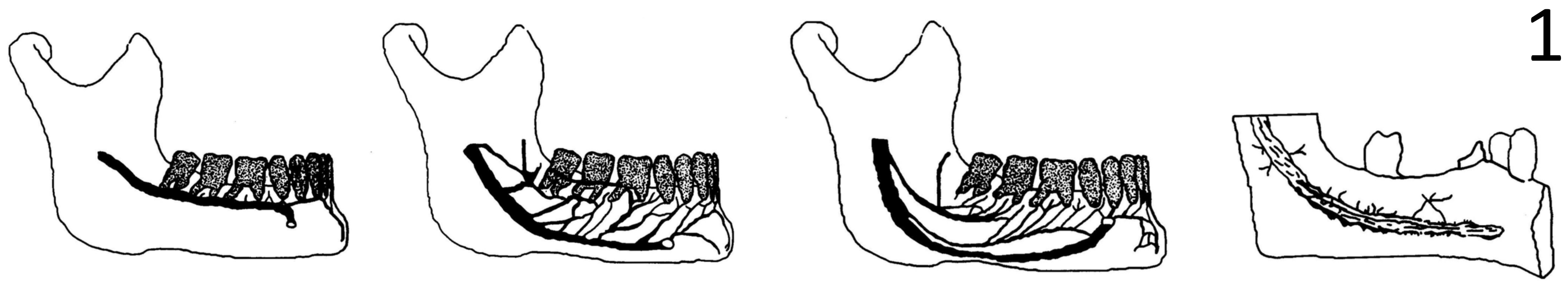
An assessment of the neurovascular structures in the mandibular canal and their effect on diet in primates

Caitlin B. Yoakum and Claire E. Terhune
Department of Anthropology, University of Arkansas

INTRODUCTION: Previous studies have concluded that the mental foramen is not an accurate proxy for touch sensitivity in relation to diet in extant species, but did not assess the underlying neurological structures of the mental nerve and surrounding structures [1]. Various authors have attempted to describe the typical course of the mandibular canal (Figure 1) and the variation seen in humans, however no study fully describes the diameter of the canal and the structures it contains (i.e. the mandibular nerve) at any location within the mandibular canal or at the opening of the mental foramen [2-5]. Many studies have shown that some nerves in the body, such as the infraorbital and optic nerve, occupy the majority of the space in the foramina through which they pass [6-8], while others have shown that other nerves, such as the hypoglossal nerve, do not occupy the majority of the foramina through which it passes [9]. The importance of understanding the size of the nerve, and not just the canal space it occupies, is noted in Cull et al. [10] due to the overwhelming evidence that total number of axons can be estimated from small cross-sectional areas of nerves, thus giving further information on the sensitivity and use of facial structures. **This study aims to examine variation in mandibular canal shape and size in primates and to examine whether canal size is related to dietary preference and/or is patterned phylogenetically.**

Figure 1: Original images taken from Anderson et al. (1991) showing the four general ways the mandibular nerve and canal can be described



METHODS AND MATERIALS:

Table 1: Summary of all species used and species averages for mental foramen, mandibular foramen, mandible length, MenFor/MandFor ratio (highlighted showing values >0.50) and assigned dietary category

Species Name	MenFor Avg	MandFor Avg	Avg Mand	Men/Mand Ratio Avg	Diet
Macaca nigra	0.24	4.59	87.58	0.06	Fruits
Aloutta palliata	0.69	6.70	72.31	0.10	Leaves
Presbytis rubicunda	0.12	2.17	61.16	0.10	Leaves
Papio anubis	3.33	20.35	158.07	0.17	Fruits
Cercocebus agilis	1.39	7.54	89.36	0.18	Fruits
Papio ursinus	3.68	11.52	140.69	0.18	Fruits
Cacajao calvus	0.59	2.13	65.57	0.19	Seeds
Lophocebus albigena	1.09	7.11	77.99	0.19	Fruits
Hapalemur griseus	0.25	1.38	44.32	0.19	Leaves
Macaca radiata	1.30	3.26	75.00	0.21	Fruits
Nasalis concolor	1.05	3.14	69.71	0.24	Leaves
Perodicticus potto	0.47	1.26	37.37	0.26	Fruits
Mandrillus sphinx	3.93	13.11	137.11	0.29	Fruits
Colobus badius	0.91	3.10	68.21	0.30	Leaves
Semnopithecus entellus	0.61	3.50	82.23	0.30	Leaves
Macaca mulatta	1.51	5.42	70.63	0.32	Fruits
Theropithecus gelada	5.20	13.75	115.57	0.34	Leaves
Papio ibeanus	4.36	11.42	132.31	0.41	Fruits
Miopithecus talapoin	0.76	1.70	43.46	0.43	Fruits
Cebus apella	0.74	1.81	61.75	0.45	Fruits
Aotus trivirgatus	0.48	0.94	36.74	0.45	Animals
Colobus guereza	1.83	3.47	81.92	0.46	Leaves
Callithrix argentata	0.39	0.62	29.04	0.47	Gum
Gorilla gorilla	17.6	34.49	160.18	0.49	Fruits
Allenopithecus nigroviridis	2.31	4.56	71.06	0.54	Fruits
Procolobus verus	2.64	2.96	57.84	0.56	Leaves
Procolobus badius	1.41	2.47	70.34	0.58	Leaves
Colobus polykomos	2.52	5.67	70.07	0.58	Leaves
Macaca fascicularis	2.28	3.09	75.86	0.59	Fruits
Callicebus moloch	0.87	1.10	40.43	0.59	Fruits
Erythrocebus patas	3.50	6.14	92.60	0.59	Animals
Callithrix humeralifera	0.42	0.58	28.44	0.60	Gum
Galago senegalensis	0.21	0.23	21.84	0.72	Animals
Saguinus oedipus	0.34	0.39	29.93	0.78	Animals
Saimiri sciureus	0.55	0.60	33.71	0.84	Fruits
Propithecus verreauxi	1.09	1.37	54.24	0.85	Leaves
Cercocebus torquatus	2.46	5.50	97.39	0.87	Fruits
Saimiri oerstedii	0.60	0.51	36.05	0.91	Fruits
Mandrillus leucophaeus	11.26	10.08	136.99	**1.12**	Fruits
Nasalis larvatus	4.03	3.90	82.39	**1.34**	Leaves

Mental foramen <50% size of mandibular foramen

Mental foramen >50% size of mandibular foramen

Larger mental foramen

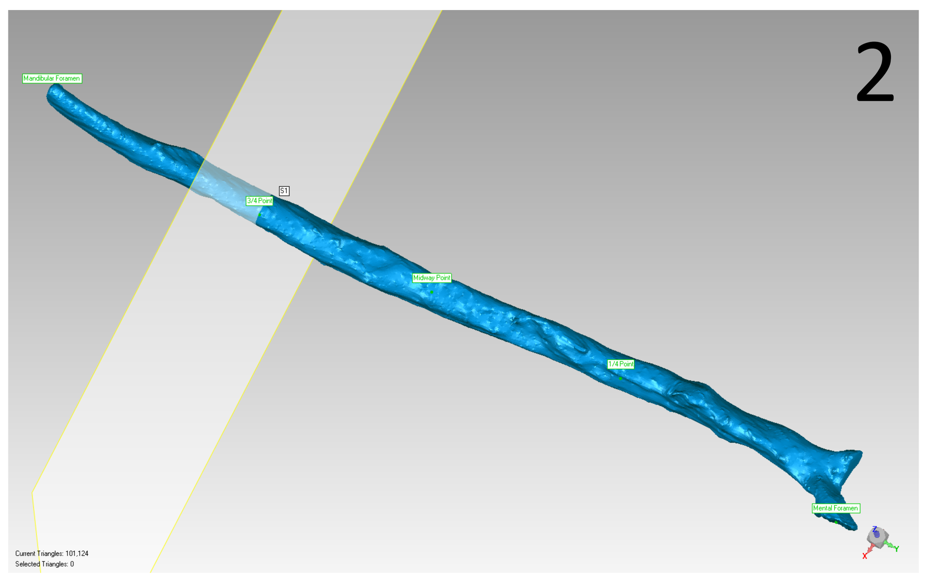
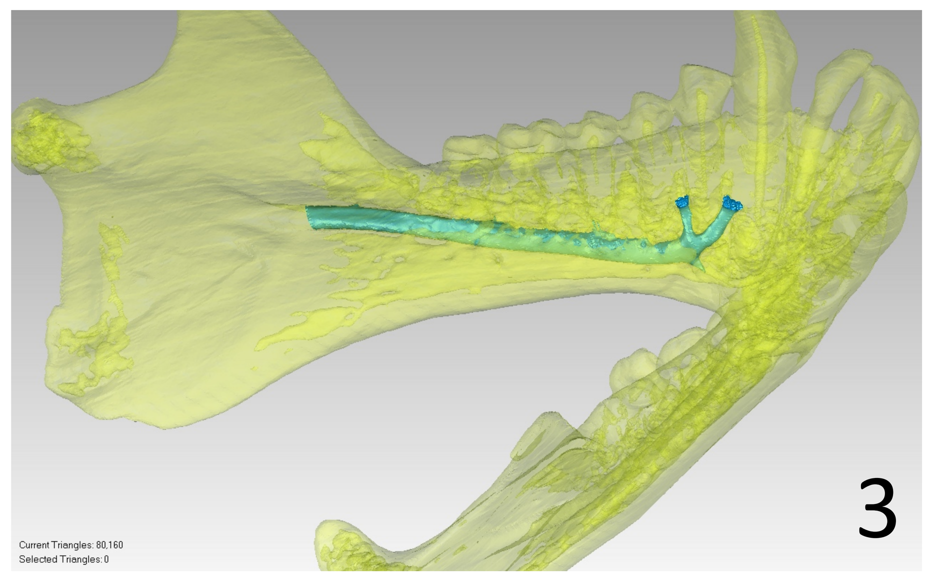


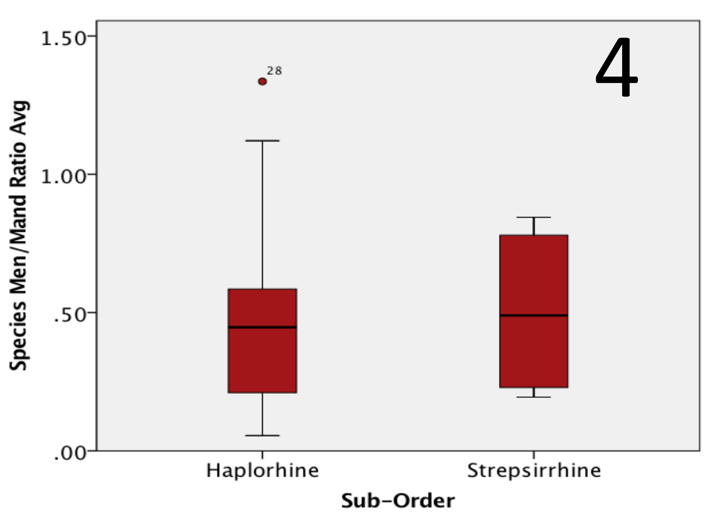
Figure 2: An example of the cross-sectional areas measured on an example mandibular canal from the species *Hapalemur griseus*



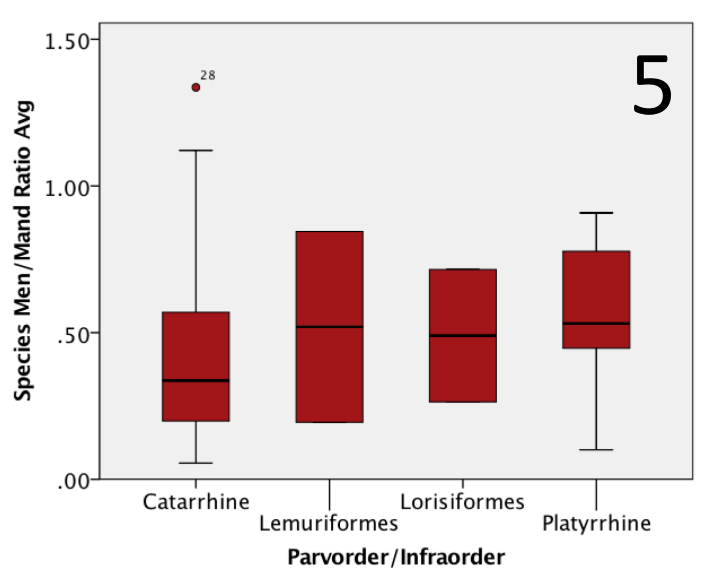
Figures 3: an example of the mandibular canal segmented within the mandible to show its size and orientation in *Saguinus oedipus*

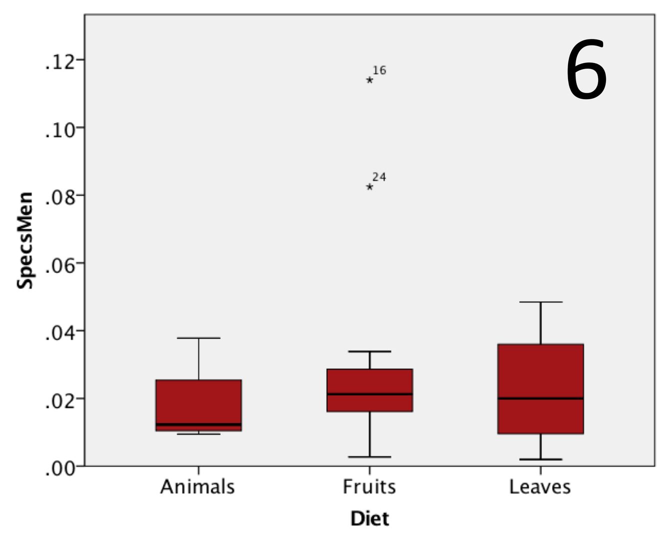
- 40 extant primate species (n= 72 males)
  - •Only males were used to eliminate sexual dimorphism
- microCT scans from Morphosource.org
- Five cross-sectional area measurements (Fig. 3): mental foramen, ¼ length from MeF to MaF, midpoint of canal, ¾ length from MeF to MaF, and mandibular foramen
- Mental/mandibular foramen ratios were created to determine relative size differences
- Ratios of the left and right side for the mental and mandibular foramen were created to assess symmetry of each specimen
- A series of one-way ANOVAs (with and without phylogeny) were used to test differences between taxonomic groups and in relation to diet

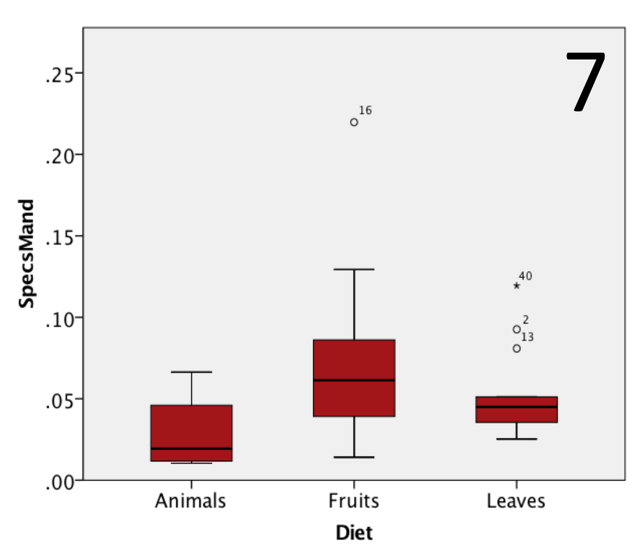
RESULTS:



Figures 4 and 5: boxplots depicting the MenFor/MandFor ratio in relation Suborder and parv/infraorder. These findings show no significant differences in mean and no overall pattern in the data by grouping. The marked specimen (28) represents the species *Nasalis larvatus*.

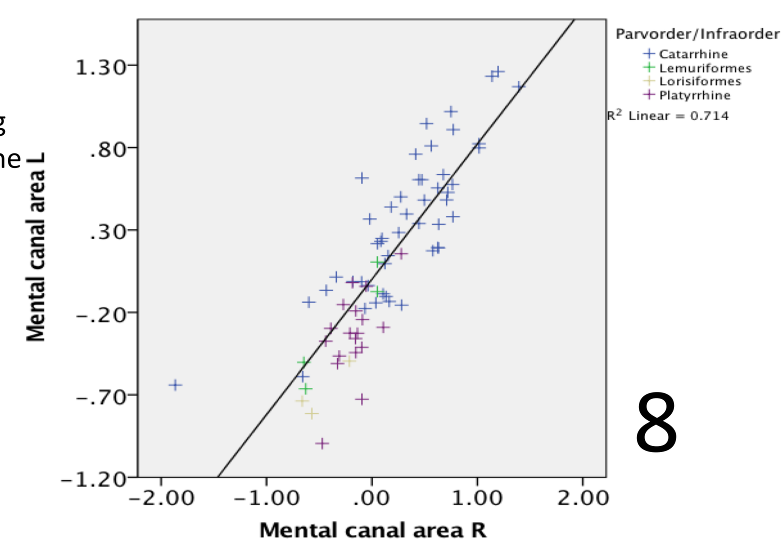






Figures 6 and 7: Box plots depicting the ANOVA results in relation to diet. The variables falling outside of the average range are: (16) *Galago senegalensis*, (24) *Mandrillus sphinx*, (40) *Semnopithecus entellus*, (2) *Alouatta palliata*, and (13) *Colobus badius*.

Figures 8 and 9: Bivariate plots showing the ratio of the left and right side for the mental foramen and mandibular foramen



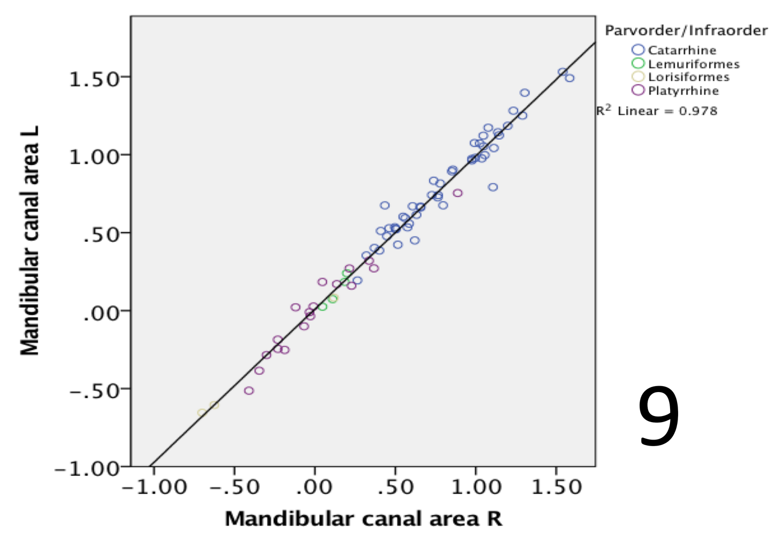


Table 2: One-Way ANOVA results demonstrate significant differences (highlighted cells) in canal area at the midway point and posterior, but not in the anterior portion of the canal

	Sub-Order	Parv/Infraorder	Family
Mental Foramen	0.242	0.149	0.816
1/4 point	0.056	0.052	0.172
Midway point	0.022	0.023	0.052
3/4 point	0.030	0.079	0.085
Mandibular Foramen	0.095	0.007	0.091

Table 3: One-Way ANOVA results in relation to Diet

	df	Mean square	F	Sig. ($p<0.05$)
Mental Avg.	3	0	0.420	0.740
Mandibular Avg.	3	0.003	1.919	0.144

Table 4: Phylogenetic ANOVA in relation to Diet

	Sum sq.	Mean square	F	Sig. ($p<0.05$)
Mental Avg.	0.001	0.000	0.423	0.943
Mandibular Avg.	0.009	0.002	1.393	0.631

Table 5: Paired T-tests used to compare the left and right side for facial symmetry

	df	Mean square	Sig. ($p<0.05$)
Mental Avg.	73	0.000	0.319
Mandibular Avg.	73	0.000	0.341

DISCUSSION AND CONCLUSION: This research indicates that the cross-sectional canal area varies along its length and differs among groups of extant primates (Figs. 4, 5). Paired *t*-tests (Table 5) indicate that there is no significant difference in the left and right sides of the mandibular canal in the individuals in this study, indicating no pattern of mandibular asymmetry. These results alone show that the mental foramen is variable in shape across groups and individuals, and is not accurately represented by the cross-sectional area of the mandibular canal and the mandibular foramen (Table 1). However, because no significant values were found when diet is compared to the foramina or canals (Tables 3 and 4), the data suggests that the cross-sectional area of the bony surfaces cannot be used as a proxy for dietary preferences. This could be in part because we used qualitative categories to assign diet, which is often biased or inconclusive for some species. Future research will include females to establish sexual differences in mandibular canal morphology and molar tooth morphology rather than qualitative dietary categories to further examine the evolutionary implications of the variation in the mandibular canal.

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CONTACT:
cbyoakum@uark.edu
cterhune@uark.edu
Terhunelab.uark.edu