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Supraorbital morphology and social dynamics in human evolution

Ricardo Miguel Godinho, Penny Spikins, Paul O'Higgins

Supplementary information

Supplementary Table 1.....	3
Supplementary Table 2.....	4
Supplementary Table 3.....	5
Supplementary Table 4.....	6
Supplementary Figure 1.....	7
Supplementary Figure 2.....	8
Supplementary Figure 3.....	10

Supplementary Table 1: applied Muscle Forces (in Newtons).

	Left	Right
Temporalis	168.02	170.67
Masseter	134.06	124.01
Medial pterygoid	124.01	117.49

Supplementary Table 2: landmarks used in the analysis of global deformation.

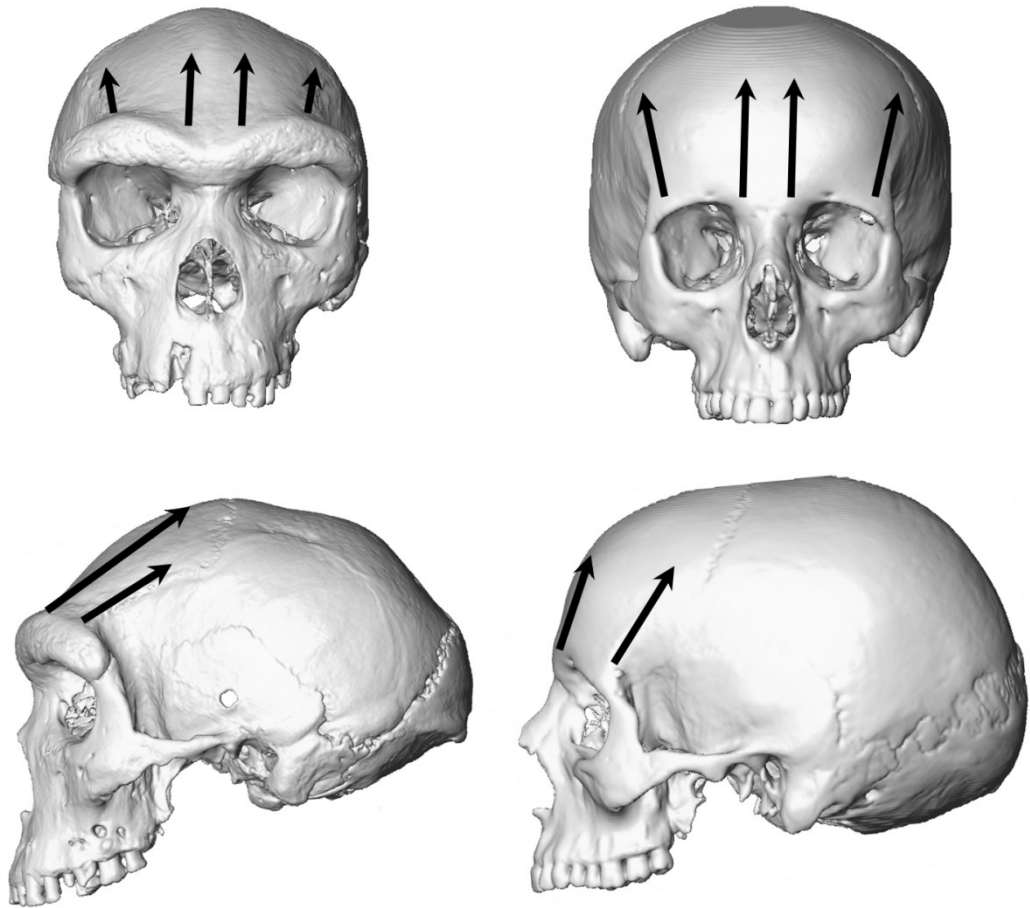
No.	Name	Definition
1	Vertex	Highest point on the midsagittal contour of the calvarium (lateral view in Frankfurt Horizontal).
2	Nasion	Intersection of the frontonasal and internasal suture.
3	Anterior Nasal Spine	Tip of the anterior nasal spine.
4	Prosthion	Most buccal and occlusal point of the interalveolar septum between central incisors.
5	Opisthocranium	Most posterior point of the neurocranium.
6; 7	Supraorbital torus	Most anterior point of the supraorbital ridge.
8; 9	Infraorbitale	Most inferior point of the infraorbital ridge.
10; 11	Nasal notch	Most lateral part of the nasal aperture.
12; 13	Ext. Alv. P4	Most buccal and occlusal point on the distal maxillary alveolus of P4
14; 15	Last molar	Last point of the dental arch, located at the most buccal and distal point of the last present molar and alveolar process.
16; 17	Zygo-temporal inferior	Most inferior point of the zygomatico-temporal suture.
18; 19	Fronto-zygomatic	Most lateral point of the fronto-zygomatic suture.
20; 21	Jugale	Deepest point in the notch between the temporal and frontal processes of the zygomatic bone (in Frankfurt Horizontal).
22; 23	Zygomatic Arch lateral	Most lateral point of the zygomatic arch.
24; 25	Zygomatic Root posterior	Most postero-superior point on the intersection between the zygomatic root and the squama of the temporal bone.
26; 27	Zygomatic Root anterior	Most anterior point on the intersection between the zygomatic root and the squama of the temporal bone.
28; 29	Zygomatic Arch medial	Most lateral point of the inner face of the zygomatic arch (superior view in Frankfurt Horizontal).
30; 31	Infratemporal Crest	Tip of the infratemporal crest.
32; 33	Euryon	Most lateral point of the neurocranium in frontal view.

Supplementary Table 3: examples of uniquely human affiliative expressions based on highly mobile eyebrows.

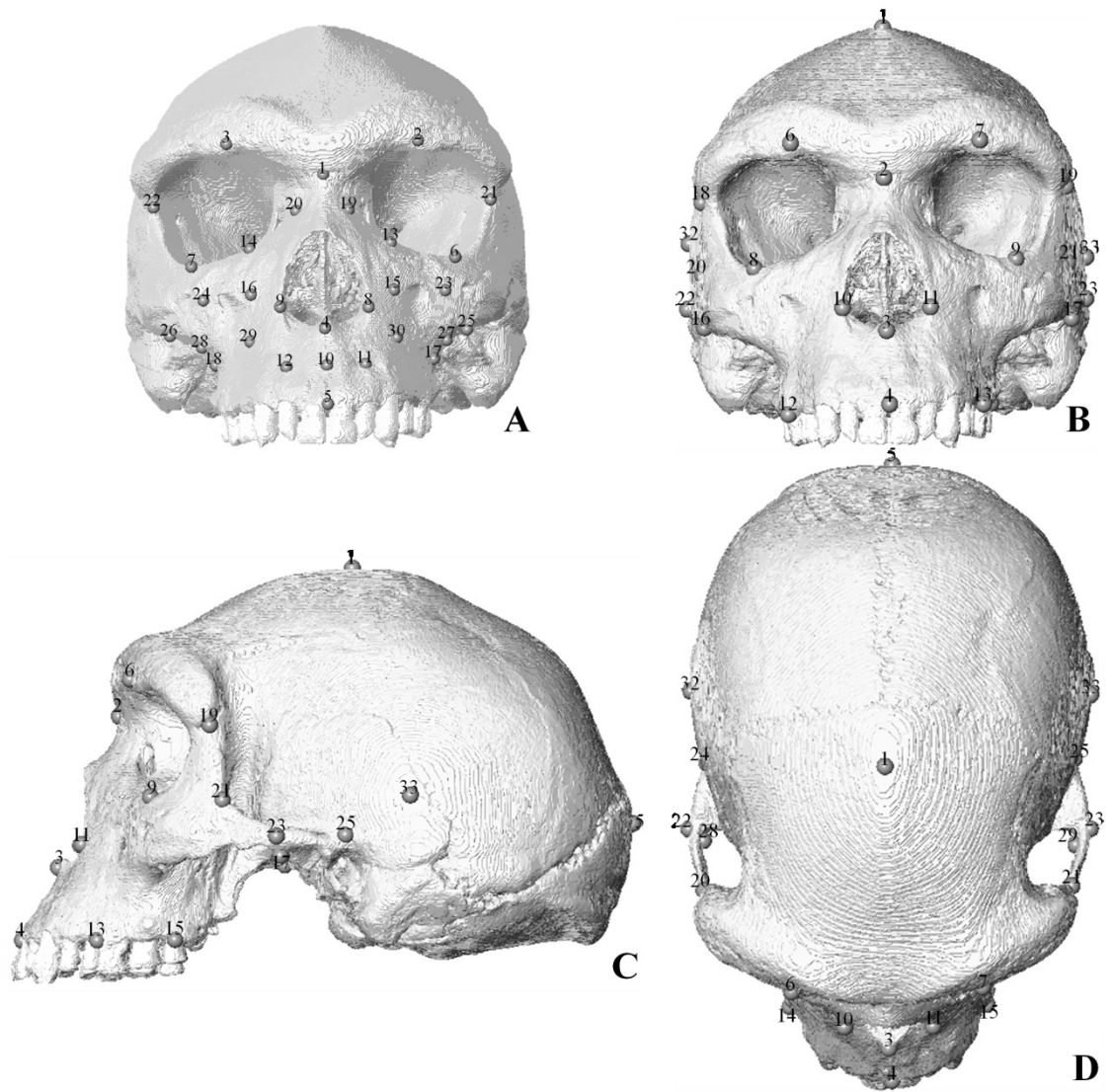
Expression	Description	Reference
Greeting/recognition/contact readiness	'Eyebrow flash' (1/6 th second raise of eyebrows)	Grammer et al. ⁵⁷
Surprise/social indignation	Slow eyebrow raise	Eibl-Eibesfeldt ⁵⁸
Skepticism	Raised outer corner of one eyebrow	Ekman ³
Sympathy	Eyebrows pulled up in the middle	Bavelas et al. ⁵⁹
Trustworthiness/pro-social intention	Dynamic movements of the eyebrows	Helman et al. ⁶¹

Supplementary Table 4: maximum (ϵ_1) and minimum (ϵ_3) principal strains experienced by the models using the original and re-oriented muscle vector directions. Anteroposterior reorientation has a maximum impact of $\sim 5\%$ on average strains. Mediolateral reorientation impacts less than 2%. See anatomical location of landmarks in extended data table 2.

Landmark	ORIENTATION OF MUSCLE VECTORS									
	Original		5° rotation posteriorly		5° rotation anteriorly		5° rotation laterally		5° rotation medially	
	ϵ_1	ϵ_3	ϵ_1	ϵ_3	ϵ_1	ϵ_3	ϵ_1	ϵ_3	ϵ_1	ϵ_3
1	0.43	-0.86	0.53	-0.80	0.33	-0.99	0.29	-0.54	0.57	-1.20
2	10.26	-15.94	7.86	-10.76	12.59	-21.03	10.35	-16.36	10.13	-15.45
3	19.99	-8.55	17.46	-7.48	22.34	-9.55	20.04	-8.57	19.92	-8.52
4	99.27	-170.50	88.99	-152.73	108.76	-186.95	99.59	-170.60	98.75	-170.04
5	0.11	-0.06	0.14	-0.07	0.14	-0.06	0.13	-0.06	0.17	-0.09
6	3.35	-5.73	2.60	-5.17	4.11	-6.28	3.39	-5.81	3.29	-5.62
7	3.33	-3.13	2.85	-2.94	3.79	-3.30	3.37	-3.21	3.27	-3.04
8	31.20	-37.02	30.46	-35.72	31.76	-38.11	31.91	-38.92	30.42	-35.09
9	24.15	-66.27	22.24	-60.87	25.87	-71.14	24.39	-66.83	23.94	-65.72
10	53.26	-143.42	46.81	-126.02	59.30	-159.71	53.01	-142.74	53.38	-143.77
11	49.30	-140.12	43.41	-122.91	54.82	-156.26	49.08	-139.23	49.39	-140.67
12	9.78	-6.26	8.59	-5.65	10.89	-6.83	10.25	-6.44	9.31	-6.07
13	3.15	-6.12	2.67	-5.39	3.61	-6.81	3.44	-6.29	2.89	-5.93
14	7.59	-10.26	7.11	-9.74	8.02	-10.76	7.70	-9.78	7.45	-10.67
15	3.21	-7.53	3.09	-7.32	3.33	-7.74	3.19	-7.34	3.21	-7.67
16	19.15	-47.47	19.57	-49.64	18.66	-45.02	19.60	-48.61	18.62	-46.19
17	18.26	-38.55	20.06	-46.19	17.16	-31.35	18.37	-36.95	18.15	-40.18
18	20.75	-9.55	19.23	-8.42	22.19	-10.66	20.71	-9.49	20.67	-9.56
19	10.76	-16.72	9.56	-14.69	11.90	-18.61	10.59	-16.20	10.92	-17.23
20	138.57	-52.25	121.88	-45.96	154.20	-58.15	132.18	-49.89	144.04	-54.27
21	142.47	-56.13	127.48	-50.34	156.40	-61.50	138.45	-54.55	145.58	-57.35
22	63.74	-147.25	67.27	-161.85	60.39	-132.06	65.41	-147.49	61.92	-146.77
23	49.27	-96.13	49.76	-107.74	49.79	-84.93	50.89	-94.14	47.61	-98.11
24	24.00	-51.08	22.48	-49.90	25.40	-52.13	23.79	-51.05	24.06	-50.81
25	23.81	-40.88	22.72	-39.67	24.77	-42.05	23.87	-41.24	23.62	-40.30
26	29.61	-22.47	30.67	-21.76	28.59	-23.16	29.04	-22.46	30.18	-22.37
27	110.70	-38.71	116.73	-40.46	104.63	-37.27	108.23	-37.94	112.76	-39.31
28	80.53	-229.40	84.41	-234.10	76.93	-224.29	86.92	-248.91	73.85	-208.80
29	78.56	-225.62	82.03	-235.64	74.64	-214.21	80.51	-230.29	76.32	-220.06
30	5.18	-13.53	4.52	-11.84	6.88	-15.81	5.42	-13.94	4.90	-13.02
31	10.11	-5.04	7.92	-5.46	12.71	-4.95	11.88	-5.10	8.41	-5.07
32	9.10	-9.02	9.45	-9.27	8.68	-8.70	8.65	-9.09	9.50	-8.89
33	9.15	-9.52	9.45	-9.88	8.79	-9.14	8.69	-9.67	9.56	-9.33
Max	142.47	-0.06	127.48	-0.07	156.40	-0.06	138.45	-0.06	145.58	-0.09
Min	0.11	-229.40	0.14	-235.64	0.14	-224.29	0.13	-248.91	0.17	-220.06
Mean	37.28	-56.02	35.36	-55.20	39.11	-56.68	37.20	-57.11	37.21	-55.07
Difference in mean (%)			94.86	98.55	104.93	101.19	99.79	101.95	99.83	98.31



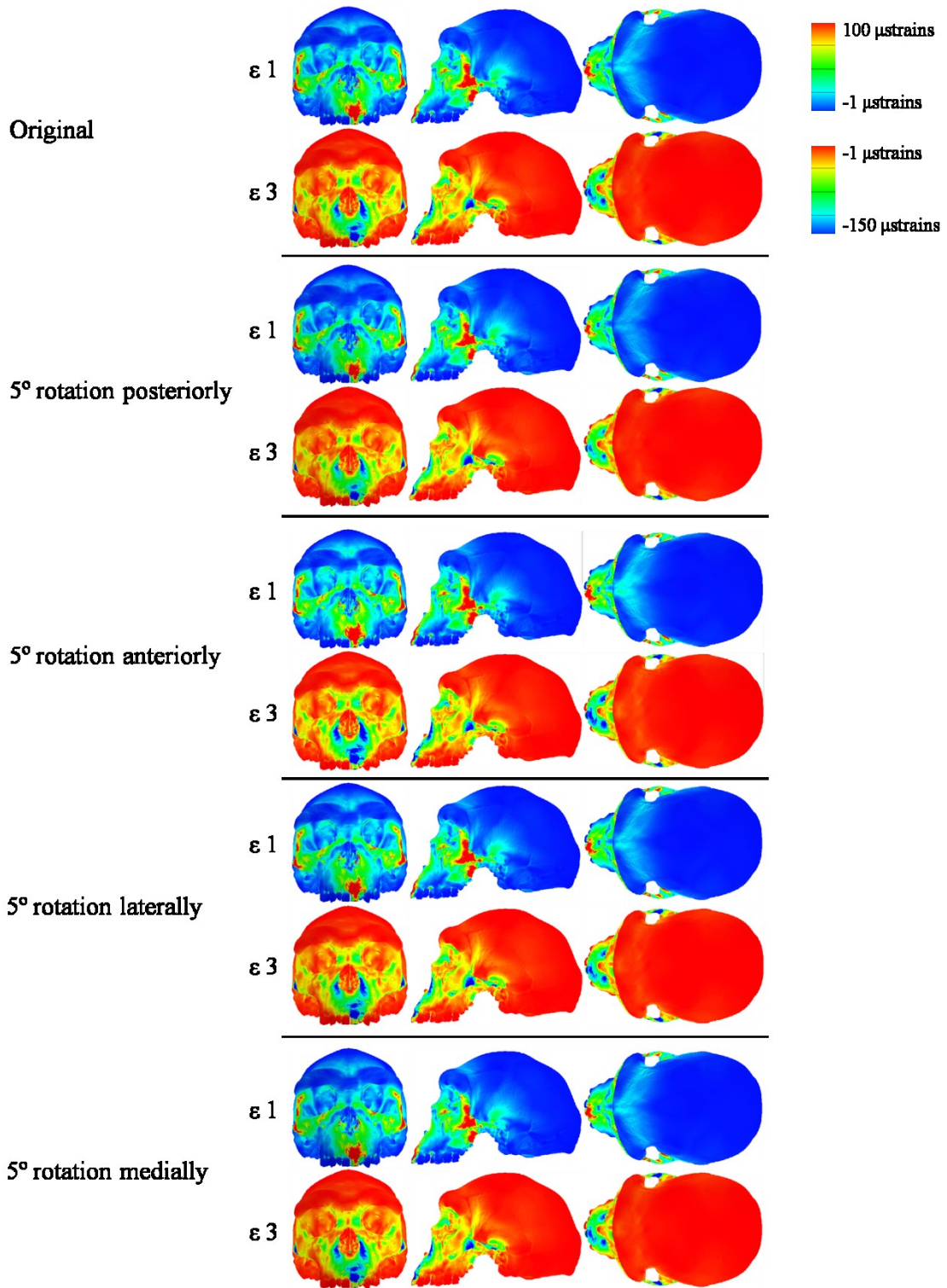
Supplementary Figure 1: Comparison of frontalis muscle vectors orientations. Note the more horizontal orientation of the vectors in Kabwe 1 and the more vertical orientation in the modern human.



Supplementary Figure 2: depiction of the (A) 30 points placed on the facial skeleton to extract ϵ_1 and ϵ_3 and of the (B, C, D) 33 cranial landmarks used for the global analysis of deformation (see extended data table 2 for landmark identification and description).

Orientation of muscle vectors

Strain contour plots



Supplementary Figure 3: Maximum (ϵ_1) and minimum (ϵ_3) principal strain contour plots of the sensitivity analysis of errors in muscle vector orientations. The results compare the original estimated directions using the Tabun 1 mandible with different orientations in which the vectors were redirected 5° posteriorly, 5° anteriorly, 5° laterally and 5° medially. Re-orientation of the vectors has a relatively small impact in strains. Extended data table 4 presents the strain magnitudes.