

Sutural Variability in the Hominoid Anterior Cranial Fossa

Robert McCarthy, Monica Kunkel, Department of Biological Sciences, Benedictine University

Email contact information: rmccarthy@ben.edu; monski91@aol.com

SAMPLE

ABSTRACT

In anthropoids, the orbital plates of frontal bone meet at a “retro-ethmoid” frontal suture in the midline anterior cranial fossa (ACF), separating the presphenoid and mesethmoid bones. Previous research indicates that this configuration appears variably in chimpanzees and gorillas and infrequently in modern humans, with speculation that its incidence is related to differential growth of the brain and orbits, size of the brow ridges or face, or upper facial prognathism. We collected qualitative and quantitative data from 164 previously-opened cranial specimens from 15 hominoid species in addition to qualitative observations on non-hominoid and hominin specimens in order to (1) document sutural variability in the primate ACF, (2) rethink the evolutionary trajectory of frontal bone contribution to the midline ACF, and (3) create a database of ACF observations and measurements which can be used to test hypotheses about structural relationships in the hominoid ACF. In adults, we catalogued presphenoid/mesethmoid contact in the midline ACF in 100% of orangutans, 91.3% of modern humans, 57.1% of chimpanzees, 42.9% of gorillas, and 21.1% of hylobatids. Presphenoid/mesethmoid contact is variable in archaic *Homo*, including *Homo neanderthalensis*, but seems to be the rule in *Australopithecus*. Frontal involvement in the midline ACF is more common in chimpanzee and gorilla males than females, providing ancillary support for the idea that frontal contribution to the midline ACF is related to some aspect of facial scaling, such as brow ridge size or upper facial prognathism. In each species, a greater percentage of adult than juvenile specimens exhibits midline frontal involvement, providing some indication that frontal bone invades the midline ACF during ontogeny. Intra- and interspecific scaling analyses are necessary to further test competing hypotheses about the structural role, if any, of frontal bone involvement in the midline ACF.

METHODS

- ACF sutures are generally not visible on CT scans or radiographs.
- So, we collected data from previously-sectioned specimens at the Cleveland Museum of Natural History (FMNH), Field Museum of Natural History (FMNH), and Smithsonian National Museum of Natural History (USNM) (see Table 4); we combined our qualitative data with data from refs. 4-5, which were collected using the same protocol (see Tables 2-3).
- We collected qualitative observations and photographs on opened crania from three museums.
- We collected caliper measurements from the basicranium, craniofacial region, and ACF (see Table 1).
- We digitized 3D landmarks on opened crania at the FMNH and USNM using a Microscribe G2 3D Digitizer.
- We collected endocranial volume (ECV) and orbit volume (OV) on closed crania from the FMNH and used a regression equation to estimate ECV for sectioned crania.

Table 1. Landmarks, measurements, and angles used in the study. Variable definitions can be found in ref. 1.

Landmark	Abbr.	Definition
Anterior nasal spine	ANS	Midline point on inferior edge of nasal opening
Basion	Ba	Midline point on anterior edge of foramen magnum
Pituitary point	PP	Midline point on bone posterior to optic canal
Posterior nasal spine	PNS	Midline point on posterior edge of hard palate
Measurement	Abbr.	Definition
Cribriform plate length	CPL	Distance between anterior and posterior edges of cribriform plate
Mid-ACF length	MAL	Distance between sphenoid greater wings and cribriform plate
Pre-sphenoid length	PSL	Distance between PP and cribriform plate
Angle	Abbr.	Definition
Facial kyphosis	AFK	Angle between Ba-PP and ANS-PNS

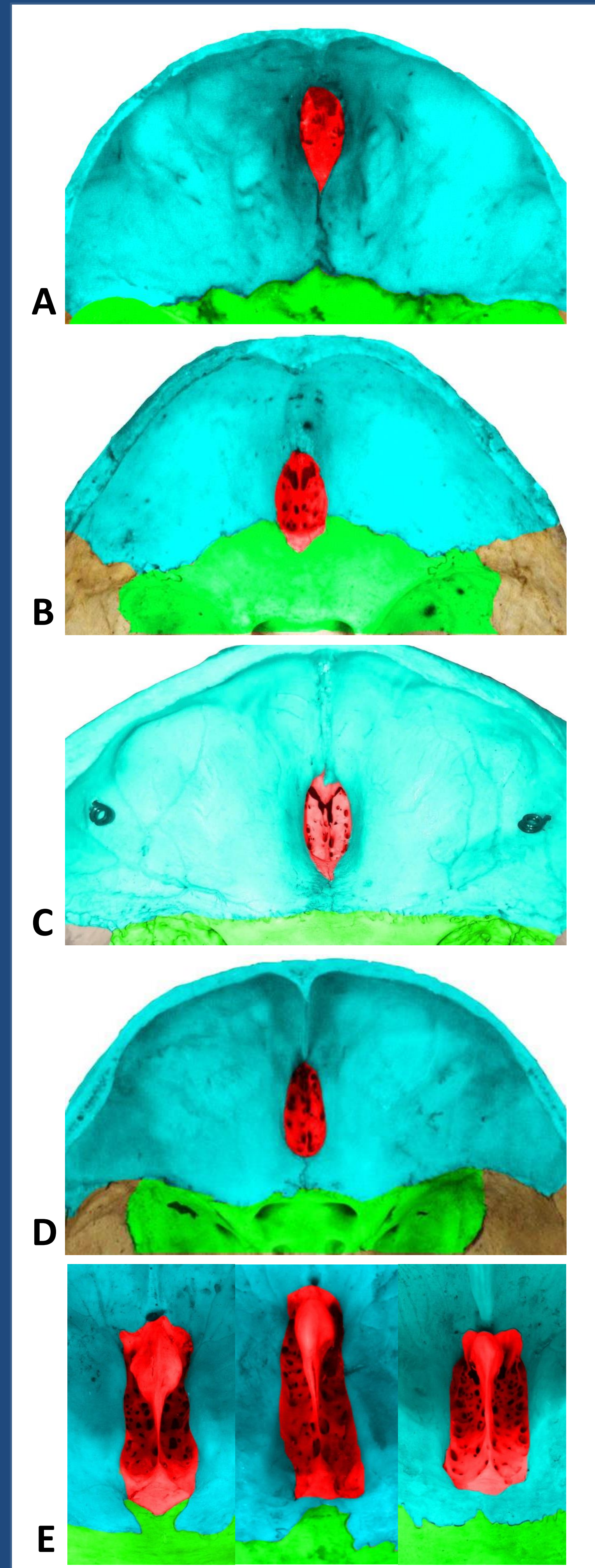


Figure 1. Bony composition of the ACF in hominoids. ACF in hylobatid (A), orangutan (B), gorilla (C), chimpanzee (D), and three modern humans (E); ethmoid = red, frontal = blue, sphenoid = green.

HYPOTHESES

Preliminary Scaling Analyses

Browridge size vs. PSL, MAL, CPL (planned) ←

ECV/OV vs. PSL, MAL, CPL ←

AFK vs. PSL, MAL, CPL ←

Table 2. Results split by age.

Group	Age	A-M43 ⁴ ; M55 ⁵		This study		Combined	
		S-E contact/n	%	S-E contact/n	%	S-E contact/n	%
Hylobatid	Adult	0/6	0	4/13	30.8	4/19	21.1
	Juvenile	0/2	0	3/10	30.0	3/12	25.0
	Combined	0/9	0	7/23	30.4	7/32	21.9
Orangutan	Adult	12/12	100.0	21/21	100.0	21/21	100.0
	Juvenile	13/13	100.0	13/13	100.0	13/13	100.0
	Combined	26/26	100.0	34/34	100.0	34/34	34/34
Gorilla	Adult	3/7	42.9	1/2	50.0	3/7	42.9
	Juvenile	5/7	71.4	1/5	20.0	6/11	54.5
	Combined	8/17	47.1	2/7	28.6	9/21	42.9
Chimpanzee	Adult	4/4	100.0	1/4	25.0	4/7	57.1
	Juvenile	13/14	92.9	3/6	50.0	15/18	83.3
	Combined	21/26	80.8	4/10	40.0	24/33	72.7
Bonobo	Adult	-	-	0/1	0	0/1	0
	Juvenile	-	-	-	-	-	-
	Combined	-	-	0/1	0	0/1	0
Human	Adult	329/363	90.6	71/75	94.7	400/438	91.3
	Juvenile	85/90	94.4	6/7	85.7	91/97	93.8
	Combined	415/453	91.6	77/82	93.9	491/535	91.8

In all species, a greater percentage of adult than juvenile specimens have a retro-ethmoid suture, adding support to previous research^{2,3} showing that frontal bone invades the midline ACF between the sphenoid and ethmoid during ontogeny.

Table 3. Results split by sex.

Group	Sex	A-M43 ⁴ ; M55 ⁵		This study		Combined	
		S-E contact/n	%	S-E contact/n	%	S-E contact/n	%
Hylobatid	F	0/3	0.0	1/6	16.7	1/9	11.1
	M	0/3	0.0	3/7	42.9	3/10	30.0
Orangutans	F	6/6	100.0	15/15	100.0	-	100.0
	M	6/6	100.0	5/5	100.0	-	100.0
Gorillas	F	2/5	40.0	1/1	100.0	3/5	60.0
	M	0/2	0.0	0/1	0.0	0/2	0.0
Chimpanzees	F	3/3	100.0	-	-	3/3	100.0
	M	0/1	0.0	0/3	0.00	0/3	0.0
Humans	F	147/160	91.9	14/15	93.3	161/175	92.0
	M	236/245	96.3	57/60	95.0	293/305	96.1

In chimpanzees and gorillas, a retro-ethmoid suture is more prevalent in males than females (red text), suggesting that frontal midline contribution is related to some aspect of facial scaling.

1. Gregory (1927)² hypothesized that frontal bone is recruited into the midline cranial base to reinforce large brow ridges or other cranial superstructures, particularly in gorillas (analyses are planned).
2. Wood Jones (1929)³ hypothesized that frontal bone is recruited into the midline cranial base in species in which the orbits grow earlier or faster than the brain (ontogenetic data will be required).
3. Ashley Montagu (1943)⁴ hypothesized that frontal bone is recruited into the midline cranial base in prognathic species.

Table 4. Specimens used in scaling analyses.

Species	Symbol	FMNH	CMNH	USNM	% Contact
Hylobatid		0	0	23	13.0
Orangutan	●	6	0	37	100.0
Gorilla	●	3	0	4	28.6
Chimpanzee	●	1	0	7	57.1
Human		0	83	0	91.8

HYPOTHESIS 2

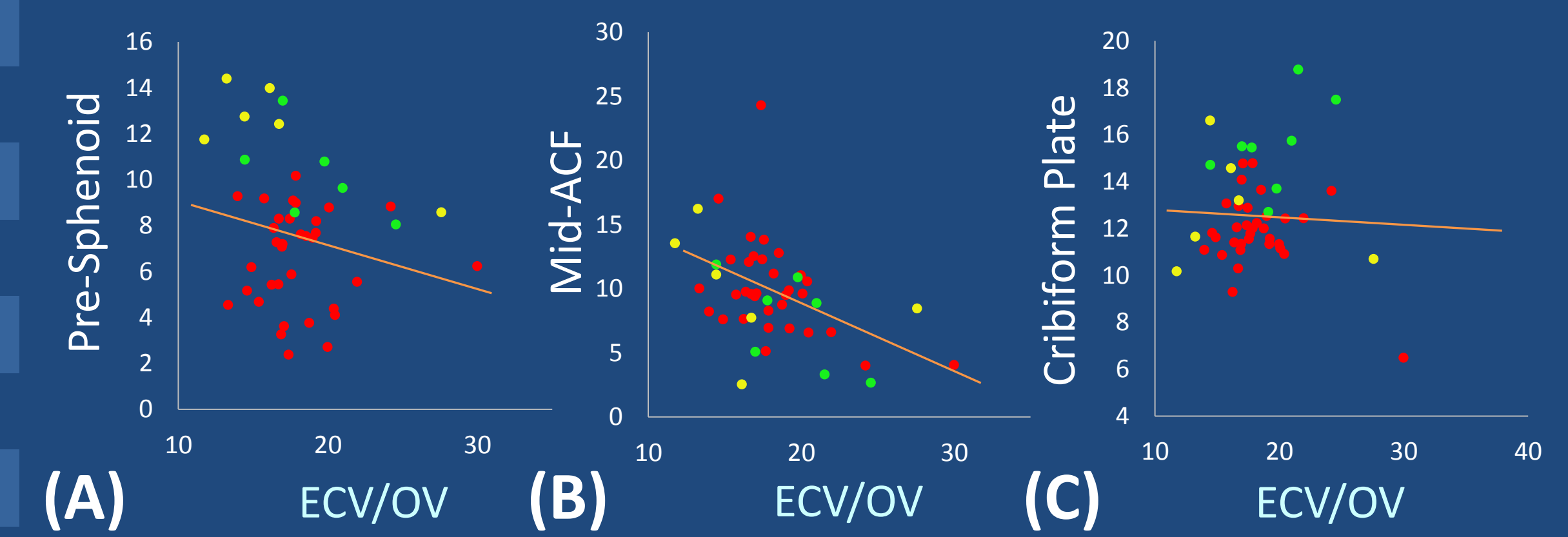


Figure 2. We found no significant relationship between ECV/OV and pre-sphenoid length (Fig. 2A, $R^2=0.03$) or cribriform plate length (Fig. 2C, $R^2=0.0$). ECV/OV is, however, correlated with mid-ACF length (Fig. 2B, $R^2=0.22$). Length of mid-ACF decreases as the ratio between ECV and OV increases. We are still processing data for hylobatids and modern humans.

HYPOTHESIS 3

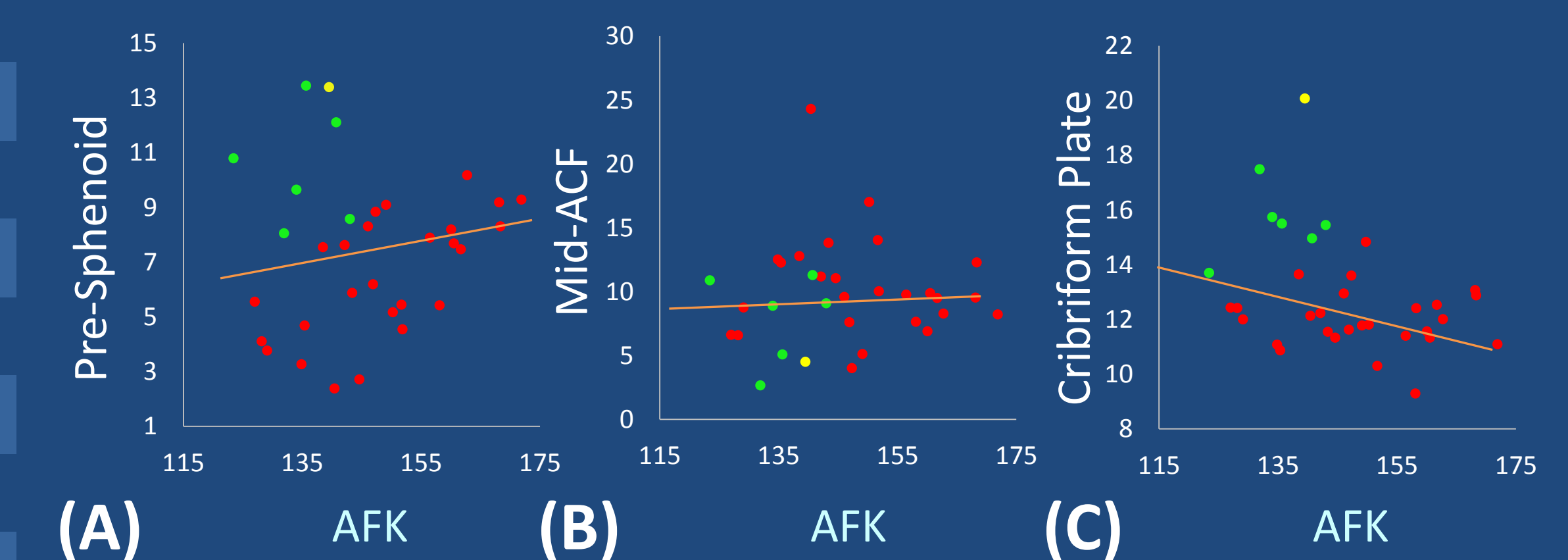


Figure 3. Degree of prognathism (AFK) is not correlated with pre-sphenoid length (A), mid-ACF length (B), or cribriform plate length (C) ($R^2 < 0.2$).

REFERENCES

- ¹ McCarthy RC. 2001. Anthropoid cranial base architecture and scaling relationships. *J Hum Evol* 40: 41-66.
- ² Gregory WK. 1927. The origin of man from the anthropoid stem – when and where? *Proc Am Phil Soc* 66: 439-463.
- ³ Wood Jones F. 1929. *Man's Place Among the Mammals*. Longmans, Green & Arnold, London.
- ⁴ Ashley Montagu MF. 1943. The mesethmoid-presphenoid relationships in the primates. *Am J Phys Anthropol* 1: 129-141.
- ⁵ Murphy T. 1955. The sphenoid-ethmoidal articulation in the anterior cranial fossa of the Australian aborigine. *Am J Phys Anthropol* 13: 285-300.

ACKNOWLEDGEMENTS

We would like thank Bart Ng, the dean of the College of Science, Lee Ann Smith, the director of the COS Natural Science Summer Research Program, Allison Wilson, director of the Fr. Ted Memorial Fund, Robin Rylaarsdam, chair of the Department of Biological Sciences, and Alexandra Bialy for funding and support; Darren Lunde and Esther Langan at the Smithsonian National Museum of Natural History; Larry Heaney, Rebecca Banasiak, and Bill Stanley at the FMNH; Lyman Jellema at the Cleveland Museum of Natural History; and Rose Fisk, Jennifer Gardner, Sylvia Larrondo, and Cynthia Kremer for logistical support. This poster is dedicated to the memory of Bill Stanley.