

# Is it possible to predict the long-term outcome of spring cranioplasty using published methods for modelling head growth in paediatric patients?

BY KATE DALRYMPLE

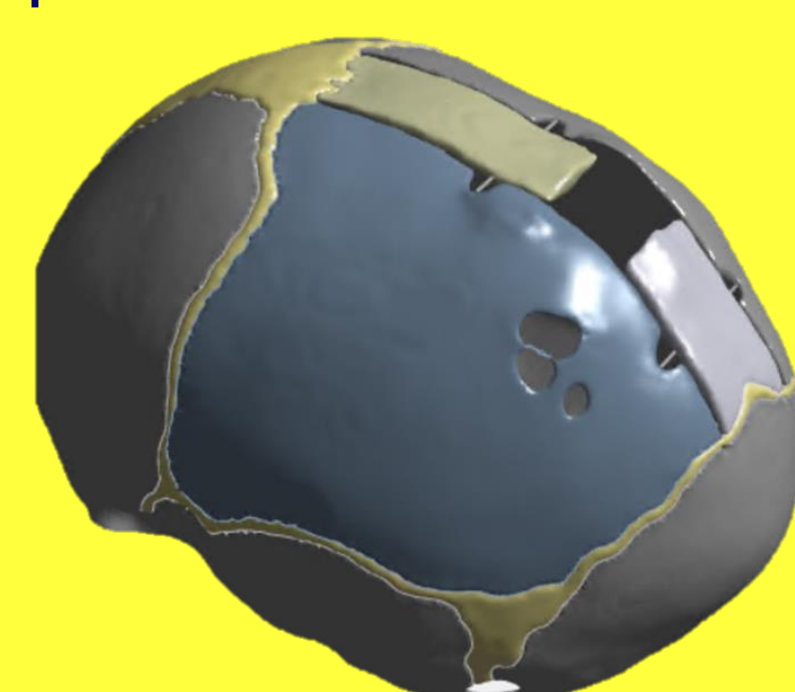
SUPERVISED BY

ALESSANDRO BORGHI

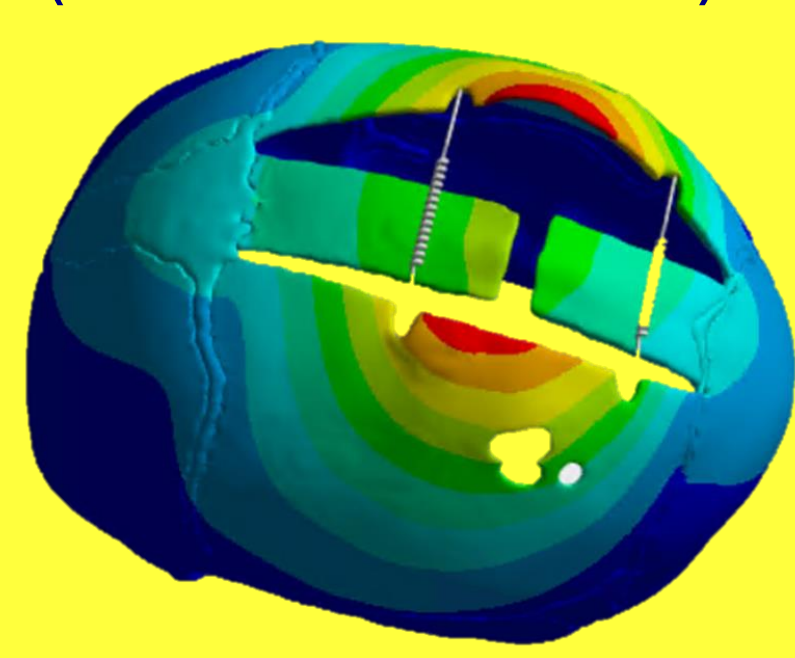
FUNDED BY THE LAIDLAW LEADERSHIP AND RESEARCH PROGRAMME

## METHOD

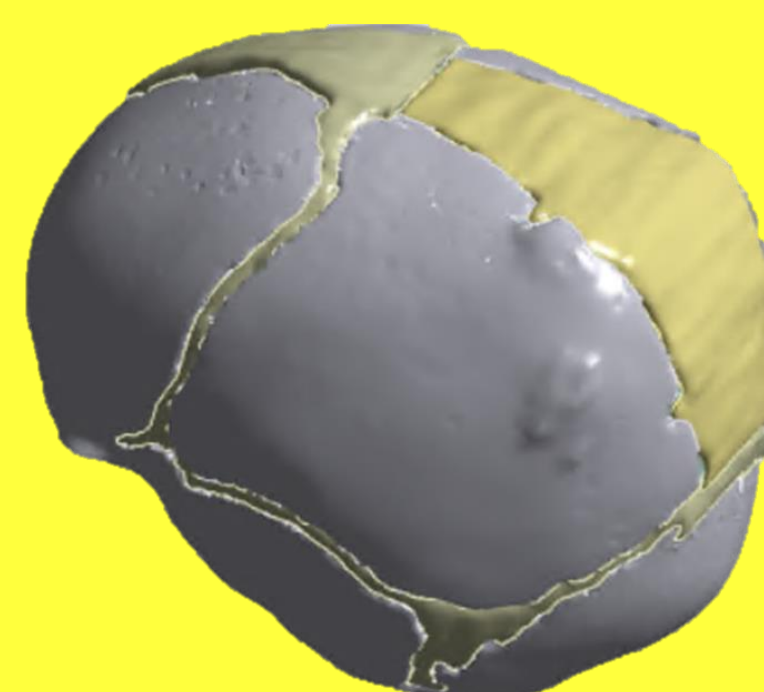
1. The CT scan is loaded into Simpleware and segmented to produce a 3D model.



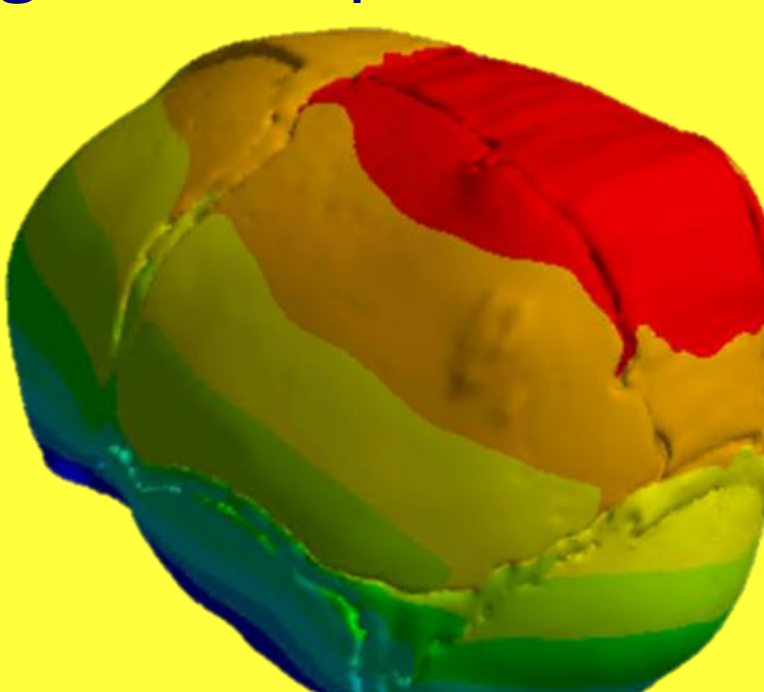
2. The 3D model is loaded into Ansys, and a spring expansion is applied. (baseline model 1)



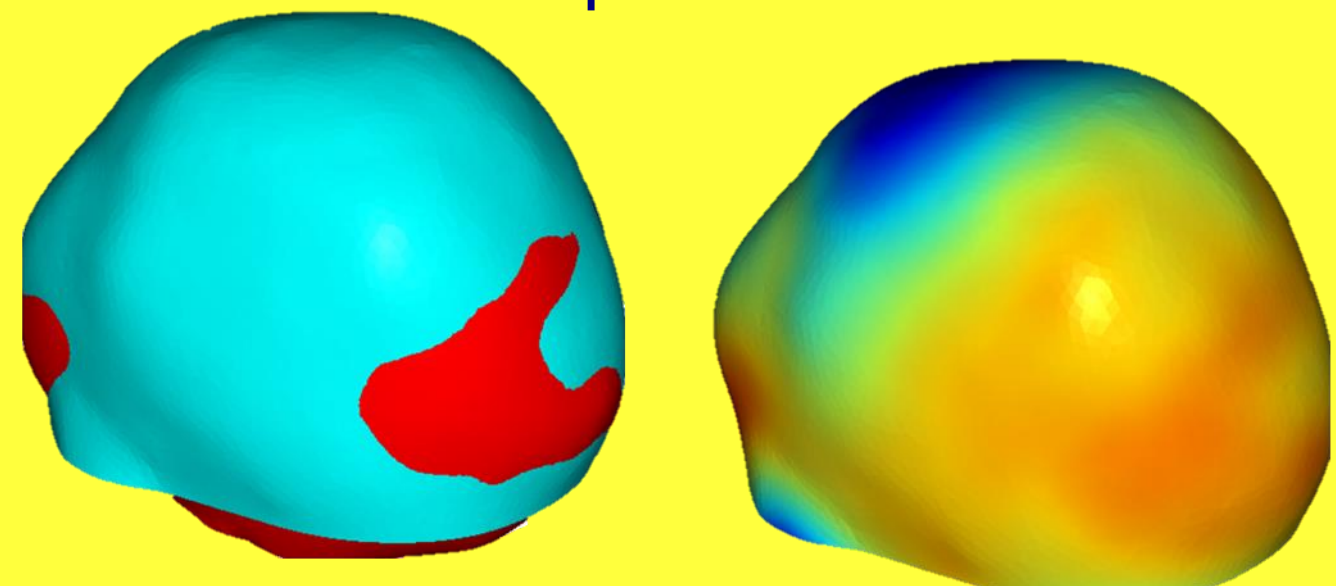
3. The model is exported into Simpleware, and a callus and ICV is added.



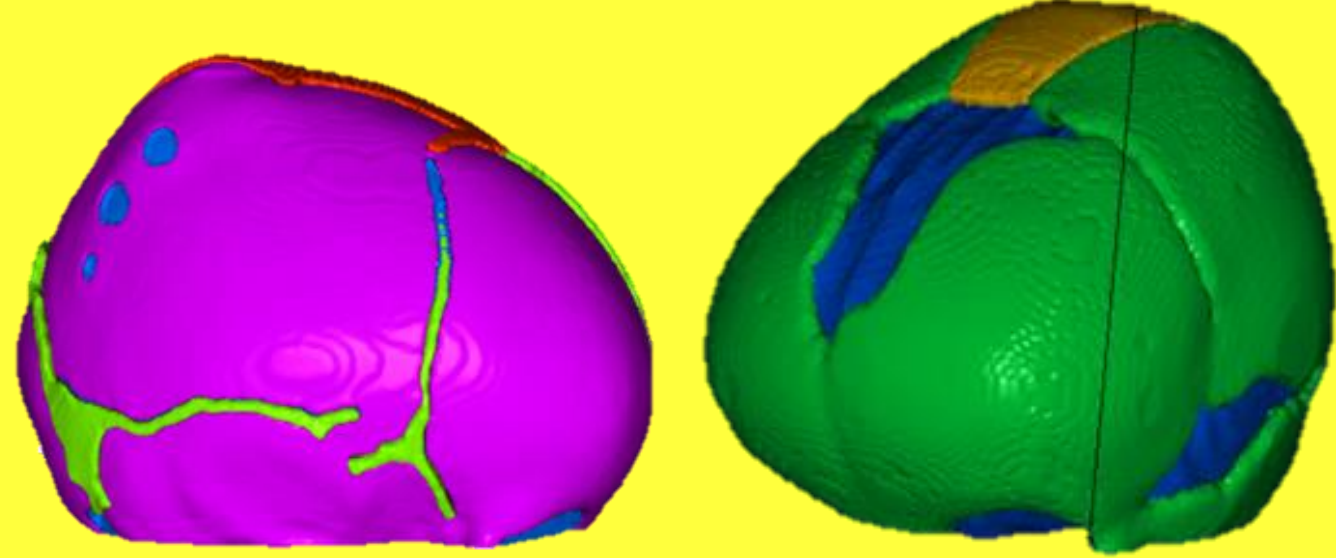
4. Model is exported into Ansys again, and growth expansion is applied.



5. The outer shell is extracted and smoothed in Meshmixer (Model 2). This is then compared with the post-op imaging of the patient in Simpleware.



6. The same process is repeated, but with sutures completely removed (model 3) and partially removed (model 4).



## RESULTS

- Graph 1 here shows the deviation of each model for each patient compared to post-op imaging as a percentage of area outside  $0 \pm 3\text{mm}$ .
- The results show that Model 2 was the best fit for patients A and B – deviation from validated model is approximately zero, as seen on the graphs.
- However, for patient C Model 3 had the lowest deviation and ergo best fit. Models 2, 3 and 4 are all better than Model 1, if comparing averages.

## INTRODUCTION

- Sagittal craniosynostosis is a medical condition affecting about 350 infants in the UK per year. In this condition, the midline cranial suture in a baby's skull ossifies prematurely, leading to an abnormally long and thin head shape and sometimes resulting in reduced quality of life.
- To correct this, surgeons at Great Ormond Street Hospital in London perform spring cranioplasty procedures - inserting metallic distractors (springs) in the skull to widen and improve the shape of the head.

### SCAPHOCEPHALY NORMACEPHALY

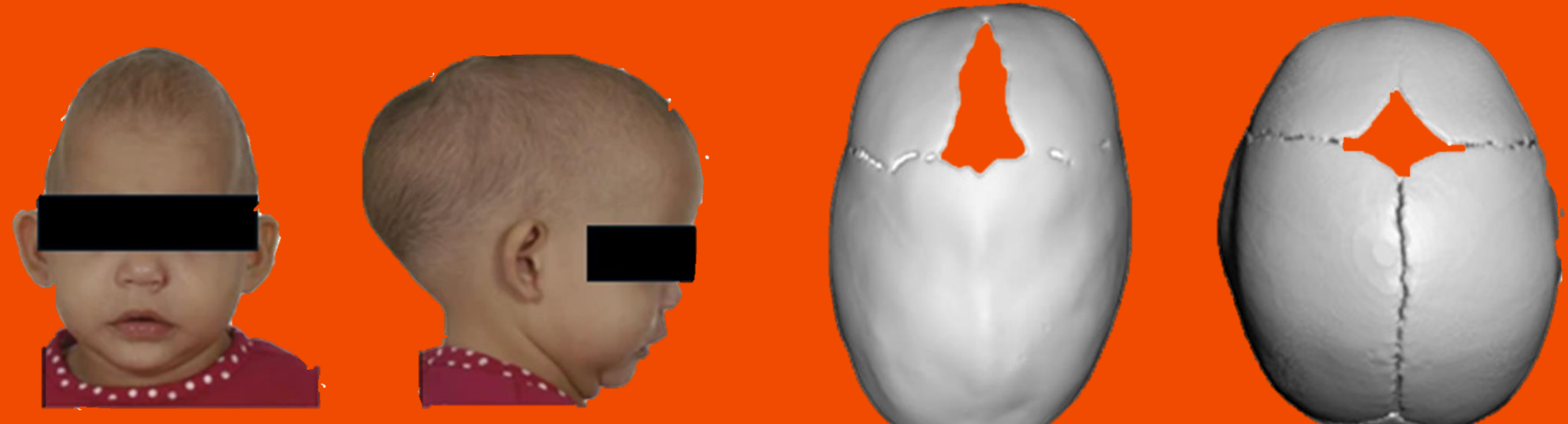
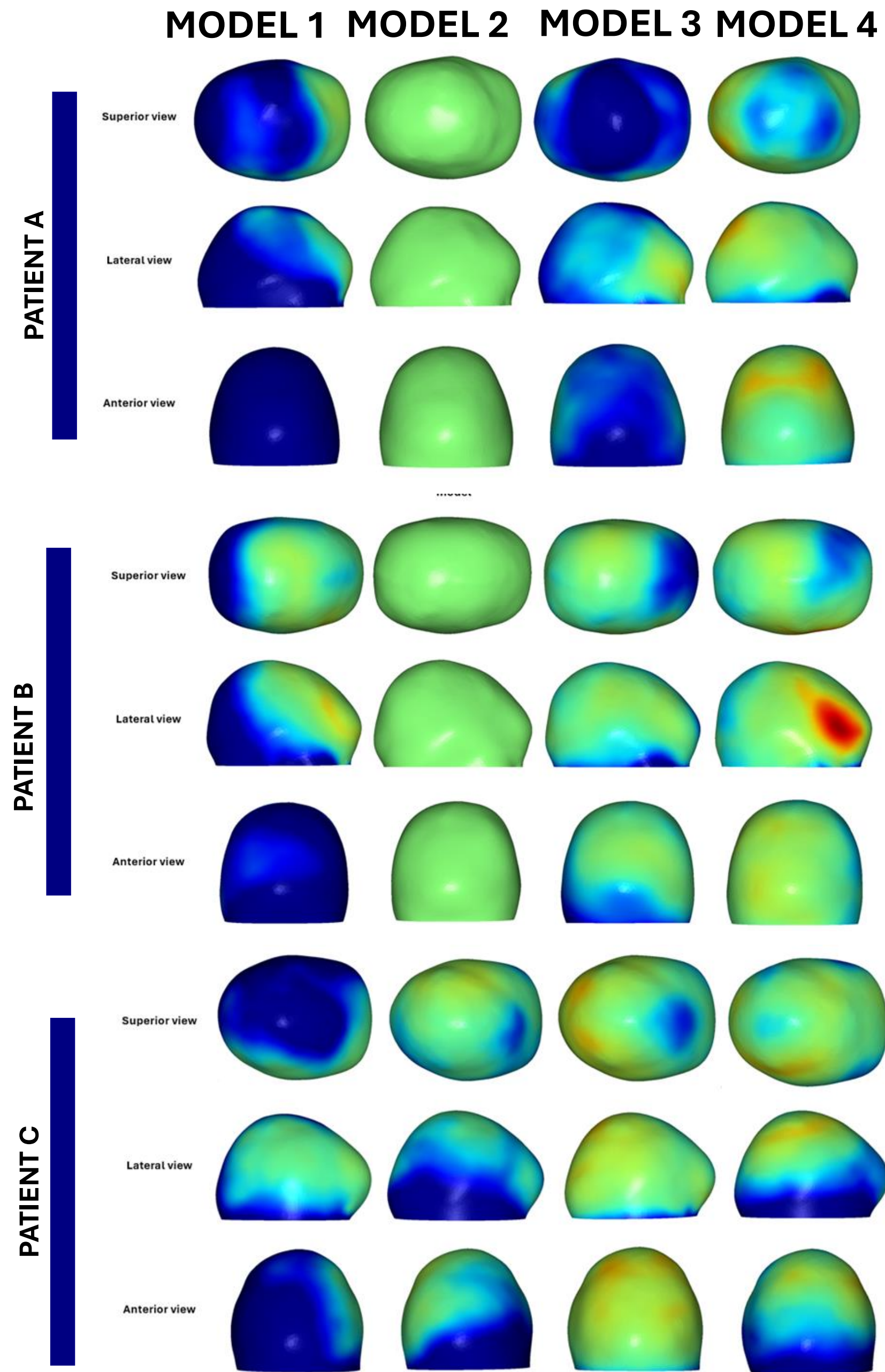
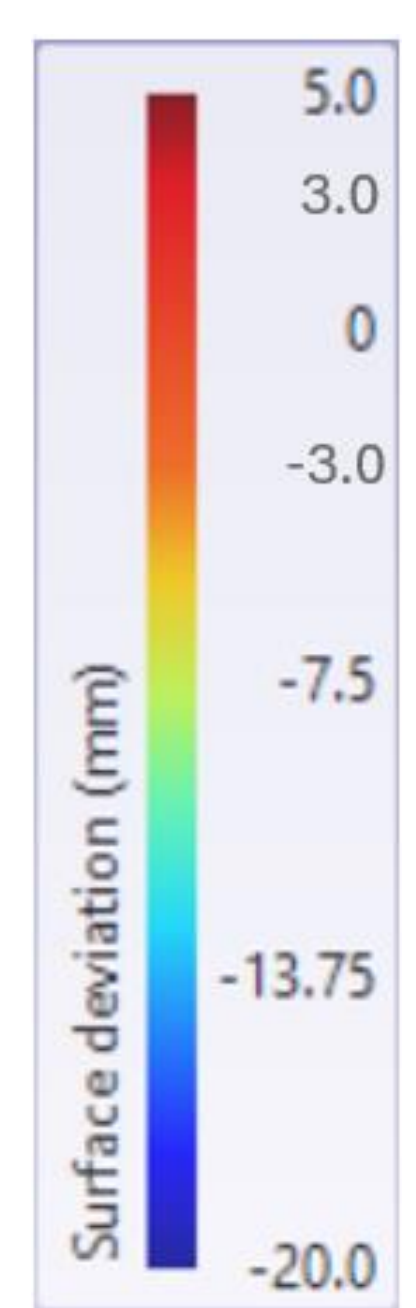


Fig 1 – Child with Scaphocephaly [1] Fig 2 – Skull with scaphocephaly and normacephaly [2]

- A range of different parameters affect surgical outcome, such as the baby's initial head shape, spring model and the distractor position along the skull.
- The combination of these factors, along with the complex nature of skull-spring interaction, can lead to a suboptimal outcome, requiring further surgery.
- A patient specific predictive model of the final head shape is a useful tool for presurgical planning. Currently short-term models exist, but not long-term head shape prediction.
- In this work we developed four different long term predictive models – based on published protocols – which were compared and validated.
- This work will contribute to research making up a useful tool for surgical planning,

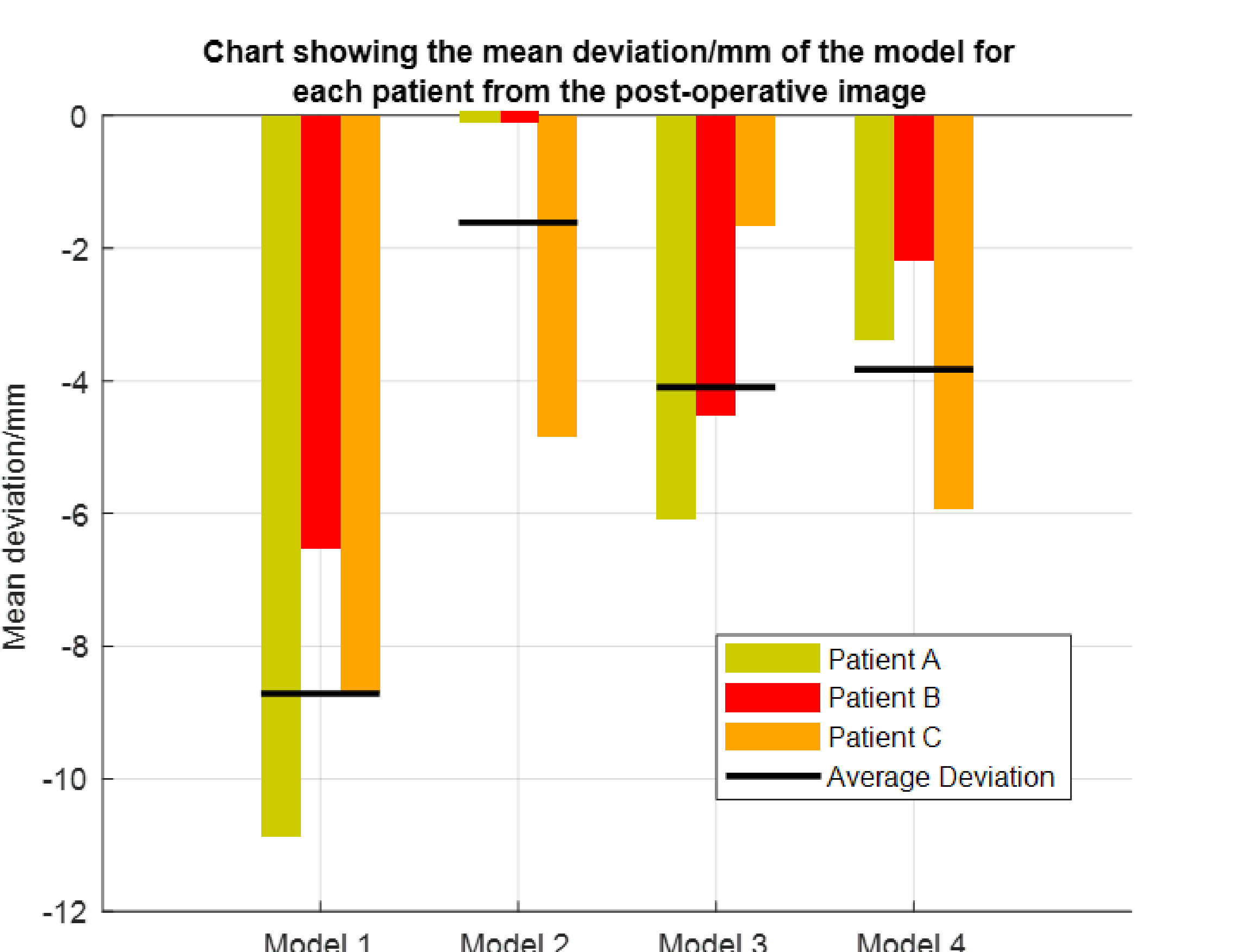
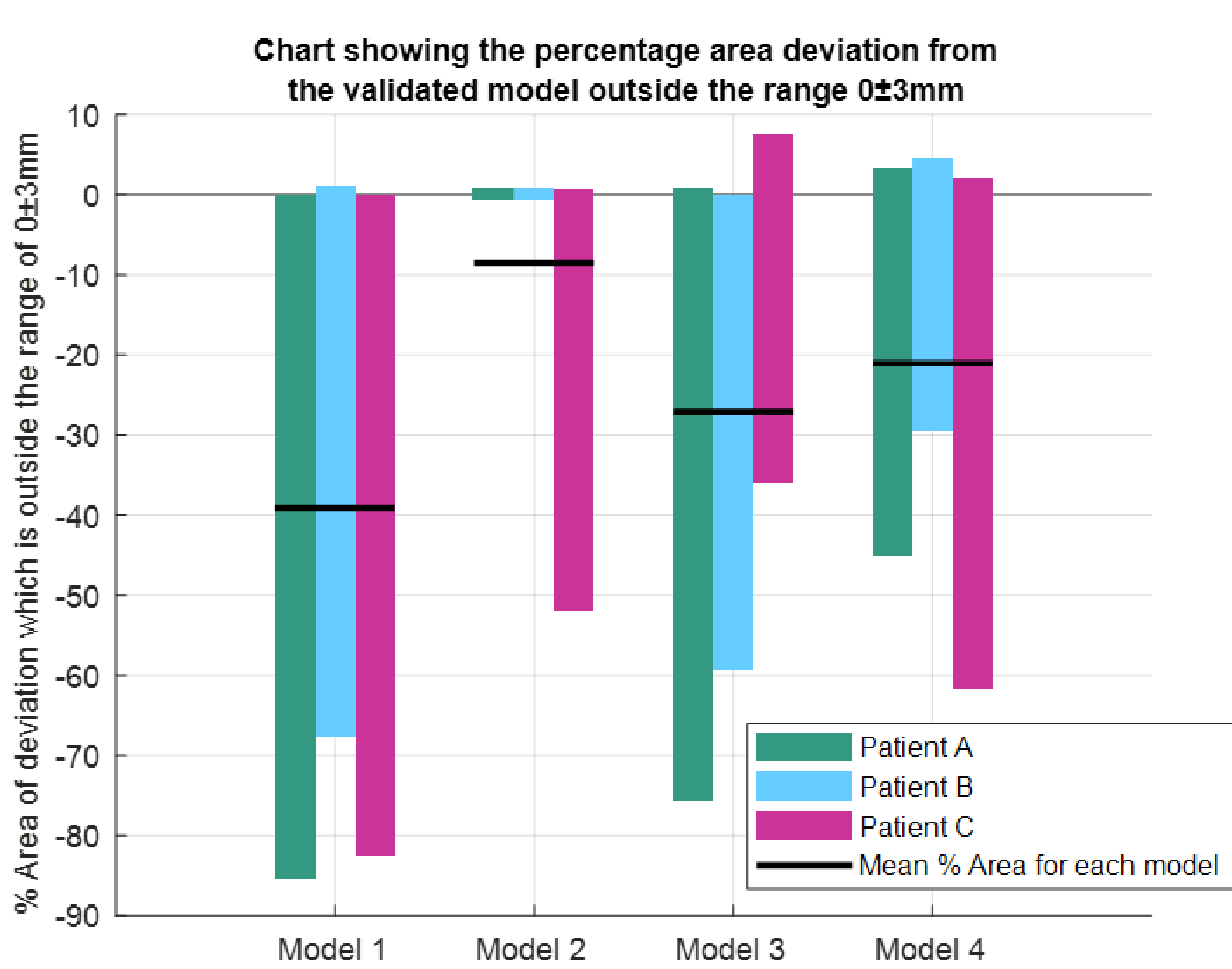


## RESULTS

The images show the deviation of four models for three patients from the post operative images.

## CONCLUSION

- Four models have been built, tested and validated here, two of which predict final head shape to within 68% accuracy (where accuracy is defined as deviation from the post operative model under  $0 \pm 3\text{mm}$ ) and one of which predicts patient A and B final head shape with 100% accuracy. Models 2, 3 and 4 were better predictors for all patients than the baseline model, showing improvement.
- All models (except model 2 for patients A and B) showed negative deviation, meaning growth was underestimated. This suggests tuning of growth coefficient is needed.
- The patients appear to fit into two categories – those best predicted by model 2, (patients A and B) and those best predicted by model 3 (Patient C).
- The key difference between models 2 and 3 is the removal of sutures in model 3 to mimic rupturing. Patient details of post-op tearing that are not available are needed to confirm the hypothesis that tearing determines fit.
- Further work on the correlation of key parameters (growth coefficient, material properties, torn sutures) with trends in growth would be useful to improve the post op shape prediction of this surgery.
- From a clinical perspective, as models get more accurate, surgeons will be able to see how the initial parameters they select (placement of osteotomies, spring stiffness, placement of springs) will affect the final shape, before carrying out the surgery. The improvement in surgical planning will lead to better outcomes.



## LIMITATIONS

- All patients assumed to have skull and sutures of the same material properties, but properties are dependent on age.
- Properties of the bone and suture will change over the growth period – not included in model.
- Skin thickness assumed to be homogenous for all patients.
- The process of segmenting the head shape in Simpleware using morphological processes could introduce error, as it is done by hand.

## REFERENCES

[1] D. Johnson and A. O. M. Wilkie, "Craniosynostosis," *Practical Genetics*, no. 19, pp. 369-373, 2011.  
 [2] A. Borghi, N. Rodriguez-Florez, W. Rodgers, G. James, R. Hayward, D. Dunaway, O. Jeelani and S. Schievano, "Spring assisted cranioplasty: A patient specific computational model," *Medical Engineering & Physics*, 2018