



CranioRate™: An Image-Based, Deep-Phenotyping Analysis Toolset, Repository, and Online Clinician Interface For Craniosynostosis

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Background

- There is currently no objective, clinical tool for evaluating morphologic severity of craniosynostosis holistically.
- Current craniometric measurements fail to capture the multidimensional variations in normal and pathological head shape which are relevant to treatment planning and prognosis.
- Deep phenotyping is defined as the precise and comprehensive analysis of phenotypic abnormalities in which the individual components of the phenotype are observed and described.
- Herein, we present severity data of a large population of patients with metopic craniosynostosis evaluated using CranioRate™, a point of care machine learning-based deep phenotyping tool.
- Objective, quantitative deep phenotypes of preoperative cranial morphology will empower clinicians with the ability to risk stratify their patients with craniosynostosis and thereby determine if, when, and how to intervene.

Methods

- Each scan was processed using the CranioRate™ algorithm, which generates two unique severity scores: Metopic Severity Score (MSS) and Cranial Morphology Deviation (CMD).
- MSS is specific to metopic synostosis and quantifies the severity of deviation from the normal head shape in the “metopic direction”; in other words, MSS quantifies the “metopic-ness” of a patient, where the score is scaled so that 0 represents an average normal control and 10 represents the most severely metopic patient in our dataset.
- By comparison, CMD is a non-specific measure of head shape that simply quantifies the deviation from normal in any direction.
- Alpha and beta testing of the CranioRate™ online portal (craniorate.org) were conducted over a two-year period (2020-2021) to evaluate the user interface and output metrics.

Results

Figure 1: MSS Values for 6 Representative Skulls

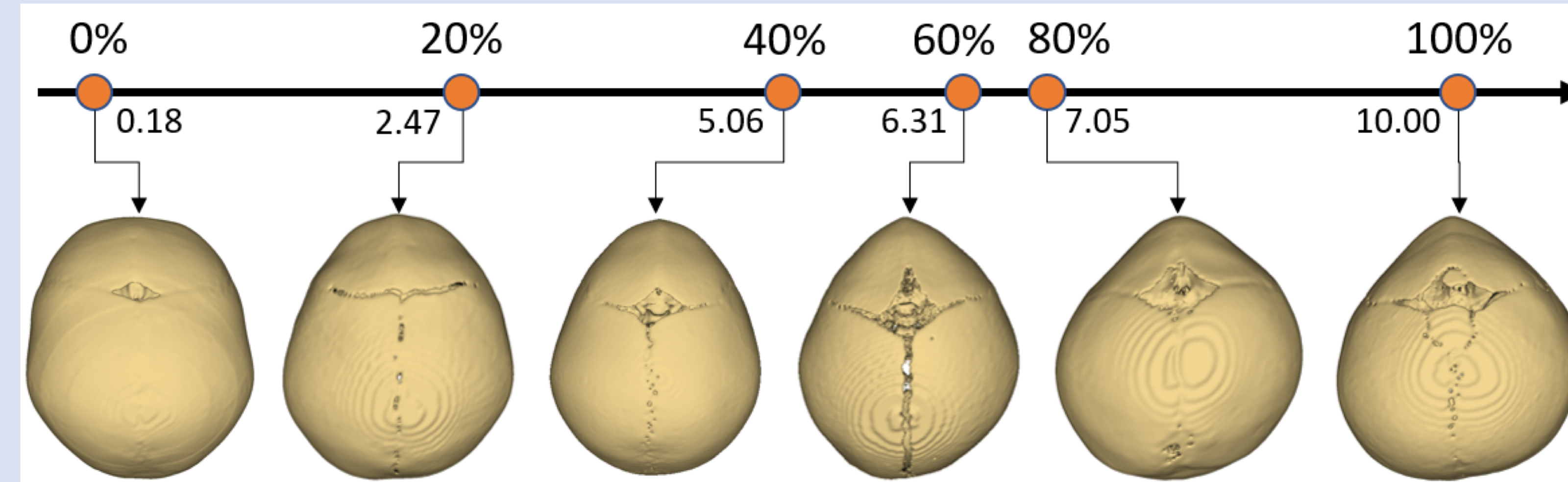


Figure 4: Online Point-of-Care Interface (craniorate.org)

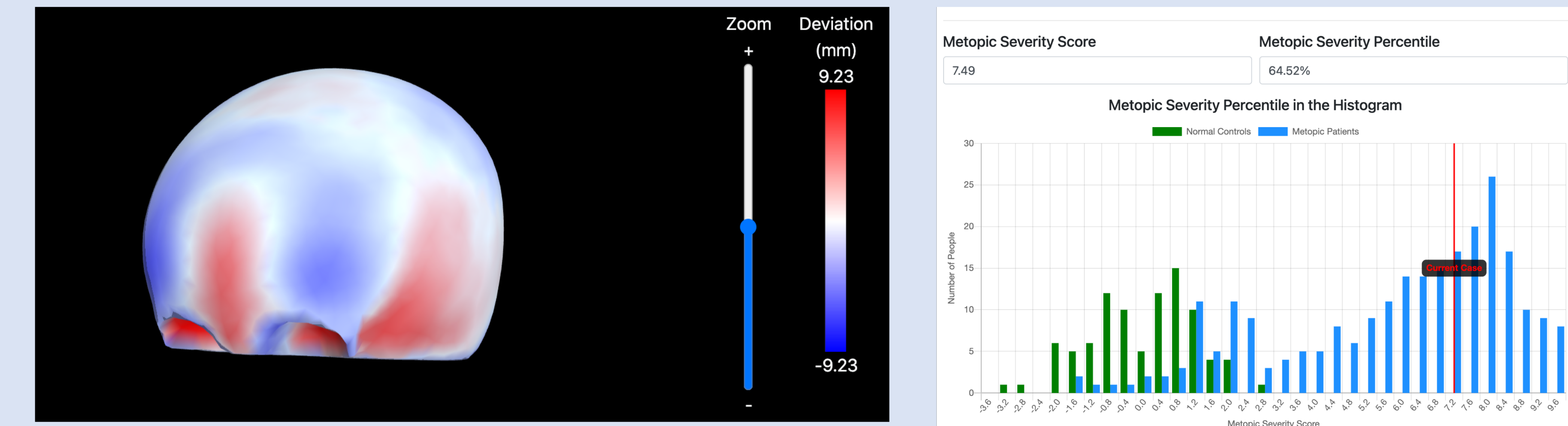


Figure 2: MSS and CMD Distributions

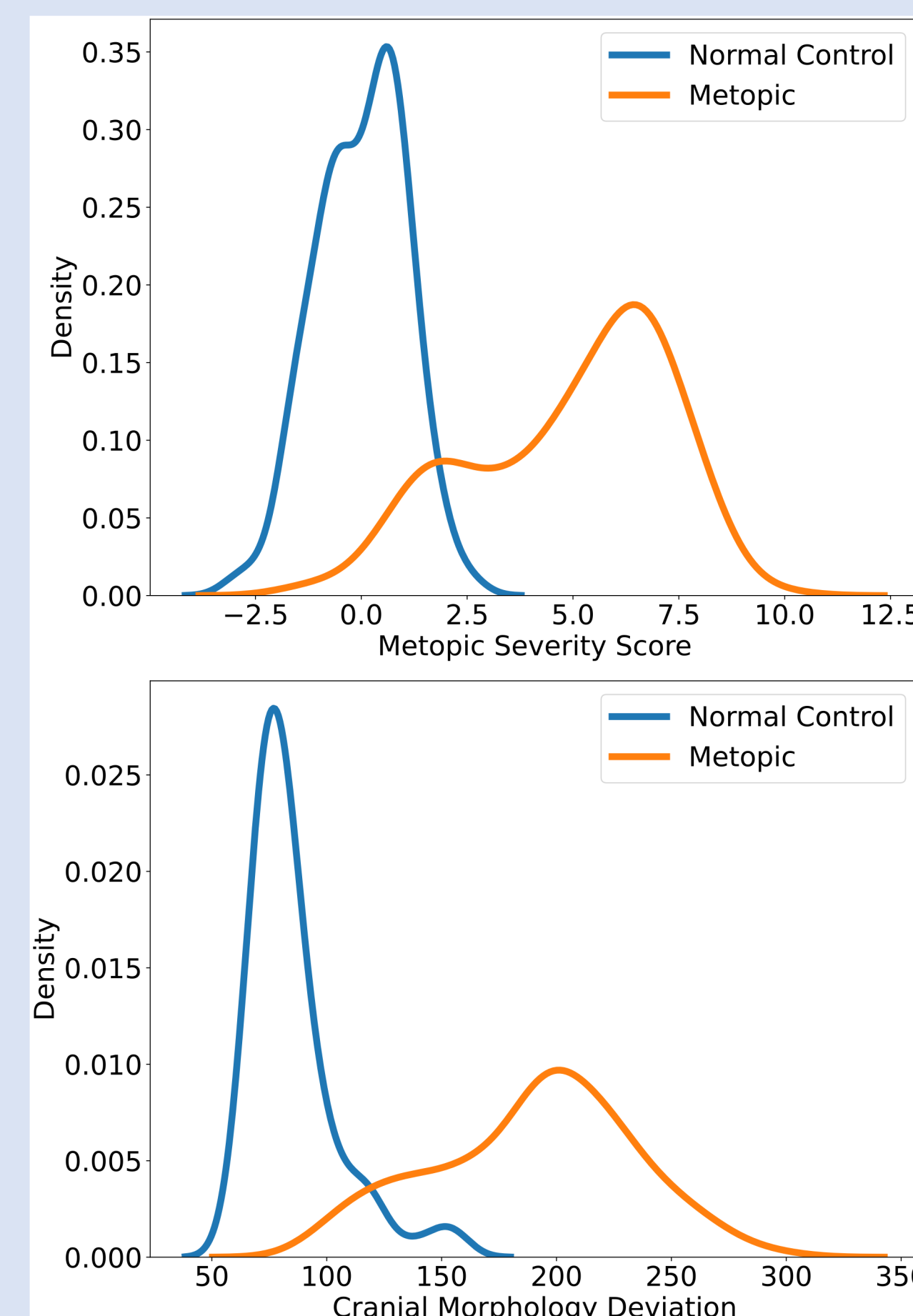
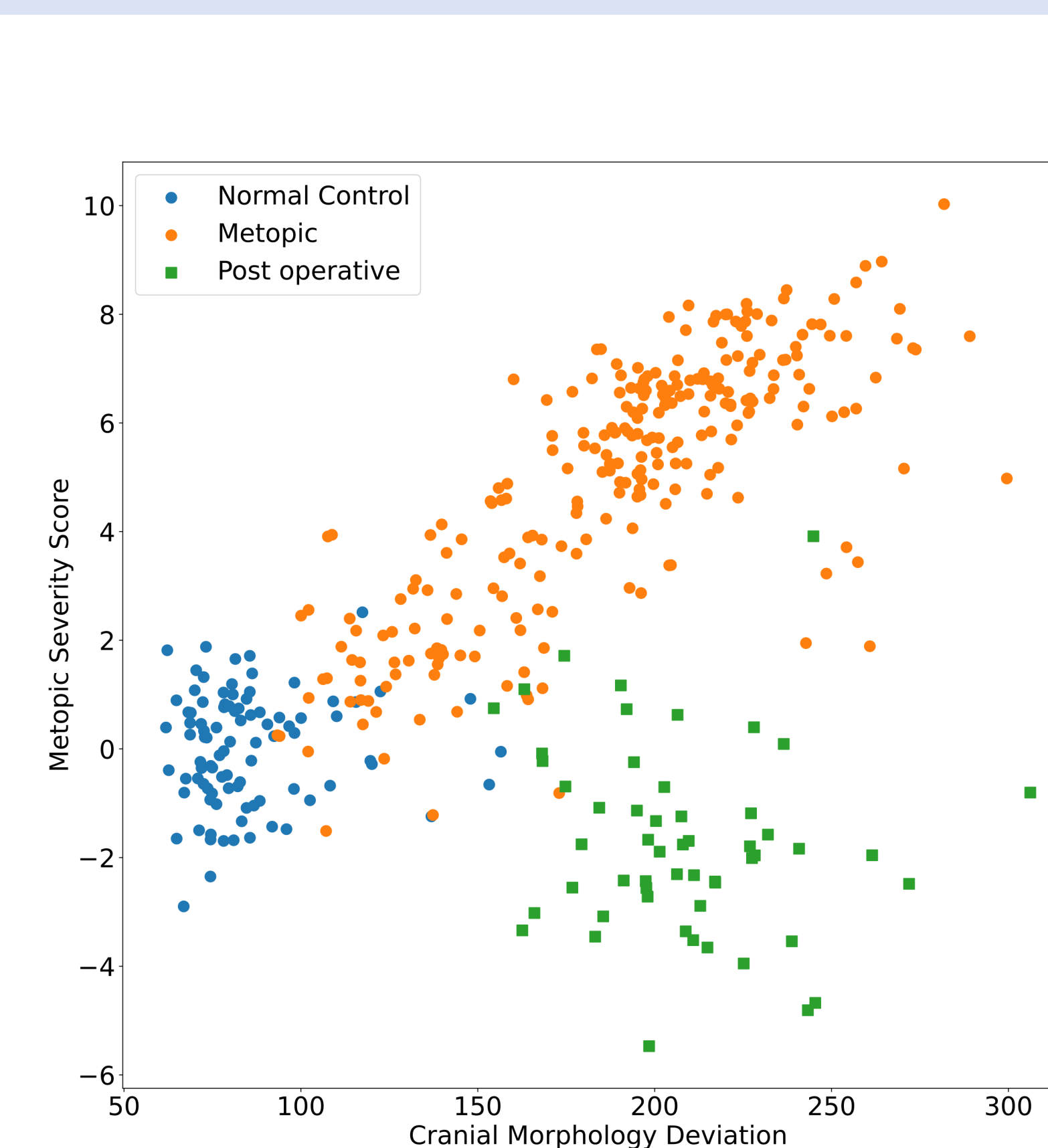


Figure 3: MSS and CMD Relationship



Conclusions

- We report the results from the deep-phenotyping of a very large cohort of patients (n=346) by quantifying phenotypic severity in metopic synostosis
- CranioRate™ effectively distinguishes between normal and pathologic head shapes with very high accuracy, superior to craniometric measurements
- The deep-phenotyping work has produced a novel skull shape distribution (Figure 2)
- The combination of MSS and CMD has the potential to evaluate postoperative outcomes in craniosynostosis surgery (Figure 3)
- We present a novel clinician interface for objective evaluation of patients with metopic craniosynostosis
- Future clinical and research extensions of this work are underway
 - 3D Photography to replace CT imaging
 - Clinical correlations between severity and decisions to operate & long-term neurocognitive/aesthetic outcomes
 - Compare groups between studies to standardize outcomes research