

Development of a Craniofacial Soft Tissue Anthropomorphic Database: Application of Diffeomorphic Algorithms to MRI

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INTRODUCTION

- Craniofacial surgery requires reconciliation of cephalometric, anthropomorphic, cultural, and experience-based factors for deformity reconstruction and aesthetic enhancement.
- In the pediatric population, assessing short- and long-term postoperative outcomes may prove particularly challenging due to rapid craniofacial growth, often anticipated with surgical “overcorrection.”
- Despite attempts to ameliorate subjectivity bias, feasible objective mechanisms for quantifying craniofacial surgical results have yet to be implemented on a large scale.
- In this study, the authors present data in developing a racially and ethnically sensitive anthropomorphic database to provide plastic and craniofacial surgeons with a set of “normal” anatomic measurements to optimize aesthetic and reconstructive outcomes.

OBJECTIVES

- Objectify craniofacial dysmorphology and outcomes by creating three-dimensional composite templates of “normal” craniofacial anatomy by age, sex, and race.

METHODS

- A list of head MRIs from 2008 to 2021 at the authors’ institution was retrospectively reviewed.
- Patients were included if they received a 3T head MRI for indications without craniofacial implication and had no preexisting pathology altering craniofacial and soft tissue structures.
- T1-weighted images were obtained at 3T (TIM Trio; Siemens Medical Solutions, Erlangen, Germany) at 1 mm³ isotropic resolution. Each of the MRI images were thresholded and manually corrected by an expert using ITK-SNAP (Figure 1).

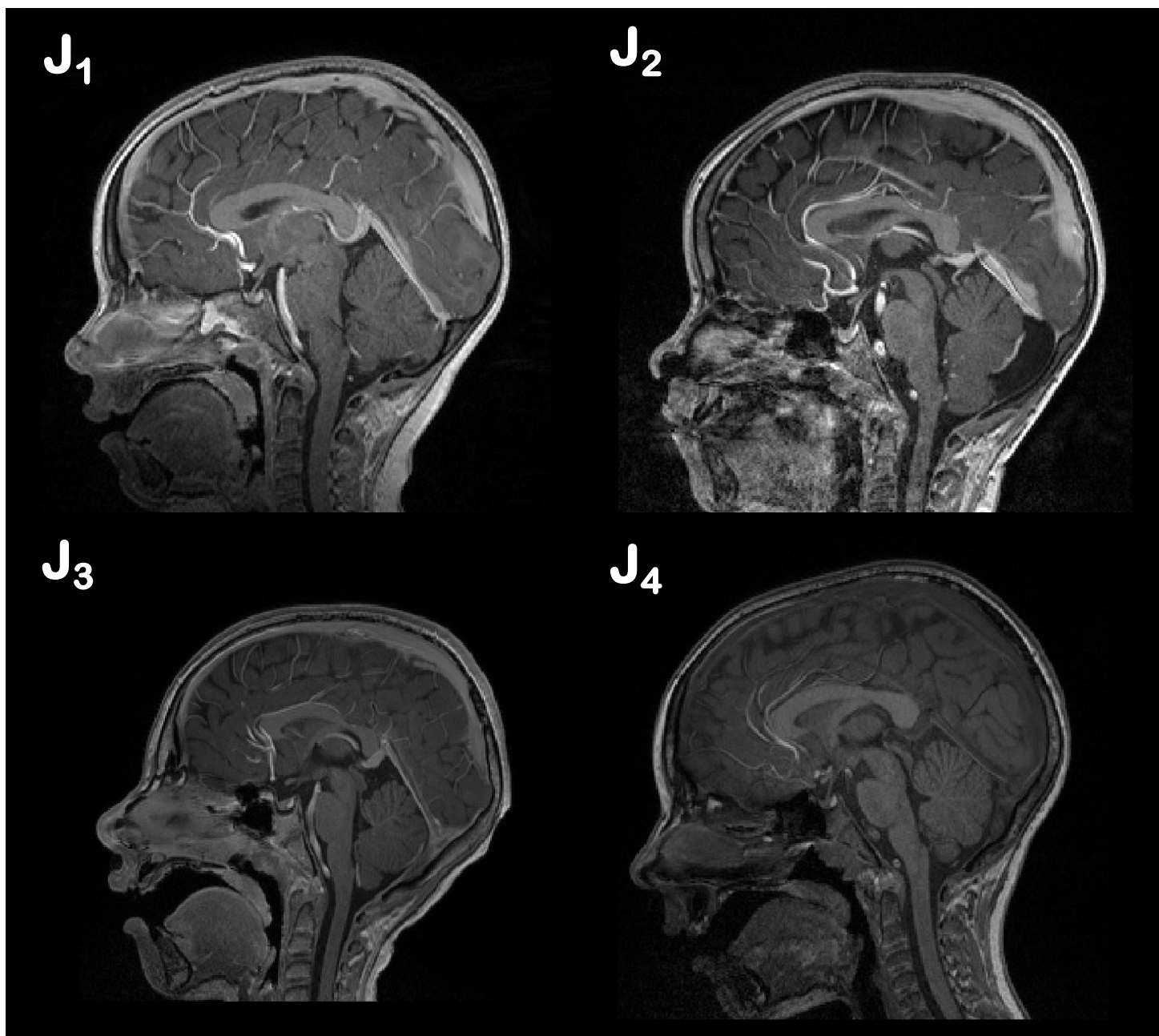


Figure 1. Sample images of subjects used to create a template ($J_1, J_2, \dots, J_4$)

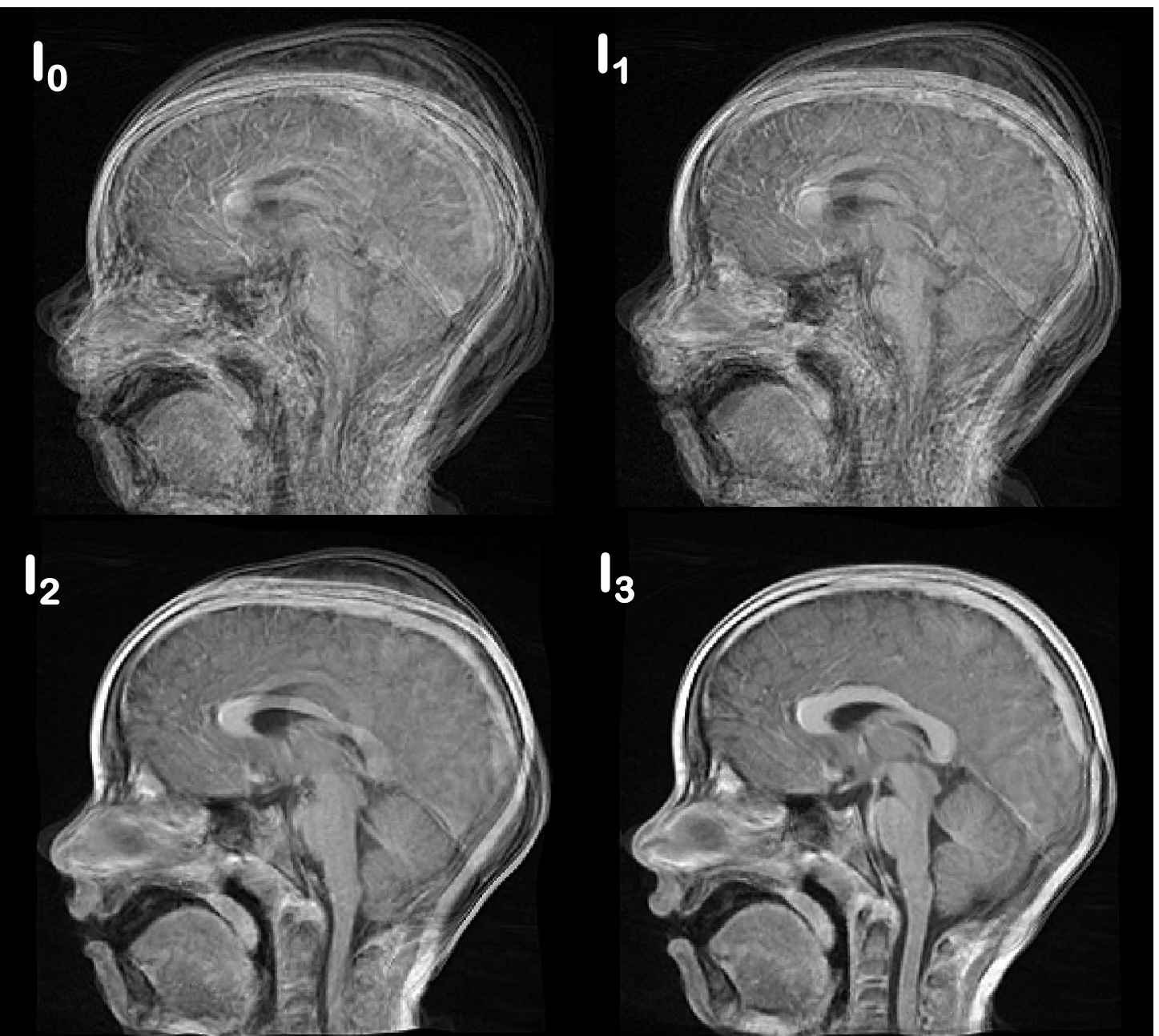


Figure 2. Demonstration of iterative template ($I_0, I_1, \dots, I_3$) creation steps

- Images were used to construct template (composite) images with Advanced Normalization Tools (ANTs) and Greedy Tools.

- The algorithms were based on both symmetric diffeomorphic image registration with cross-correlation and a diffeomorphic image averaging approach, alternating between averaging all image intensity and registering all images to the intensity average.

- The template creation approach was as follows: I_0 was initialized to arithmetic mean of $J_1, J_2, \dots, J_N$ (Figure 1).

- For $m = 0 \dots M$, where “m” is the loop iteration, each image J_i was registered to I_m . Each image J_i was deformed to obtain $\hat{J}_i$, and the new mean template “ I_{m+1} ” was constructed using $\hat{J}_i^m$ (Figure 2).

- Template MRIs were thresholded to generate binary segmentations and used to generate quantitative anatomic renderings in Materalise Mimics v23 (Materalise, Ghent, Belgium)⁵ (Figure 1, lower right).

RESULTS

	Head circumference	Lateral canthus to lateral canthus	Nasion to nasal tip	Right ear height	Left ear height
Seven-year-old	52.87 cm	88.09 mm	26.99 mm	60.99 mm	60.87 mm
Eight-year-old	53.88 cm	90.71 mm	31.42 mm	61.02 mm	61.67 mm

Table 1 | Selected average anatomic values from composites of seven- and eight-year-old male, female, black, and white composites

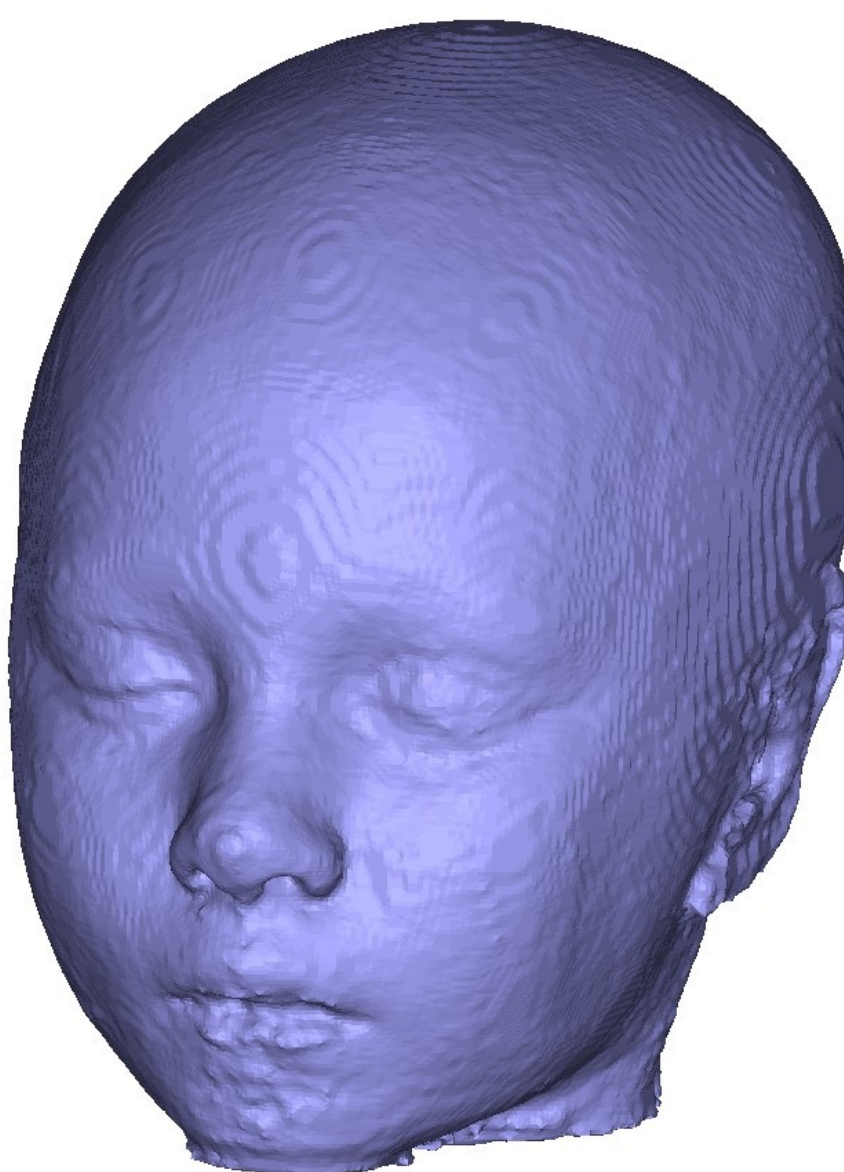
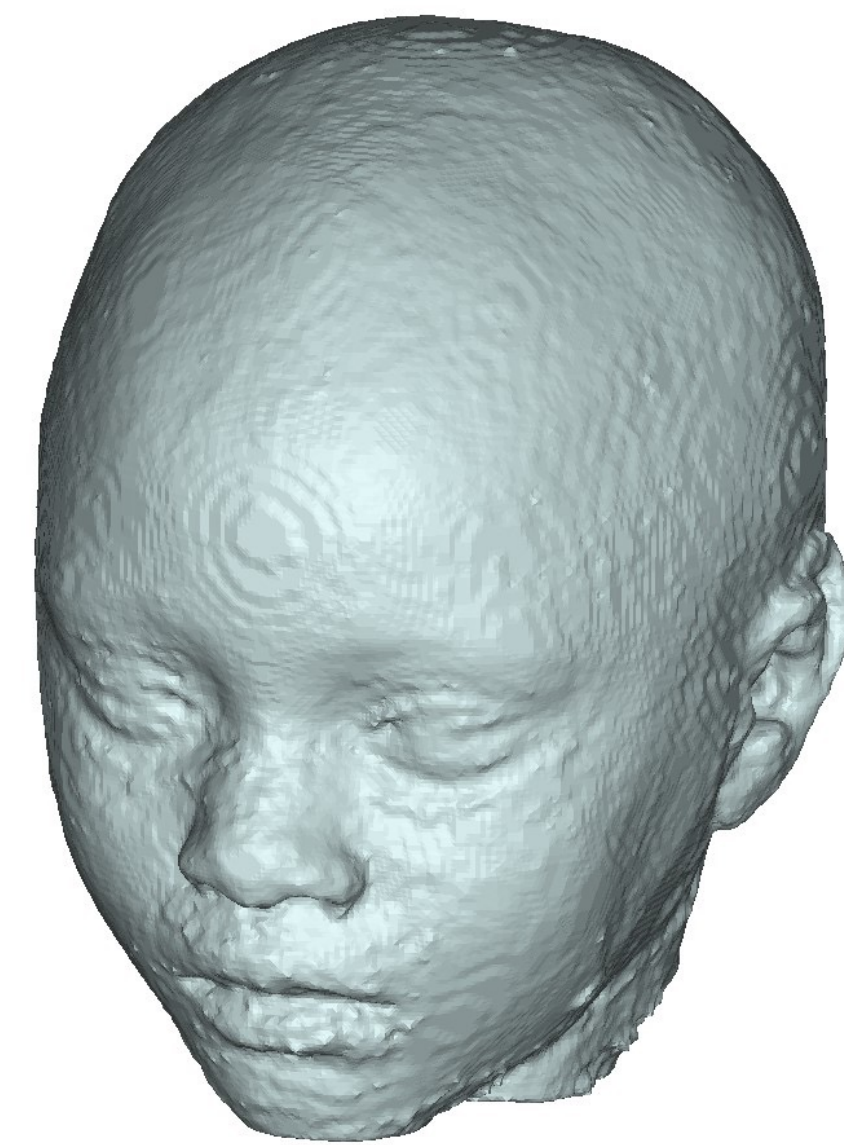


Figure 3. Sample resultant template images of seven-year-old white female (top) and eight-year-old black female (bottom)

FUTURE DIRECTIONS

- Fortification of database
- Development of mathematical tools to characterize anatomic normality
- Generation of indices to grade preoperative severity
- Quantification of postoperative surgical results to reduce subjectivity bias

CONCLUSION

- Application of diffeomorphic algorithms via ANTs to MRI is effective in creating composite templates to represent “normal” craniofacial and soft tissue anatomy, which may aid in assessing short- and long-term postoperative outcomes.
- Future research into methods to objectify craniofacial dysmorphology and postoperative results is warranted.