Quantifying Morphological Variation in the Nasal Floor of Extant and Fossil *Homo*

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Introduction

Variation in nasal floor shape has been documented in extant and fossil *Homo*. In particular, Neandertals show a very high frequency of depressed nasal floors, which was originally argued to be the result of cold-climate adaptation. More recently, this hypothesis has been rejected[1]. The cause for variation in nasal floor topography is still unclear, though recent research suggests a relationship with the development of the anterior dentition[2-4].

Despite the frequency with which this trait has been discussed in the literature, nasal floor shape has never been quantitatively assessed. All prior research has relied on visual scoring methods. Prior researchers[1-3, 5] have employed a 3 category system:

Flat: the nasal floor is level from the inferior border of the piriform aperture to the maximum posterior extent of the palatines
Sloped: the nasal floor is at a slight gradient, being more raised anteriorly
Depressed: the floor exhibits a marked descent just posterior to the piriform aperture

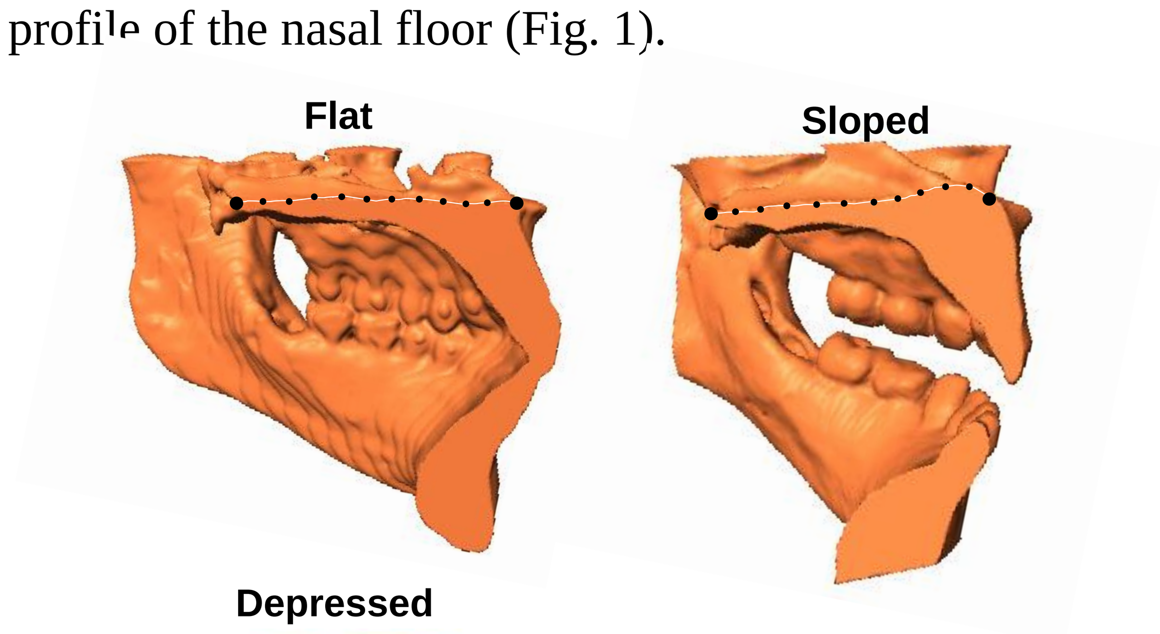
Project Aims

There is reason to believe nasal floor shape is not discrete, but exists along a continuum. Quantification of this trait was previously limited by a lack of technology which allowed for landmarking of internal surfaces and a lack of a methodology with which to quantify curves or surfaces. This project takes a sliding semi-landmark approach to quantifying nasal floor shape to answer the following questions:

1. Is nasal floor configuration a continuous trait?
2. What does a quantitative approach reveal about patterns of nasal floor shape variation?

Materials and Methods

CT scans from medical (UIHC) and museum provenience (Open Research Scan Archive), along with 3D laser scans of two Neandertal specimens, comprise the sample in this project. Scans were sliced in a transverse plane (using Geomagic) to create a lateral profile of the nasal floor (Fig. 1).



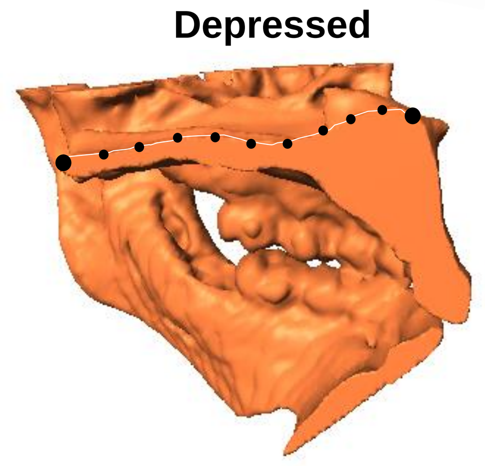


Fig.1 Landmark diagram. Large points are landmarks (anterior and posterior nasal spines), and smaller points represent semi-landmarks. Scans shown are all from UIHC patients (flat: age 19 yrs, sloped: age 5 yrs, depressed: age 3.5 yrs). All images scaled to same size.

A line was digitized using from the anterior-most point of the floor to the posterior-most point using tpsDIG2 (Fig. 1)[6]. Points along the line were treated as sliding semi-landmarks and sliding semi-landmark analysis was performed using the Geomorph package in R[7].

Nasal floor shape was also visually scored using the traditional, qualitative method described by Franciscus[1].

The sample consists of an age- and sex-combined group of subadults extant humans of European, African, and Native American ancestry and includes two Neandertals (Gibraltar 2, 4.25 yrs and Roc de Marsal, 3.0 yrs). Extant human ages ranged from 3.5 years to 20 years old (Table 1).

Table 1. Sample Composition.

Population/Ancestry	n
European	28
Sub-Saharan African	8
North African	1
Native American	1
Ancestry Unknown (extant *H. sapiens*)	3
Neandertal	2
Total	43

A relative warps analysis (RWA) was performed using R. ANOVA was conducted on each of the first 4 RWs using traditional, visual coding of nasal floor configuration as the independent variable. Additional analyses were undertaken to test for for significant shape differences between the three coded categories, using R.

Results

The RWA yielded 24 relative warps, the first 4 of which each represented >5% of the total variation. Of these 4 RWs, only RW1 (p=0.00385) and RW4 (p=0.0158) showed statistically significant differences between the three coded nasal floor configurations (Fig. 2).

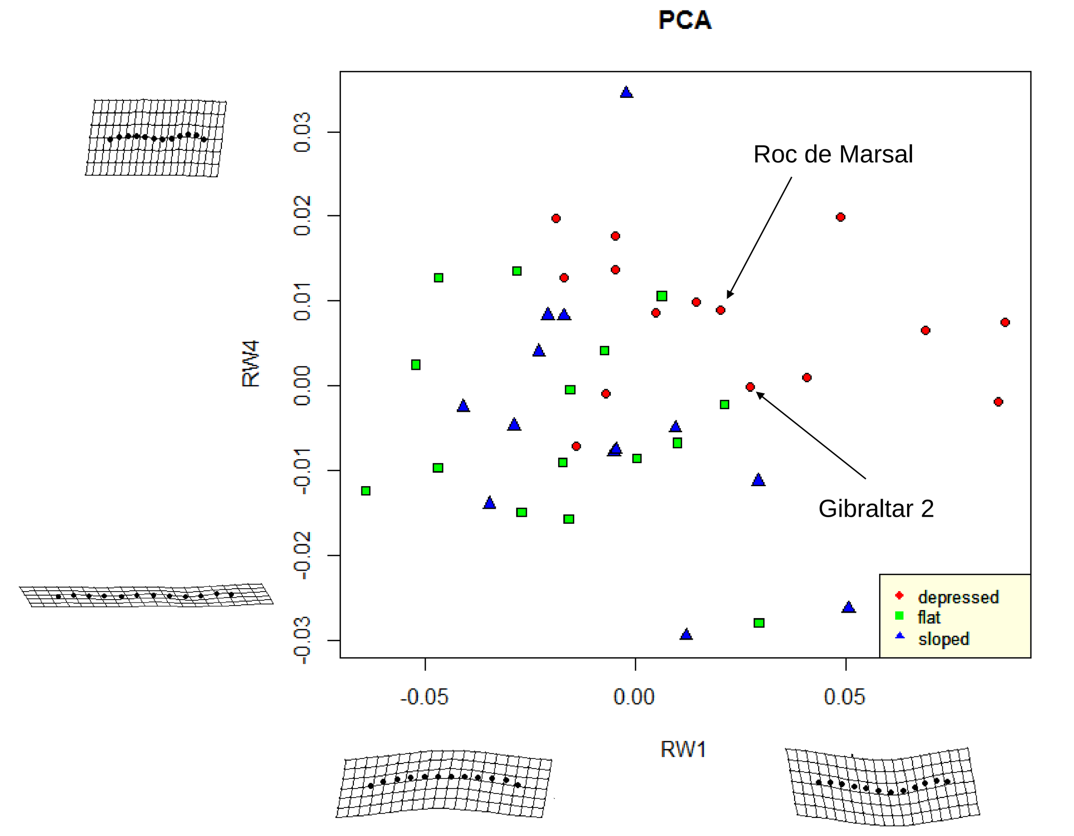


Fig. 2 Scatterplot showing RW1 and RW4. Individuals are labelled by their nasal floor coding. RW1 describes nasal floor curvature related to the presence or absence of a depression or elevation of the pre-palatine maxilla. RW4 describes nasal floor variation that ranges from very flat, to a morphology that displays depression posterior to the pre-maxillary suture.

The pairwise comparisons (Table 2) indicate that flat vs. depressed floors and sloped vs. depressed floors were significantly different along both RW1 and RW4, but sloped vs. flat floors were not.

Table 2 P-values for the pairwise differences between the three nasal floor configurations for RW1 and RW4. For both RWs, sloped and flat floors are not statistically significantly different.

RW1	Depressed	Flat	RW4	Depressed	Flat
Flat	p=0.0012	-	Flat	p=0.011	-
Sloped	p=0.0211	p=0.3441	Sloped	p=0.015	p=0.972

A linear discriminant analysis (Table 3) also shows that sloped was the category that was most likely to be misclassified (most frequently as flat).

Table 3. Linear discriminant analysis: Diagonal, bold-faced numbers indicate how many of each category were classified correctly. Off-diagonal numbers indicate incorrectly classified specimens.

	Depressed	Flat	Sloped
Depressed	**13** (86.7%)	2 (13.3%)	0 (0%)
Flat	3 (20%)	**10** (66.7%)	2 (13.3%)
Sloped	1 (7.7%)	9 (69.2%)	**3** (23.1%)

Discussion

Prior research[1-3,5] has relied upon traditional, visual coding of nasal floor shape that reduces nasal floor variation into three categories. However, our geometric morphometric analysis of nasal floor shape reveals that two of these three categories, flat and sloped, are statistically indistinguishable from one another. Furthermore, variation appears to be arrayed along a continuum, from flat to depressed floors, with a tendency for sloped floor individuals to group with flat ones. All three floor configuration groupings overlap, with differentiation at the extremes.

The two Neandertal specimens included in this analysis were both coded as depressed, and group morphometrically with the extant humans exhibiting depressed nasal floors, near the mean shape for nasal floor depression. This implies that it is appropriate to treat this trait as morphologically homologous across these taxa.

The fact that sloped nasal floors group mostly with flat floors is not unsurprising, given that the difference between them, as per the definitions given in Franciscus[1], is likely a matter of orientation and the current analysis does not take relative orientation into account. Future research which takes orientation of the nasal floor relative to the rest of the facial skeleton into account is necessary to determine whether these two categories are in fact meaningfully different.

References

1. Franciscus, RG. 2003. *J. Hum. Evol.* 44: 699–727.
2. Nicholas, CL, Franciscus RG. 2010. *Am. J. Phys. Anthrop*.
3. Wu, X-J, Maddux, SD, Pan, L & Trinkaus, E. 2012. *Anthropological Science*.
4. Nicholas, CL, Franciscus, RG. n.d.
5. McCollum, MA. 2000. *Am. J. Phys. Anthrop.* 112: 275–283.
6. Rohlf, FJ. 2013.tpsDIG2 verson 2.17
7. Adams, D, Otarola-Castillo. 2012. Package 'geomorph': Geometric morphometric analysis of 2D/3D landmark data.