3D Segmentation and Modeling of Thoracic Organs for Surgical Planning and Medical Research

Carlos Uriel Castelán Sánchez[1], Juan Alfonso Beltrán-Fernández[1]*, Mauricio González Rebattú[2], Alejandro Gónzalez-Rebattú[2], Elías Humberto Hermida-Ochoa[3], Alejandro Tonatiuh Velázquez-Sánchez[1], Erik Omar Alvarado-Alcántara[1], Karen Pamela Vázquez-Thierry[1], Pablo Moreno-Garibaldi[1]

Corresponding Author: jbeltran@ipn.mx*

ABSTRACT:

A methodology for the segmentation and 3D modeling of thoracic organs from computed tomography (CT) scans is presented. Specialized software tools are utilized for the segmentation process, allowing for the creation of accurate and detailed 3D models of organs such as the kidneys and pancreas.

The resulting 3D models can be used for surgical planning, allowing surgeons to better understand the anatomy of the patient and plan more effective interventions. Additionally, these models can be used for medical research, enabling researchers to study the anatomy and function of thoracic organs in greater detail.

This work demonstrates the potential of 3D segmentation and modeling for improving surgical planning and medical research.

Keywords: 3D segmentation, Thoracic organs, Surgical planning, Medical research, Computed tomography (CT)

INTRODUCTION

A workflow for segmenting and modeling thoracic organs from computed tomography (CT) was developed to support surgical planning and biomedical research.

Three-dimensional anatomical models were generated for organs such as scapula, lumbar vertebrae, humerus and also the kidneys and pancreas using semi-automated image processing tools.

This approach enables accurate representation of patient-specific anatomy, supporting preoperative planning, experimental modeling, and educational applications.

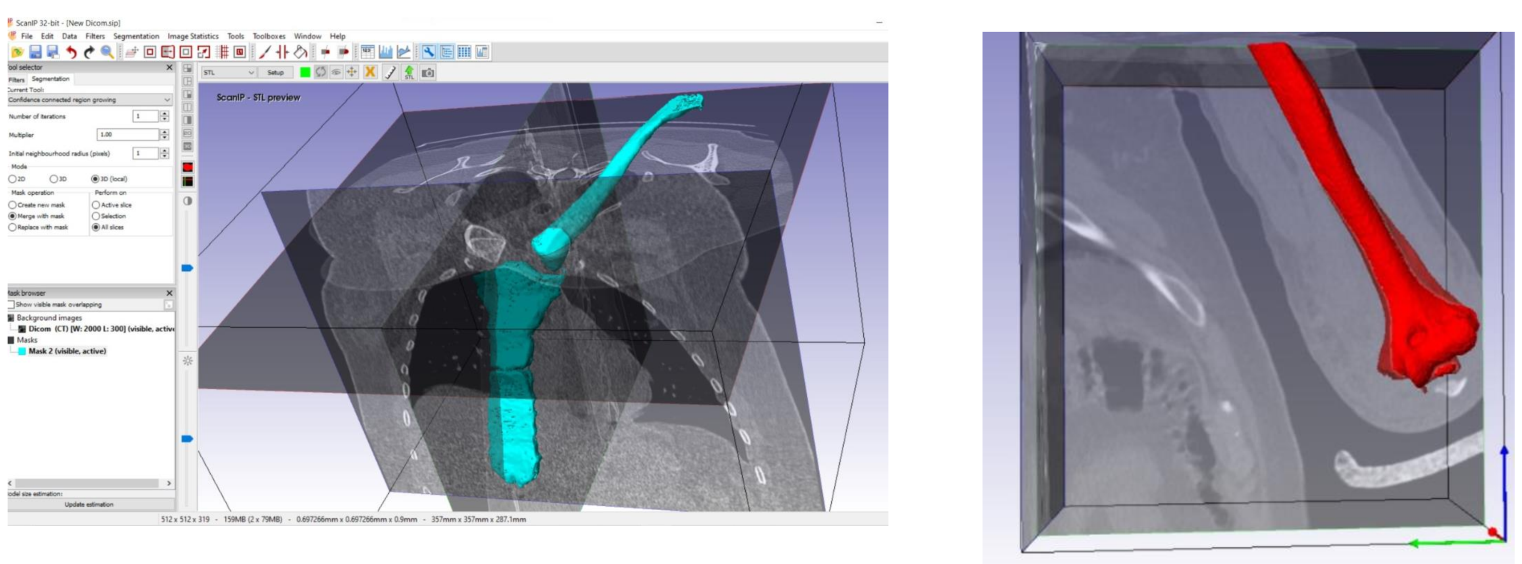

Fig. 1 Scan IP Segmentation

METHODS

a) CT DICOM datasets were obtained from clinical sources.
b) Segmentation was performed using specialized software with manual refinement.
c) 3D surface meshes were created and exported in STL format.
d) Finite element models were generated and subjected to simulated loading conditions (10 to 100 N).
e) Von Mises stress, principal stresses, and deformation distributions were extracted from simulations.

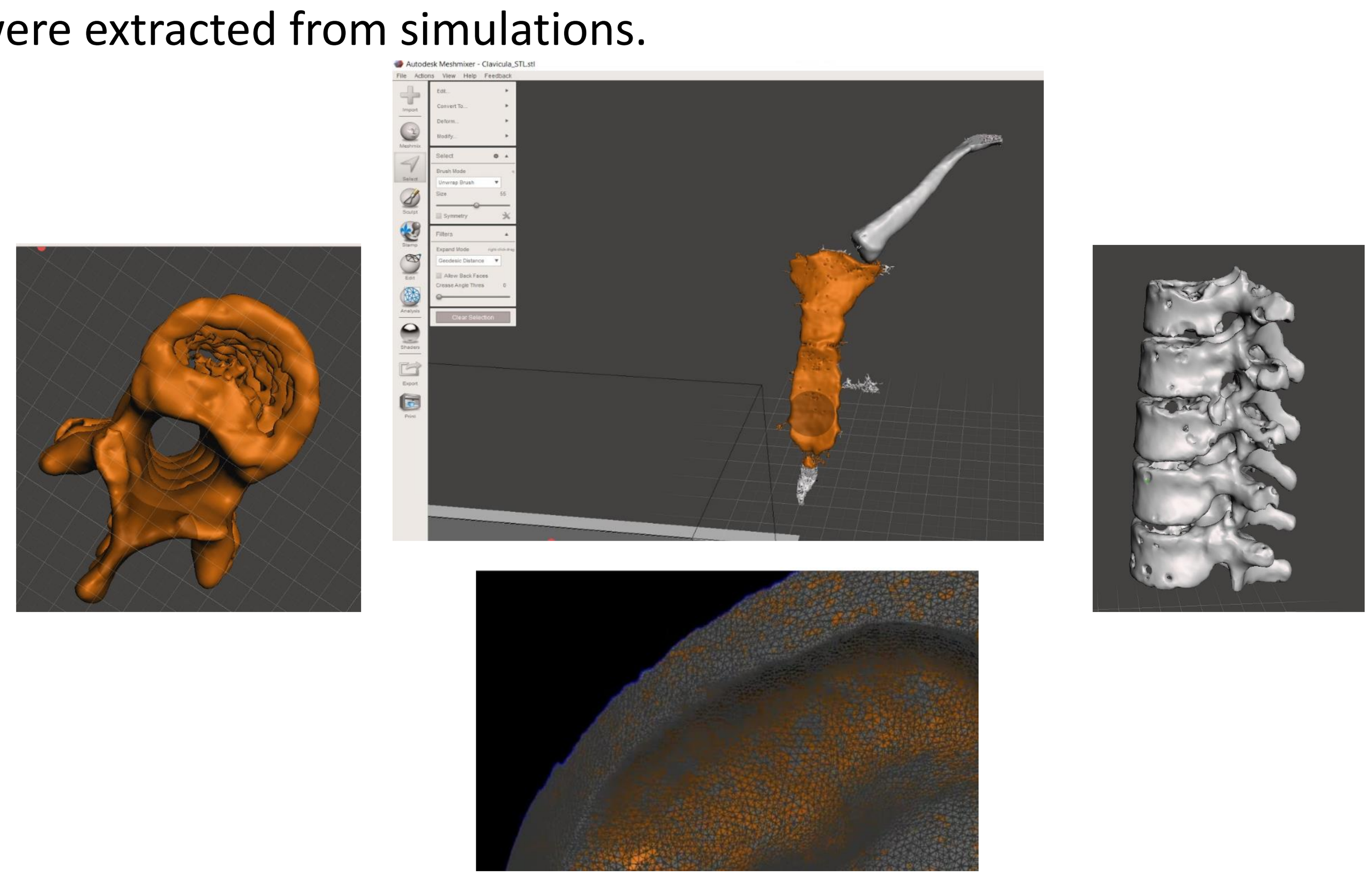

Fig. 2 Meshmixer © for optimization of elements

RESULTS

The finite element analysis was app the following key results:

- Von Mises stress: up to **19.6 MPa**
- Maximum principal stress: varied per tissue
- Unitary strain: dependent on mesh density
- Total deformation: **2.1 mm** under 100 N load
- Mesh: over 26,000 nodes and 145,000 elements in critical zones
- The models were found to be structurally valid and clinically interpretable.

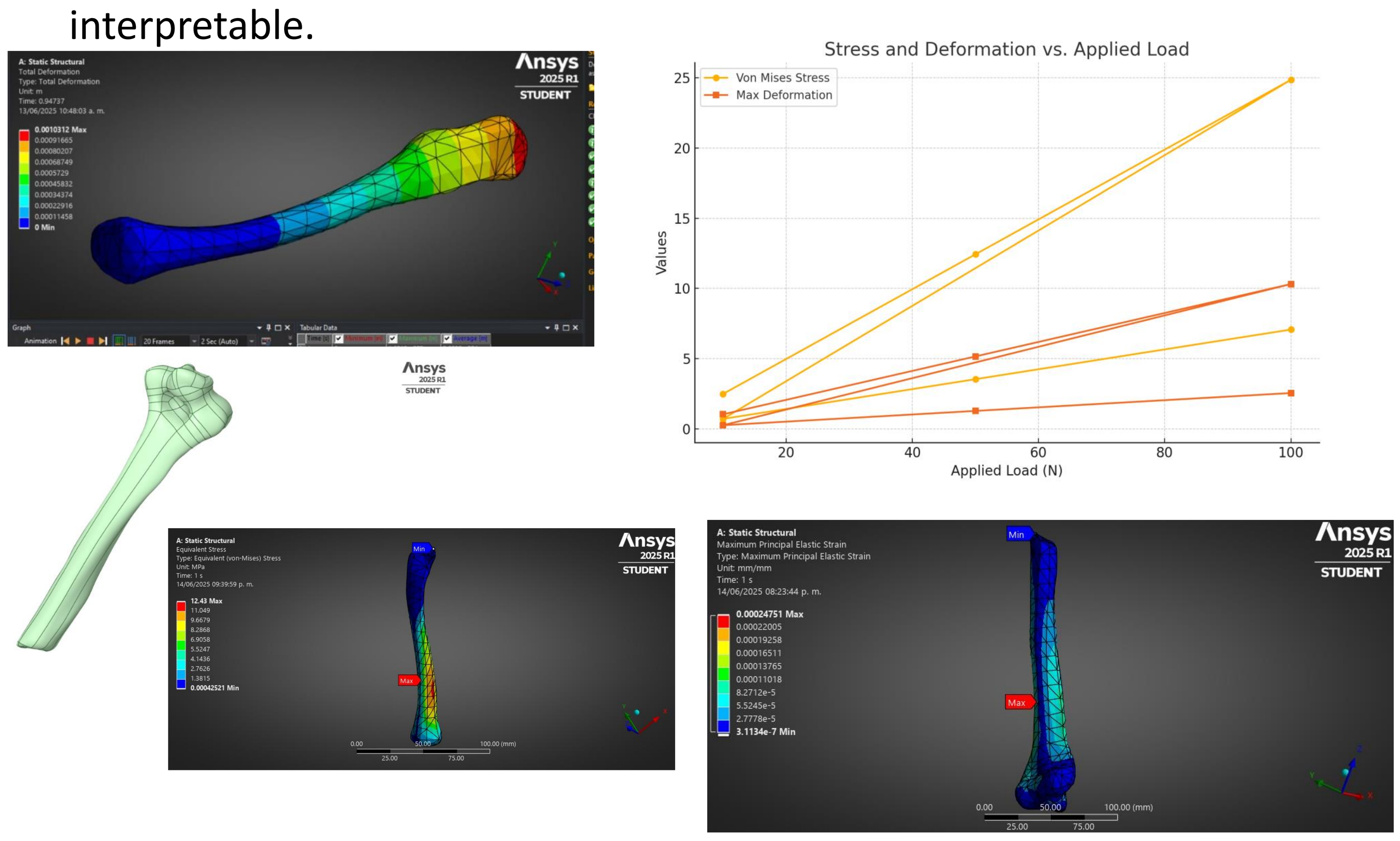

Fig. 3 FEM Simulation results

DISCUSSION

The use of 3D segmented models improves anatomical understanding and allows customized simulations under controlled loading.

These models have shown to be useful for:

Virtual surgical navigation, 3D printing of organ models, Image-based strain tracking, Biomechanical training tools and the model transferability to other anatomical regions and medical contexts also can be considered.

CONCLUSION

It was demonstrated that thoracic organ models can be generated from CT data and used effectively for surgical simulation and medical experimentation. The digital workflow can be applied across diverse clinical and engineering domains, integrating advanced computational methods with real-world anatomy.

ACKNOWLEDGMENTS

The authors thank the collaborating institutions and medical staff for their contributions to image access, anatomical review, and simulation validation.

This research was supported by:

Instituto Politécnico Nacional (IPN), Hospital Regional 1° de Octubre (ISSSTE)

Hospital de Ortopedia Dr. Germán Díaz Lombardo – CILAB

REFERENCES

- **Qian J., Siewerdsen J., Daly M.**, "Automatic thoracic anatomy segmentation on CT images using hierarchical fuzzy models and registration," *Medical Physics*, 2016. DOI: **10.1118/1.4942486**
- **Yaniv Z., Merkow J., et al.**, "CT-ORG, a new dataset for multiple organ segmentation in CT: 140 volumes covering six organ classes," *Scientific Data*, 2020. DOI: **10.1038/s41597-020-00715-8**
- **Aroeira R. M. C., Pertence A. E. M., Kemmoku D. T., Greco M.**, "Three-dimensional geometric model of the middle segment of the thoracic spine …" *Research on Biomedical Engineering*, 2017. DOI: **10.1590/2446-4740.08916**
- **Uzundurukan A., Poncet S., Boffito D. C., Micheau P.**, "Computed Tomography-Based Finite Element Model of the Human Thorax for High-Frequency Chest Compression Therapy," *Proceedings of ICBES 2023*. DOI: **10.11159/icbes23.123**
- **Wasserthal J., Breit H.-C., et al.**, "TotalSegmentator: robust segmentation of 104 anatomical structures in CT images," *arXiv preprint*, 2022. DOI: **10.48550/arXiv.2208.05868**

NAPLES, ITALY 30 JUNE - 4 JULY
ACEX2025 NAPLES
18th International Conference on Advanced Computational Engineering and Experimenting

Instituto Politécnico Nacional, Sección de Estudios de Posgrado e Investigación, Escuela Superior de Ingeniería Mecánica y Eléctrica, Unidad Zacatenco, "Unidad Profesional Adolfo López Mateos", Edificio 5, Segundo Piso, Colonia Lindavista, Alcaldía Gustavo A. Madero, C.P. 07738, Ciudad de México.

ACEX275