Growth assessment in single-suture craniosynostoses using geometric morphometrics : similarities and differences with Jean Delaire's cephalometric principles

Kevin BLOCH[1,2], Maya GEOFFROY[2], Eric ARNAUD[3], Giovanna PATERNOSTER[3], Sebastien LAPORTE[2], Roman KHONSARI[1]

Institutions :

- [1]Assistance Publique—Hôpitaux de Paris, Hôpital Necker—Enfants Malades, Service de Chirurgie Maxillofaciale et Chirurgie Plastique, Université de Paris; Paris, France
- [2] Arts et Métiers ParisTech, Institut de Biomécanique Humaine Georges Charpak, Paris, France
- [3] Assistance Publique—Hôpitaux de Paris, Hôpital Necker—Enfants Malades, Service de Neurochirurgie pédiatrique, Université de Paris; Paris, France

Introduction. Trigonocephaly is a single-suture craniosynostosis characterized by the premature closure of the metopic suture. Shape assessment in this condition using Delaire's analysis is challenged at two levels: the very young age of the patients and their severely deformed skull. The objective of this article was to evaluate tri-dimensional shape variability in trigonocephaly using innovative morphometric methods.

Method : 90 preoperative CT-scans of trigonocephaly patients from Necker Hospital were included. After segmentation, a dense correspondence was established between each skull and a skull template using a Non Rigid Iterative Closest Point Algorithm. Principal Component Analysis was applied on the registered cohort.

Results : 10 Principles components explained 95,74% of the variation of the skulls.

PC1 explained 64,06% of the variability of the shapes. PC1 modeled the variation of size of the skulls (Fig. 1.a). There was a homothetic variation of the skull size when varying PC1 along three Standard Deviation (SD) around mean values (Fig. 1.b). There was a correlation between this mode and age ($r = 0,71$, $p < 0,001$).

PC2 explained 11,31% of shape variations. It represented the overall shape of the skulls. The synthetic mesh at +3SD had a longer and thinner head whereas the synthetic mesh at -3SD had a shorter head but larger inter-parietal width.

Conclusion : We provide the largest study statistically analyzing the tridimensional shape variability of pre-operative trigonocephaly skulls.

Geometric morphometric is an alternative method for assessing the global architecture of the skull based on main directions of variations. In this prospect, our approach shares similarities with Delaire's principles in that the description of individual variations do not rely on comparisons with absolute values but on the assessment of global deformations.