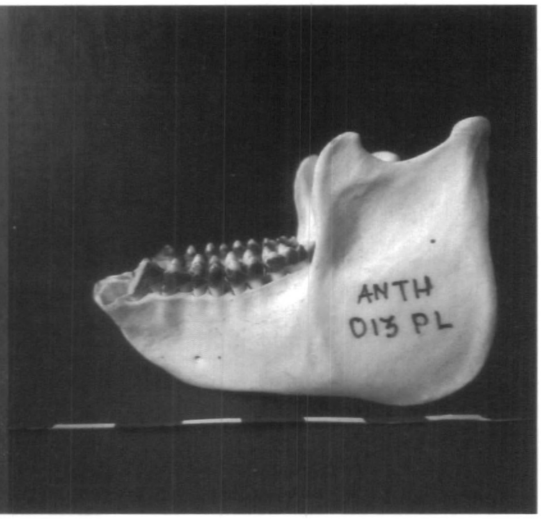

Fig. 1a: Langur skull front

Fig. 1c: Langur lower jaw

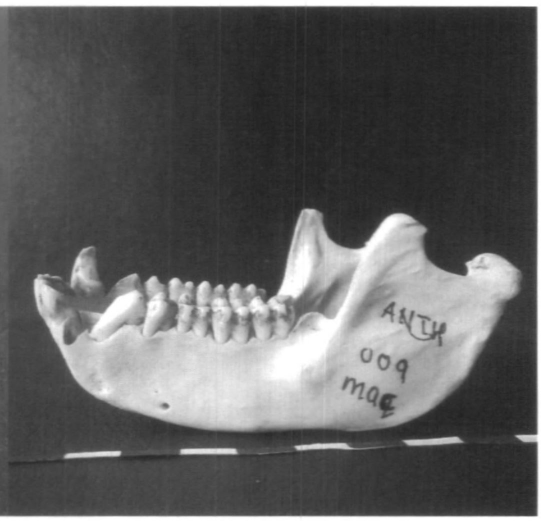

Fig. 1b: Macaque skull front

Fig. 1d: Macaque lower jaw

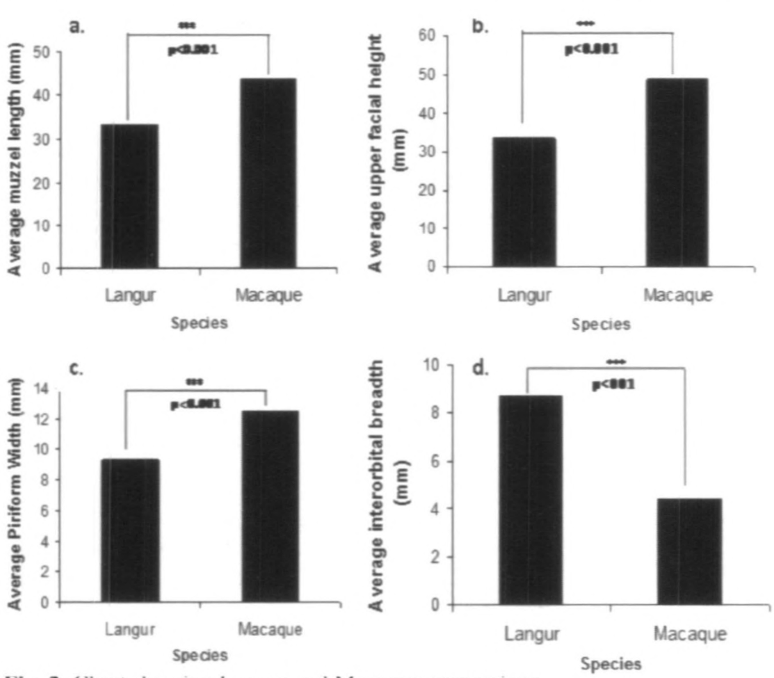

Fig. 2: Chart showing Langur and Macaque comparison

In the mandible, ascending ramus is more upright and the minimum ramus breadth is wider in purple-faced langurs than in macaques. Overall the langur mandible is wider than the macaque mandible (Fig. 1).

There is a conspicuous difference between the purple-faced langur teeth and macaque teeth. Langurs have smaller incisors than the macaques and this was more prominent in mandibular incisors than in the maxillary incisors. Furthermore, langurs have low cusp teeth compared to high cusp teeth of macaques (Fig. 1).

There were no significant variations in the Maximum Cranial Length, Maximum Cranial Breadth and Bizygomatic Breadth between the two species (Table 3). However, there was a statistically significant difference in the muzzel length of the langures and macaques. The macaque has a longer muzzle than a langur (Mann-Whitney, U=58.00, N1= 10, N2 = 10, $p < 0.001$) (Fig. 2a).

Statistically significant differences were also recorded in Nasal Height (NH), Nasal Breadth (NB) and the width of the Piriform Aperture (PIRW), respectively (NH: Mann-Whitney, U=55.00, N1= 10, N2 = 10, $p < 0.001$;

Table 3: Average value for each craniometric character and relevant standard deviation

Craniometric character	Purple-faced langur (SD) mm	Macaque (SD) mm
MCB	56.87 (2.28)	56.33 (2.53)
MCL	77.17 (3.87)	77.40 (4.74)
BZB	73.39 (4.93)	72.28 (5.92)
MUZL	33.39 (2.36)	43.73 (5.66)
NB	9.37 (1.07)	12.53 (1.43)
NH	27.87 (2.47)	41.35 (4.87)
PIRH	18.68 (1.45)	17.57 (3.07)
PIRW	9.37 (1.07)	12.53 (1.43)
UFB	33.69 (3.32)	48.66 (6.73)
UFH	58.19 (1.97)	57.17 (3.64)
IOB	4.45 (0.71)	8.69 (0.96)
BOB	51.48 (1.80)	47.71 (2.17)
OB	22.31 (0.91)	23.22 (1.36)
PB	20.38 (1.42)	19.59 (2.08)
PL	26.14 (1.99)	30.37 (3.88)
SH	19.5 (1.63)	15.4 (1.92)
BCB	62.73 (3.77)	56.30 (4.71)
BGB	47.13 (3.95)	35.23 (4.82)
BMEB	19.54 (1.39)	14.82 (2.03)
MRB	24.83 (1.93)	22.32 (3.29)
MBL	51.12 (5.33)	48.37 (9.99)
MBH	18.43 (1.42)	16.65 (2.24)
MBB	7.30 (0.73)	7.46 (0.90)
HOR	41.53 (3.14)	31.09 (3.81)

NB: Mann-Whitney, U=58.00, N1= 10, N2 = 10, $p < 0.001$; PIRW: Mann-Whitney, U=58.00, N1= 10, N2 = 10, $p < 0.001$). Macaques have wider noses than purple-faced langurs. No significant species difference was found in the height of piriform aperture. Other craniometric characters that did not show significant species differences were Biorbital Breadth, Orbital Breadth and Palatal Breadth (Table 3). As observed in the cranial morphology significant differences between these two species were seen in the Upper Facial Height and Inter Orbital Breadth (UFH: Mann-Whitney, U=56.00, N1= 10, N2 = 10, $p < 0.001$; IOB: Mann-Whitney, U=55.00, N1= 10, N2 = 10, $p < 0.001$) (Fig. 2b, 2d).

Regarding mandibular variation, statistically significant differences were found in Bi Condyler Breadth, Bi Gonial Breadth and Height of Ramus (BCB: Mann-Whitney, U=46.00, N1= 10, N2 = 08, $p = 0.008$; BGB: Mann-Whitney, U=38.00, N1= 10, N2 = 08, $p = 0.001$; HOR: Mann-Whitney, U=47.00, N1= 10, N2 = 08, $p= 0.01$). Langur mandibles were wider and taller than macaque mandibles. However no significant differences were seen in Bimental Eminence Breadth and Mandibular Body Length.

Discussion

The results obtained from this study for Sri Lankan macaque and langurs thus confirms the differences described between the Cercopithecinae and Colobinae sub families by various scientists for other species (Fleagle 1988). When considering the cranial morphology, most conspicuous morphological differences between these two species were the long muzzle of toque macaque compared to the short face of the purple-faced langurs. Other Cercopithecine characters were the narrow interorbital breadth, wide piriform aperture and supra orbital notch. This was confirmed by the statistically significant data from the craniometrical analysis. In the cranium there were significant differences in the interorbital breadth, muzzle breadth, nasal breadth, nasal height and piriform width. This was similar to the earlier studies conducted to determine if the Cercopithecine subgroups could be distinguished on the basis of their cranial morphology (Delson 1975a; Cardini and Elton 2008). When considering the dental morphology, langurs have smaller incisors and larger molars than macaques. This is similar to the studies conducted by Hylander 1975 a,b; Kay and Hylander 1978; Pan 2007. They concluded that these features may have been related to the increased use of incisors in macaques for biting and cutting of fruits and increased use of molars in langurs for the chewing, crushing and grinding of the strong fibers in leaves and grasses. This could be applied to macaque and langur species in Sri Lanka as well.

However, when compared, the average maximum cranial length, maximum cranial breadth and bizygomatic breadth, significant differences between the two species were not observed. The evolutionary and phylogenetic relationship could be responsible for this. These two species have coexisted during the environmental and climatic changes in Asia since the early Pleistocene. Therefore it is possible that they evolved some common characteristics to adapt to similar environment and climatic conditions. As a result these two groups could have developed some similarities between the body size and teeth. This could account for the similarities in their cranial length and breadth measurements and some of the similarities seen in their dental morphology.

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