

Computational analysis of Ti-6Al-4V thoracic implants with a spring-like geometry for anterior chest wall reconstruction

Alejandro BOLAÑOS, Alejandro YÁNEZ, Alberto CUADRADO, María Paula FIORUCCI, Belinda MENTADO

Cite this as: Alejandro BOLAÑOS, Alejandro YÁNEZ, Alberto CUADRADO, María Paula FIORUCCI, Belinda MENTADO, 2025. Computational analysis of Ti-6Al-4V thoracic implants with a spring-like geometry for anterior chest wall reconstruction. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 26(7):679-693. <https://doi.org/10.1631/jzus.A2400431>

Background

- For many years, rigid thoracic implants have been used in cases of chest wall reconstruction.
- These solutions often lead to premature implant failure due to excessive internal stresses caused by their rigidity.
- They also result in patient discomfort and limited thoracic mobility.
- There is a need to shift the paradigm in thoracic surgery: the use of flexible prostheses with more complex geometries, made possible by advances in manufacturing technologies.

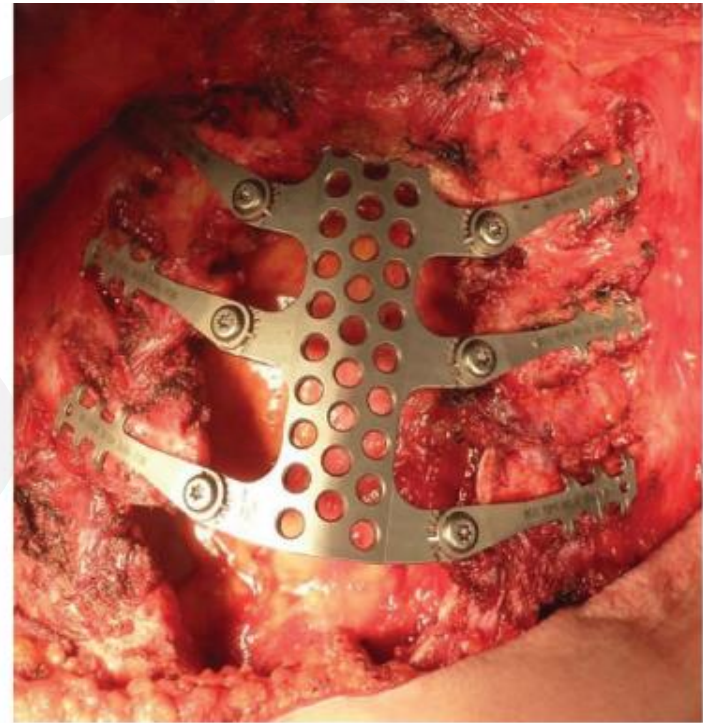


Fig. 1. Rigid implant designed for chest wall reconstruction

Methodology

■ Obtention of the full thorax model and individual semi ring-rib models

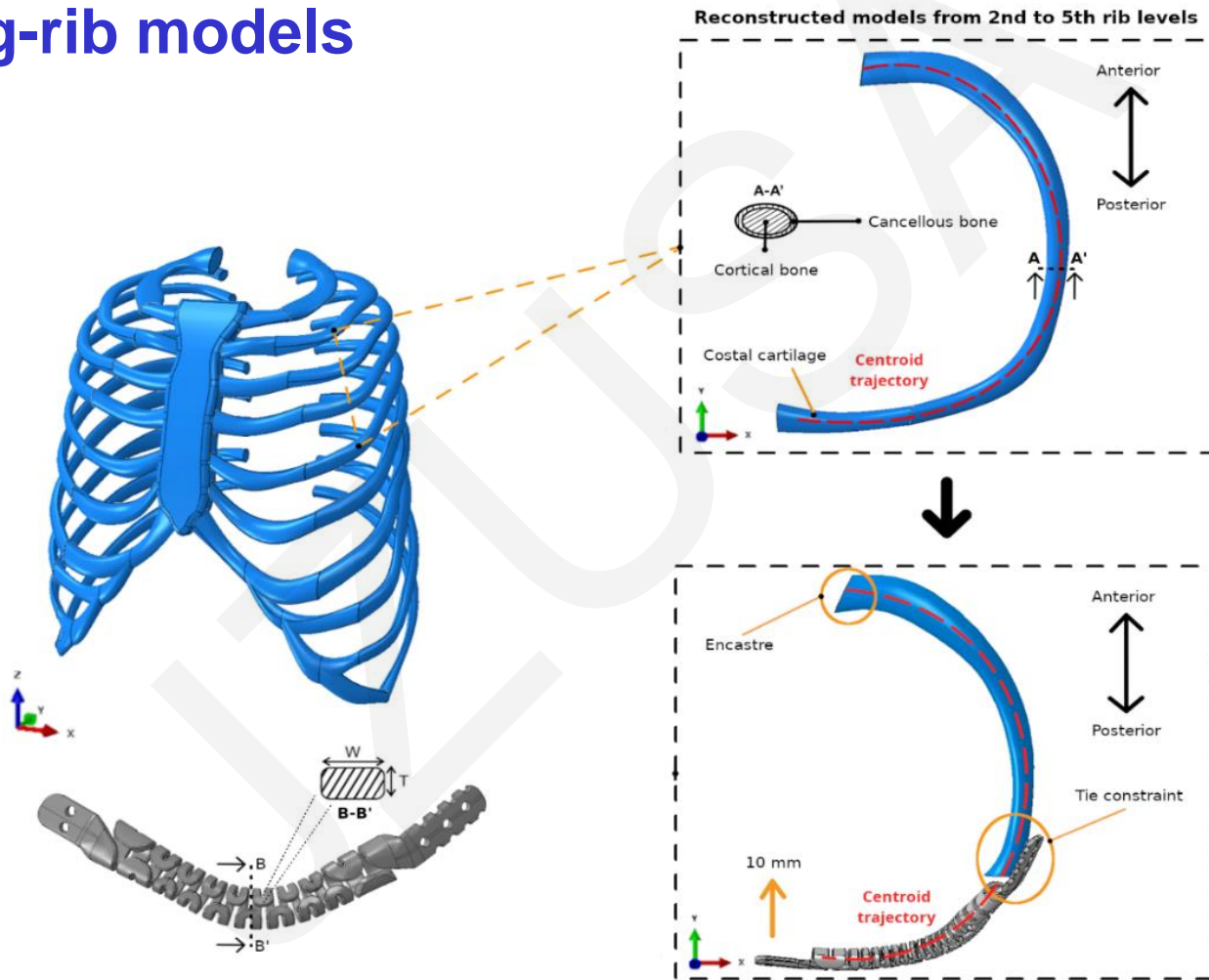


Fig. 2. Semi ring-rib models obtained from the native model with the inclusion of spring-like designed implants .

Methodology

■ Obtention of rib cage reconstruction models

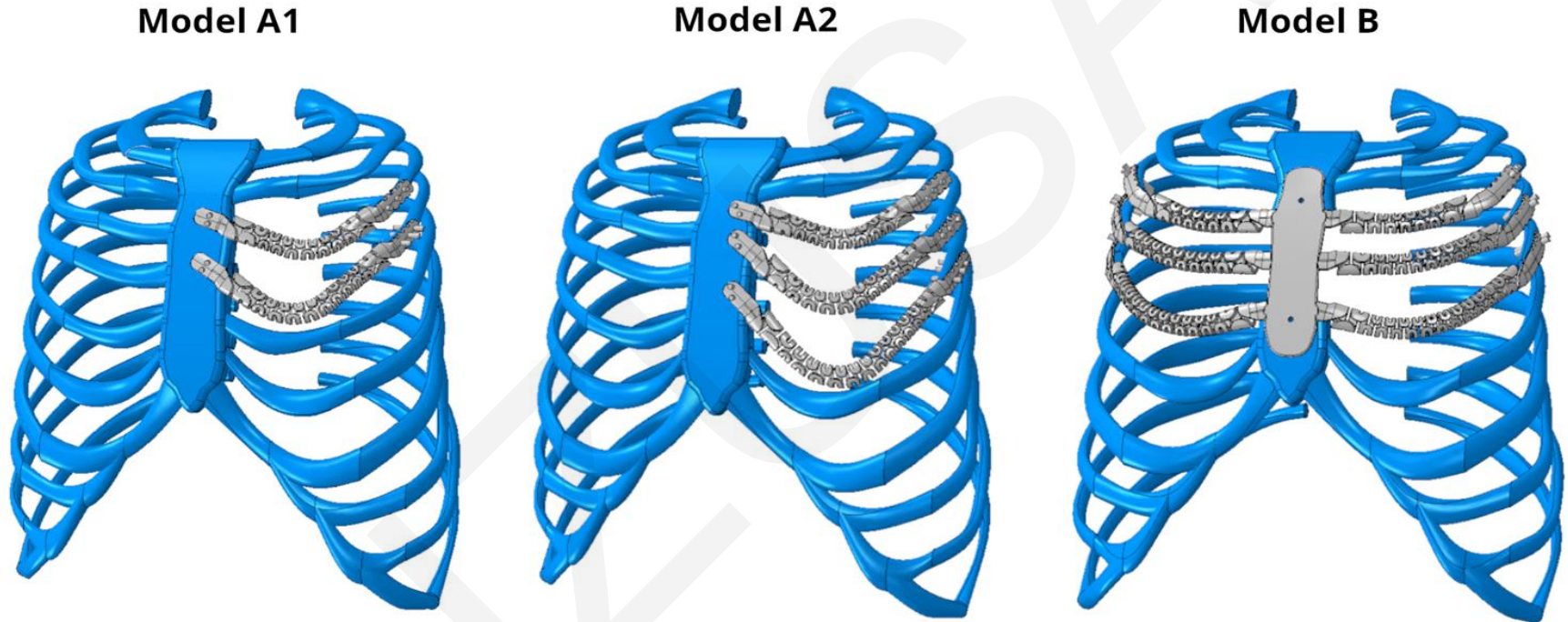


Fig. 3. Proposed implant configurations in this study: Reconstruction of the third and fourth left ipsilateral ribs (Model A1). Reconstruction of third, fourth and fifth left ipsilateral ribs (Model A2). Reconstruction of the third, fourth and fifth bilateral ribs (Model B).

Results

Validation of the full thorax native model

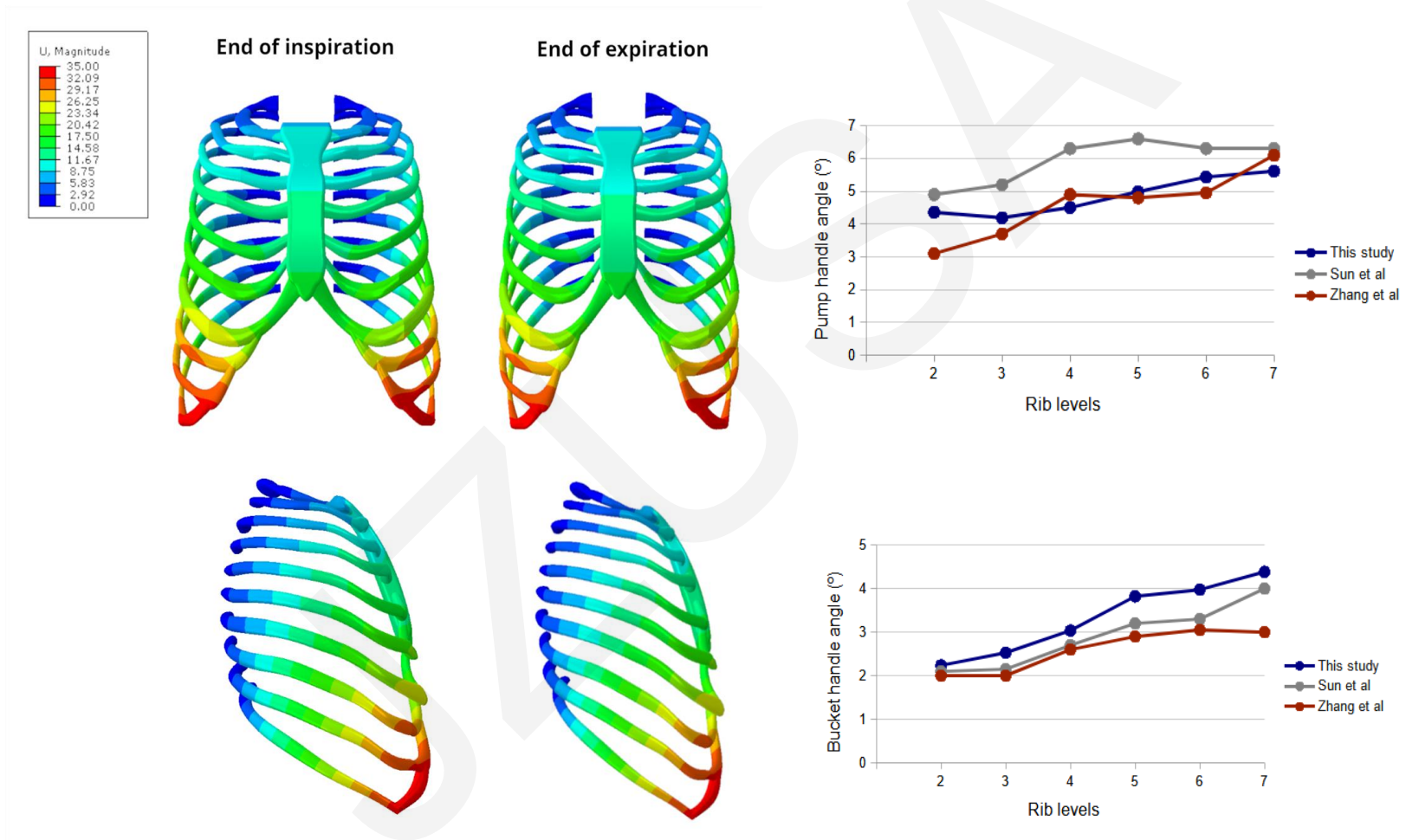


Fig. 4. Total displacement (mm) of the native model from the end of the inspiration phase to the end of the expiration phase, compared with other studies. Sun, C. et al (2024). Zhang, G. et al (2016).

Results

■ Isolated semi ring-rib models

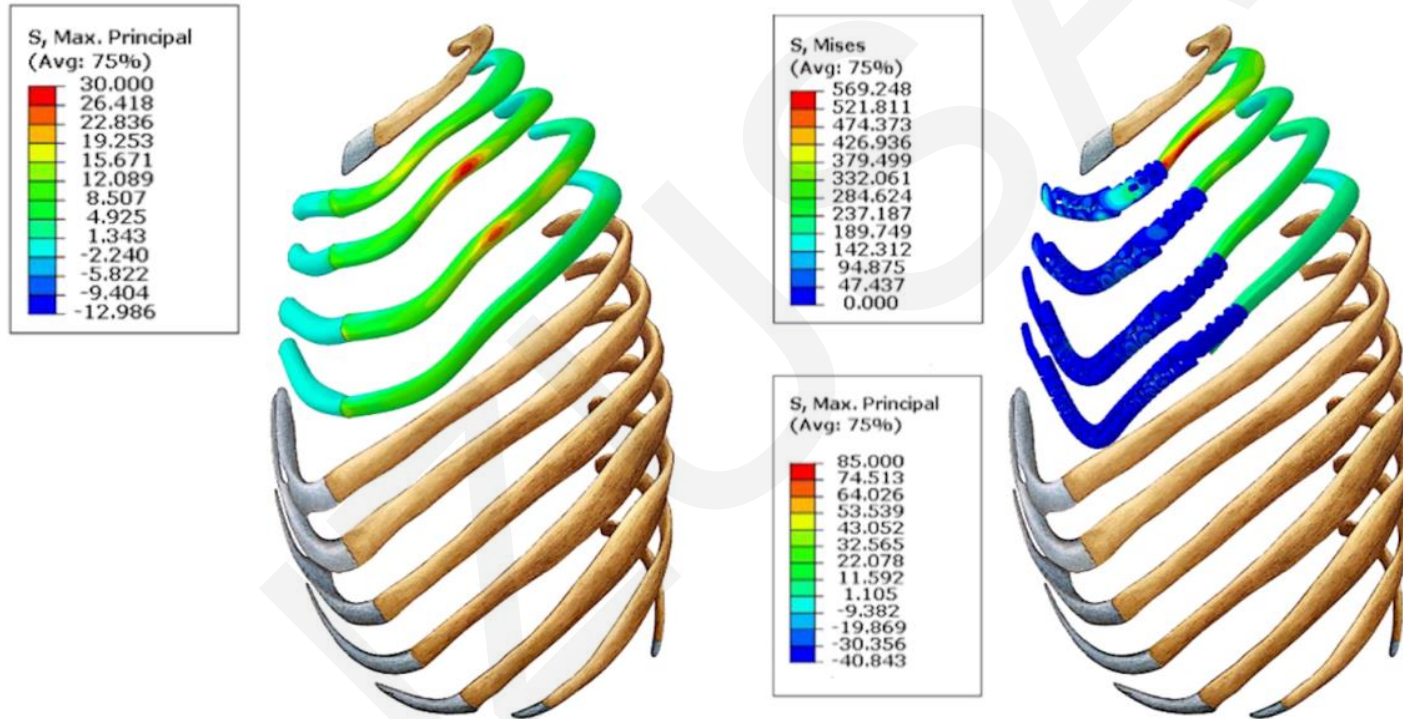


Fig. 5. Photographic composition showing the distribution of maximum principal stresses (MPa) and the von Mises stresses (MPa) in the cortical bone and in implants, respectively, of the isolated rib models from the second to the fifth rib level.

Results

■ Chest wall reconstruction models

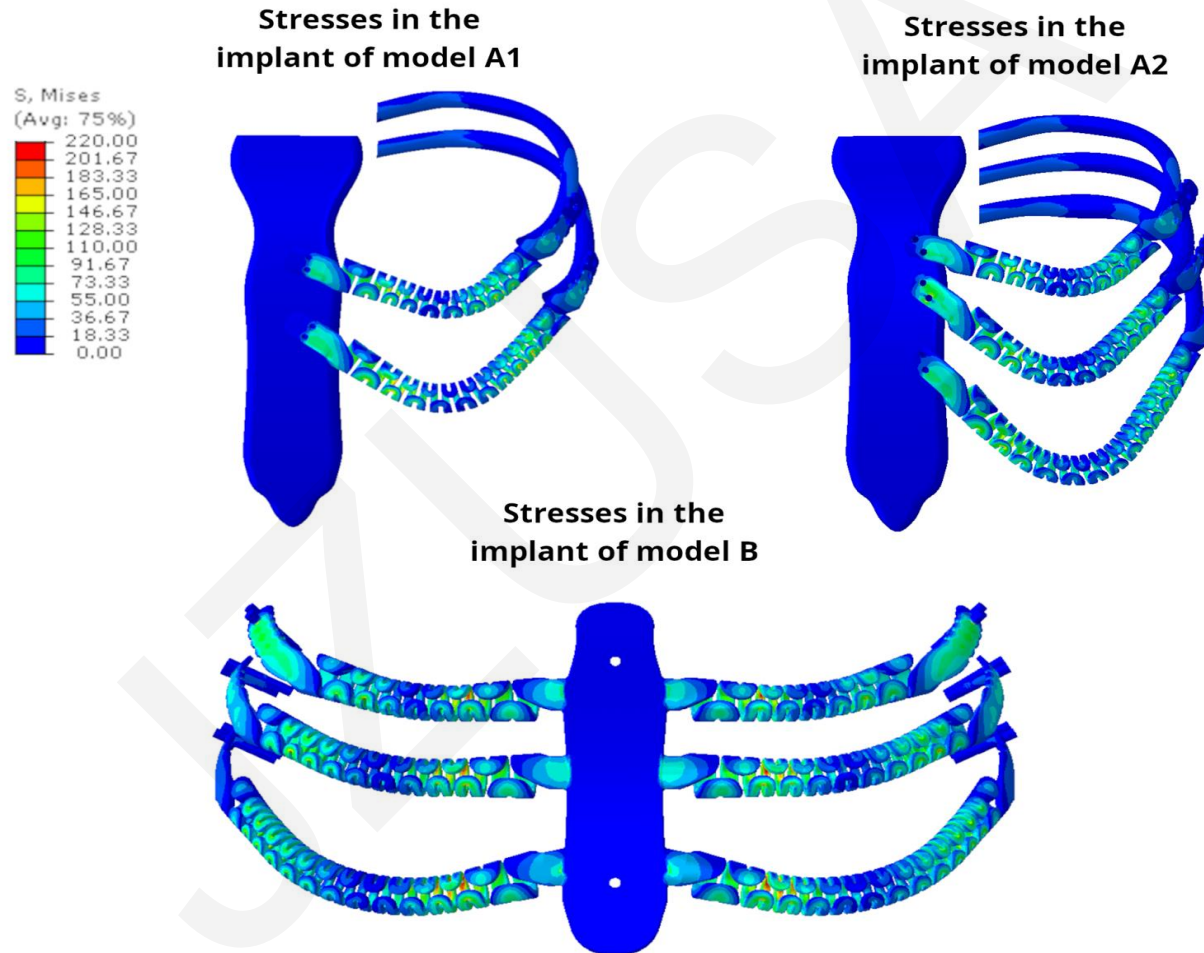


Fig. 6. Distribution of von Mises stresses (MPa) in the implants for the three models.

Conclusions

- Implants showed good mechanical performance and flexibility, except at the second rib level.
- High stiffness at level 2 increased cortical bone stress.
- Spring-like geometry improved flexibility from ribs 3 to 5.
- All designs withstood stress and preserved load distribution.
- Results support flexible and durable custom-made implants.

Limitations

- Excluding thoracic muscles reduces the model's realism.
- Further fatigue testing is needed to assess implant durability.