Shape analysis of the human zygomatic bone - data evaluation

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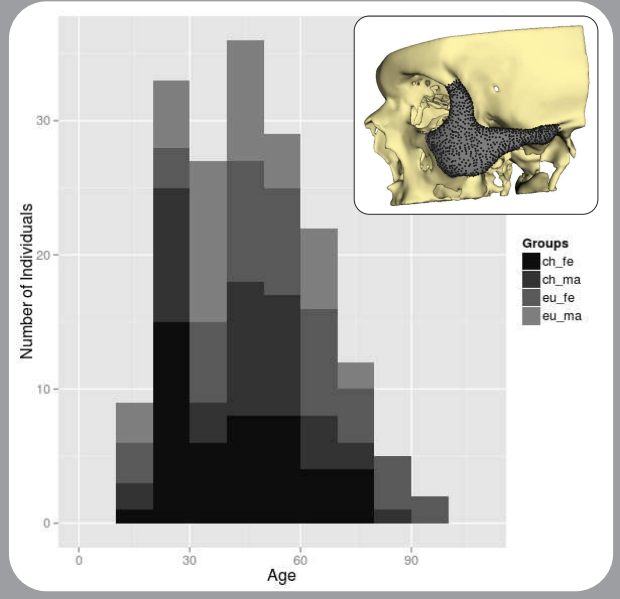

Fig. 1: Age distribution of the four subgroups Chinese female (ch_fe: n=46), Chinese male (ch_ma: n=41), European female (eu_fe: n=47), and European male (eu_ma: n=41).

Introduction

Shape variation of the zygomatic bone is crucial in forensic facial reconstruction, reconstructive surgery and evolutionary studies. We analysed the shape of the left zygomatic bone, depending on the factors population affinity and sex, with a dense set of homologous points obtained by semi-automatic surface registration. This method can describe the whole shape of an object, which could not be achieved by manually placed landmarks.

Materials and Methods

Materials

The raw data consisted of 200 surface meshes representing the left human zygomatic bone. Shape analysis was performed with 1559 homologous 3D-coordinates of 175 datasets (Fig. 1), a result from semi-automatic surface registration[1].

Methods

After a Procrustes Fit, Principal Component Analysis was performed to reduce dimensionality. MANOVA and permutation tests were carried out on the first 20 PCs which account for 90% of total shape variance. 50-50 MANOVA (Langsrud 2002) is suitable for testing group differences in highly correlated data. Between-group PCA (Mitteroecker and Bookstein 2011) allows the evaluation of the prediction of group affinity. All analyses were carried out with the statistical environment "R"[2].

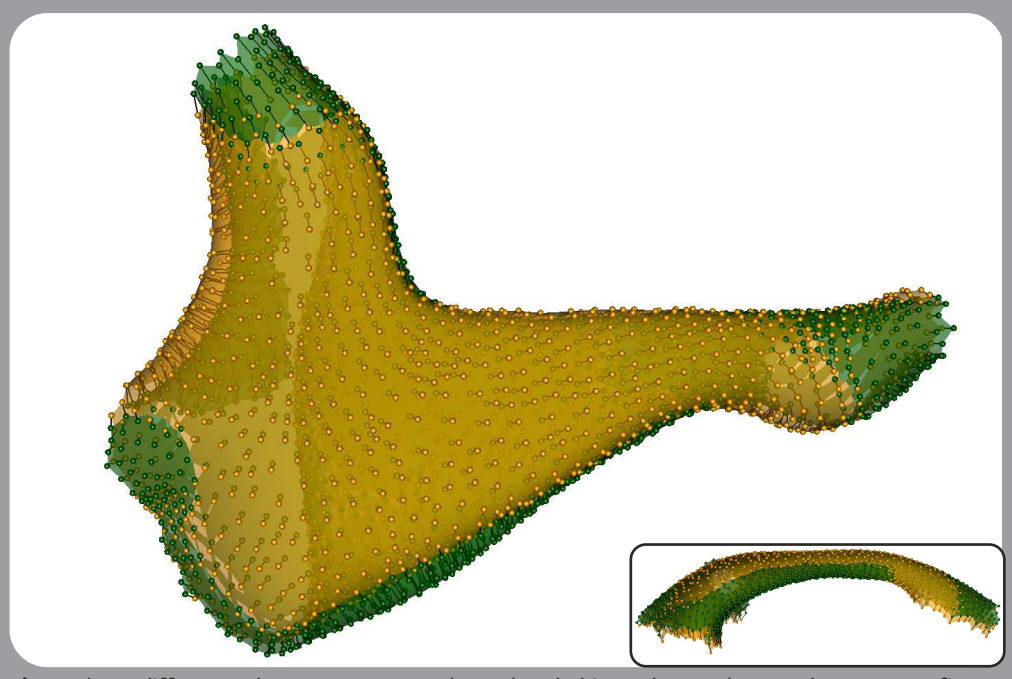

Fig. 2: Shape differences between European (Green) and Chinese (Orange) mean shapes. Large figure: Lateral view. Small figure: Inferior view.

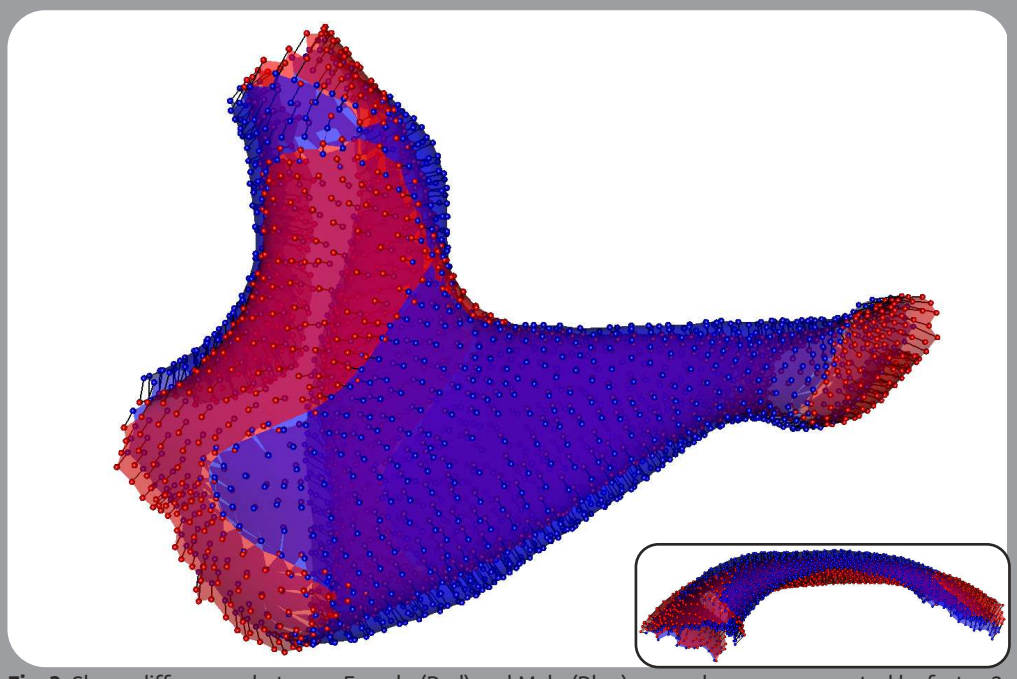

Fig. 3: Shape differences between Female (Red) and Male (Blue) mean shapes, exaggerated by factor 2. Large figure: Lateral view. Small figure: Inferior view.

Results

Population affinity and sex both show significant influence on the shape of the zygomatic bone (Table 1, Fig. 2 and Fig. 3). The interaction between the two, though, does not. Shape differences between European females and males do not differ significantly from those between Chinese females and males. Between-group PCA achieved a clear separation of populations, whereas sexes are not very distinct (Fig. 4).

Groups	MANOVA	50-50 Manova	Permutation test
Pop	< 2e-16 ***	< 2e-16 ***	1e-04 ***
Sex	< 2e-16 ***	6.24e-07 ***	5e-04 ***
Pop*Sex	0.5259	0.235	Angle: 0.251
			Distance: 0.936

Table 1: P-Values of different methods testing for shape differences between the groups "European vs. Chinese" (Pop), "Female vs. Male" (Sex), and the interaction between Population affinity and sex (Pop*Sex).

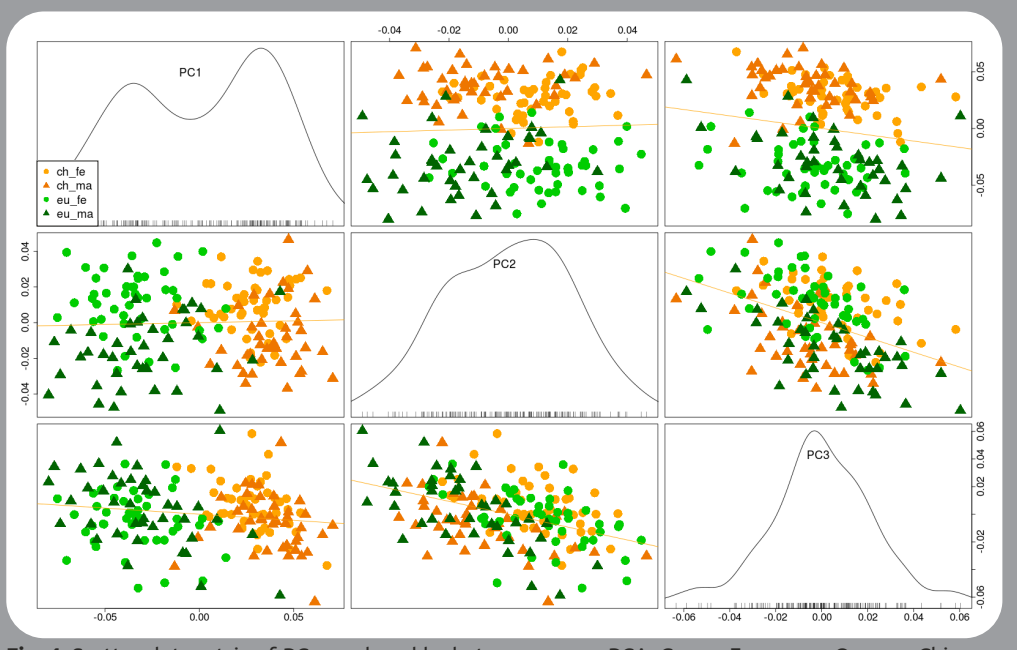

Fig. 4: Scatterplot matrix of PCs produced by between-group PCA. Green: European, Orange: Chinese, Circles: Female, Triangles: Male.

Conclusion

Shape analysis of the zygomatic bone with 1559 homologous coordinates showed significant shape differences due to population affinity and sex. Shape differences between mean European and mean Chinese zygomatic shape are clearly visible. Sexual dimorphism is similar in both populations and not as distinct as population differences.

References

Mitteroecker, P. and Bookstein, F. 2011. Linear discrimination, ordination, and the visualization of selection gradients in modern morphometrics. Evolutionary Biology, 38:100–114.

Langsrud, O. 2002. 50-50 multivariate analysis of variance for collinear responses. Journal of the Royal Statistical Society: Series D (The Statistician), 51(3):305–317.

Footnotes

[1]See S. Schlager, A. Rüdell, "Shape analysis of the human zygomatic bone - surface registration", Poster no. 9 at this session (47).

[2]mainly with the package "Morpho" by S. Schlager: https://sourceforge.net/p/morpho-rpackage/

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