

Development of Surface-Based Craniometrics for Assessing Regional and Global Shape Abnormalities in Sagittal Craniosynostosis

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INTRODUCTION

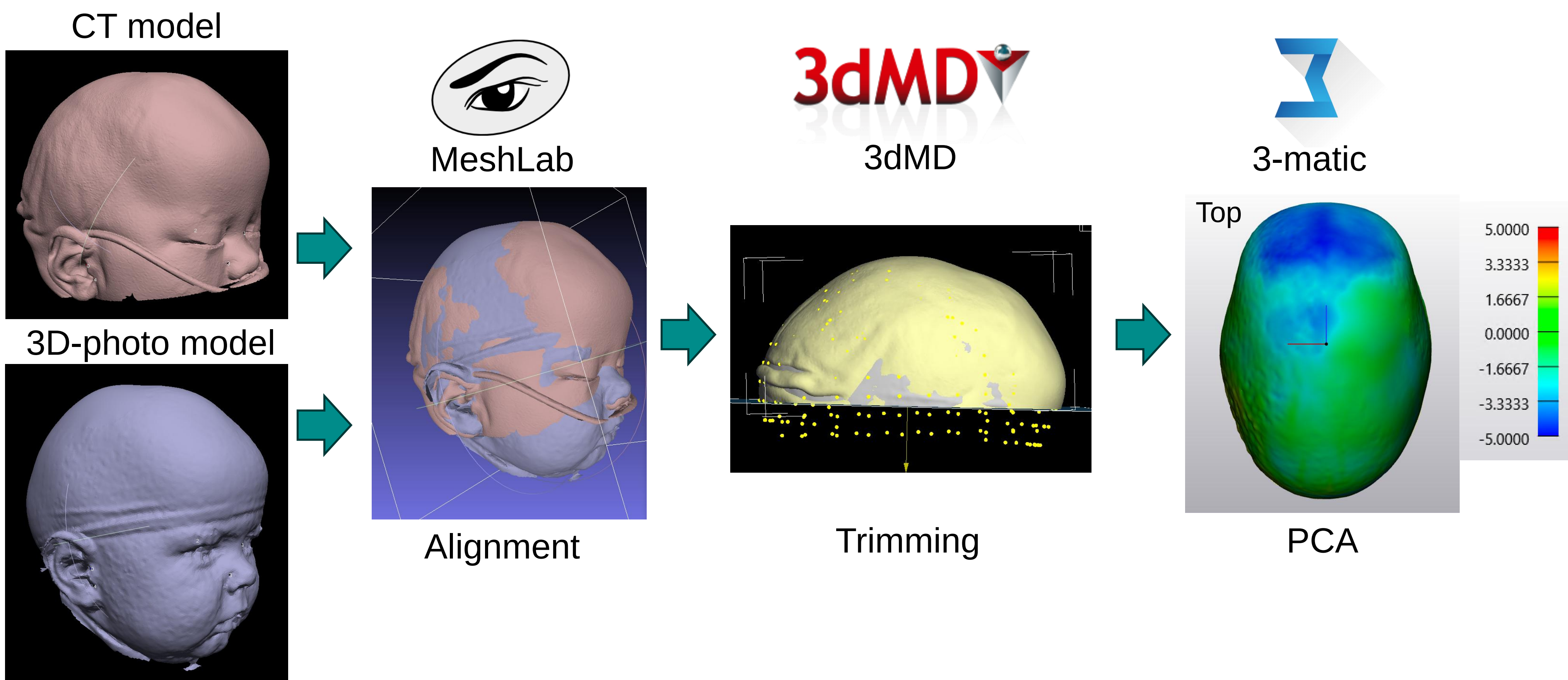
- Traditional 2D indices like the cephalic index fail to capture the regional complexity of head shape abnormalities in sagittal craniosynostosis.
- Surface-based indices, derived from 3D photogrammetry or CT-derived skin surfaces, offer an objective and non-invasive approach for evaluating cranial morphology.
- This study validates a pipeline for surface-based craniometric assessment and compares 3D photographic models to CT-derived models.

Objectives

- To validate surface-based indices for quantifying regional and global cranial shape abnormalities in sagittal craniosynostosis.
- To assess the agreement between CT-derived and 3D photogrammetry-derived models using part comparison analysis (PCA).

METHODS

- Ten patients with sagittal craniosynostosis were analyzed using both CT and 3D photogrammetry within an average of 9.5 days between scans.
- CT DICOMs were converted to STL skin models using **Mimics 24.0** (Materialise, Leuven, Belgium); 3D photographs acquired using **3dMD** (3dMD Inc., Atlanta, GA, USA) were exported as OBJs.
- Models were rigidly aligned using **MeshLab 2023.12**, and PCA was performed in **3-matic 16.0** (Materialise, Leuven, Belgium) to assess surface deviation.
- All models were trimmed at the level of Axial Plane 0—defined by the nasion and bilateral trignon—using **3dMD**, following a standardized cranial alignment method.
- Previously developed indices (**FBI**, **OBI**, **VNI**, **SCI**) were applied to both CT and 3D photo datasets to compare diagnostic utility and modality agreement.



RESULTS

	Sex	Age at CT (months)	Age at 3dMD (months)	Date Difference (days)	PCA Average (mm)	PCA Std Deviation (mm)	% within ±5 mm
Patient 1	Female	5.2	5.1	3	0.53	0.73	100%
Patient 2	Male	2.2	2.0	4	-0.56	2.08	98%
Patient 3	Male	4.5	4.7	6	0.61	0.77	100%
Patient 4	Male	7.1	6.9	7	-0.10	1.07	100%
Patient 5	Male	4.6	4.3	7	-1.37	1.54	100%
Patient 6	Male	3.9	3.5	12	-0.19	1.28	100%
Patient 7	Male	5.3	4.9	14	-0.31	1.30	100%
Patient 8	Male	2.6	2.1	14	-1.03	1.57	100%
Patient 9	Female	2.4	2.0	14	-0.39	1.17	100%
Patient 10	Female	4.7	4.2	14	-0.23	0.86	100%
Average	7:3 M:F	4.2	4.0	9.5	-0.31	1.24	99.8%

- PCA demonstrated a mean surface deviation of **-0.31 mm (±1.24 mm)** between CT and 3D photogrammetry, with **99.8%** of surface points falling within ±5 mm.
- SCI values derived from both modalities showed high correlation ($r = 0.96$), confirming consistency.
- Previously validated performance of these indices includes:
 - FBI: 93.5% sensitivity, 92.9% specificity
 - OBI: 74% sensitivity, 61% specificity
 - VNI: 91.2% sensitivity, 92.2% specificity.
 - SCI: >99% sensitivity and specificity

CONCLUSIONS

- Surface-based indices offer a robust, objective method for evaluating both regional and global shape deformities in sagittal craniosynostosis.
- High concordance between CT and 3D photo-derived models supports the use of 3D photogrammetry as a reliable, radiation-free alternative for cranial shape assessment.
- These indices may enhance clinical decision-making, surgical planning, and long-term outcome tracking in pediatric craniofacial care.

REFERENCES

- Bins, G. P., et al. (2022). "Measure of frontal morphology in sagittal craniosynostosis: The frontal bossing index." *FACE* 3(3): 396–402.
- Bins, G. P., et al. (2023). "A new measure of posterior morphology in sagittal craniosynostosis: The Occipital Bullet Index." *Pediatr Neurosurg.* 2023;58(6):383-391.
- Bins, G. P., et al. (2023). "Creation of the Scaphocephalic Index: Measurement of global and regional severity in scaphocephaly." *Plast Reconstr Surg.* 2024 Aug 1;154(2):335e-347e.
- Cignoni, P., et al. (2008). "MeshLab: an open-source mesh processing tool." *Eurographics Italian Chapter Conference*: 129–136.
- Hussien, D. A., et al. (2019). "Stereo photogrammetry vs computed tomography for 3D medical measurements." *Karbala Int J Mod Sci* 5(4): 2.
- Abdel-Alim, T., et al. (2021). "Three-dimensional stereophotogrammetry in the evaluation of craniosynostosis: Current and potential use cases." *J Craniofac Surg* 32(3): 956–963.