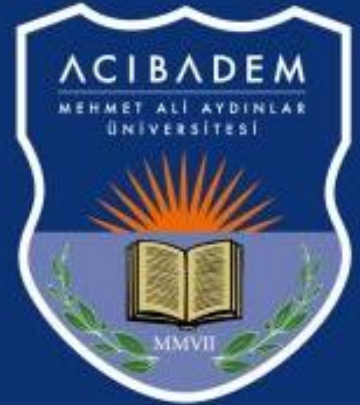


A Novel 'Arrow Type' Mini-Sternotomy: Comparative Study Of Biomechanical Stress Simulation With Conventional J And T Type Mini-Sternotomy

Eyup Alper Saygili¹, Murat Bastopcu² , Gokhan Arslanhan² , Zeynep Sila Ozcan³ , Anil Karaagac² , Muharrem Kocyigit⁴ , Sahin Senay³ , Cem Alhan³

1 Acibadem University School of Medicine, Istanbul, Turkey, 2 Acibadem Maslak Hospital, Department of Cardiovascular Surgery, Istanbul, Turkey, 3 Acibadem University School of Medicine, Department of Cardiovascular Surgery, Istanbul, Turkey, 4 Acibadem University School of Medicine, Department of Anesthesiology, Istanbul, Turkey



ACIBADEM
ÜNİVERSİTESİ

Introduction

Sternotomy, particularly median sternotomy, is a cornerstone of cardiac surgery, offering excellent thoracic exposure and accounting for over a million procedures annually worldwide. However, it carries risks such as sternal wound infections, dehiscence, and prolonged recovery. To address these issues, minimally invasive approaches like partial sternotomies have gained popularity, providing quicker recovery and fewer complications.

The J-shaped sternotomy, widely used for aortic valve replacement and some coronary bypass surgeries, involves a midline incision extending laterally at the second or third intercostal space. This configuration balances adequate exposure with enhanced postoperative stability by preserving sternal integrity. Despite its advantages, the technique may limit access to posterior cardiac structures, prompting modifications to optimize exposure.

Here, we present a novel modification to the J sternotomy, incorporating a triangular extension at the distal end of the incision. This approach aims to enhance surgical access while preserving sternal stability and improving patient outcomes.

Surgical Technique

The modified Arrow Type J sternotomy procedure explanation is divided into steps:

- Preparation:** The surgical field is prepped and draped under sterile conditions, and the anatomical landmarks are identified. These include the suprasternal notch, the sternum's midline, the third and fourth intercostal spaces, xiphoid process, and 12th ribs.
- Initial Incision and Sternal Sawing:** A vertical midline incision of approximately 8 cm is made starting from the suprasternal notch, extending downward between third and fourth rib. Incisions' bleeding is controlled with electrocauterization and bone wax. Initially, a standard sternal saw is used to divide the sternum along this midline, providing a straight vertical portion of the sternotomy. Once the vertical incision reaches the fourth rib, the oscillating orthopedic saw is introduced for the second phase of the sternal division. The switch in instruments is essential as achieving the required sharp angle with a standard sternal saw is challenging and less controlled. The saw is angled to exit through the third intercostal space, ensuring that the lateral cut forms a triangular shape. This angled extension spares an additional rib compared to the conventional J sternotomy. (Figure 2)
- Sternal Retraction and Thoracic Exposure:** Once the sternum is divided, sternal retractors are applied to expose the thoracic cavity. The triangular shape of the distal portion of the incision allows for a wider field of vision, particularly for accessing structures in the lower thorax. This modification is particularly advantageous in complex cases where improved visualization of posterior thoracic structures is essential.
- Sternal Closure:** After completing the procedure, the sternum is closed using standard sternal wires, including an additional wire for the triangular portion of the incision to ensure optimal stability. Modified Arrow Type J sternotomy provides enhanced geometric stability with the angled sternal cut, which acts like a locking mechanism to lateral expansion forces sternum experiences while inspiring.

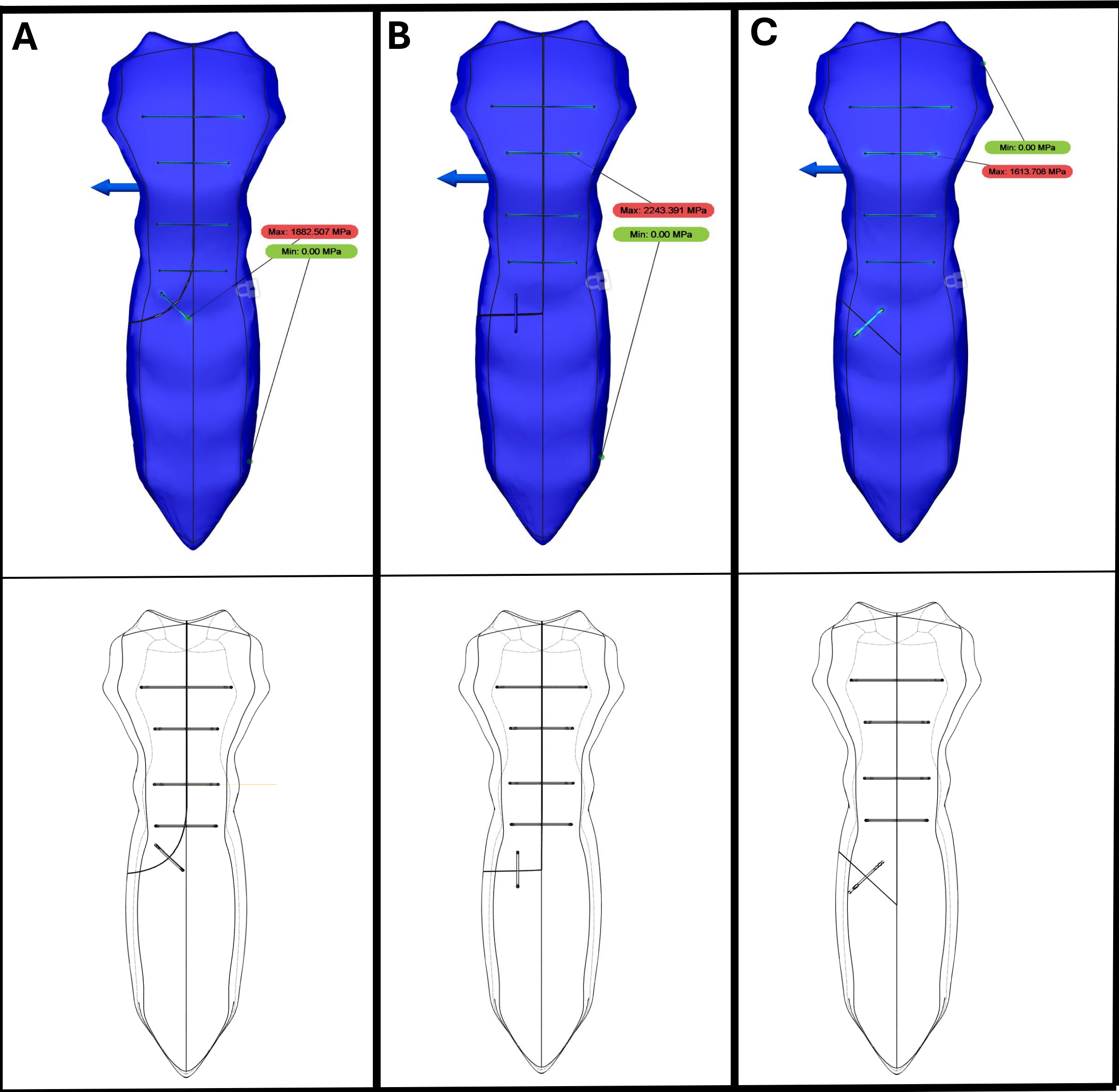


Figure 1. Virtual osteotomy geometries used for the finite-element study. Simulation views (top) and matching 2-D outlines (bottom) illustrate the conventional J (A), T (B) mini-sternotomies and Arrow-type J (C). Blue arrows mark lateral retraction; green/red arrows mark axial respiratory loading.

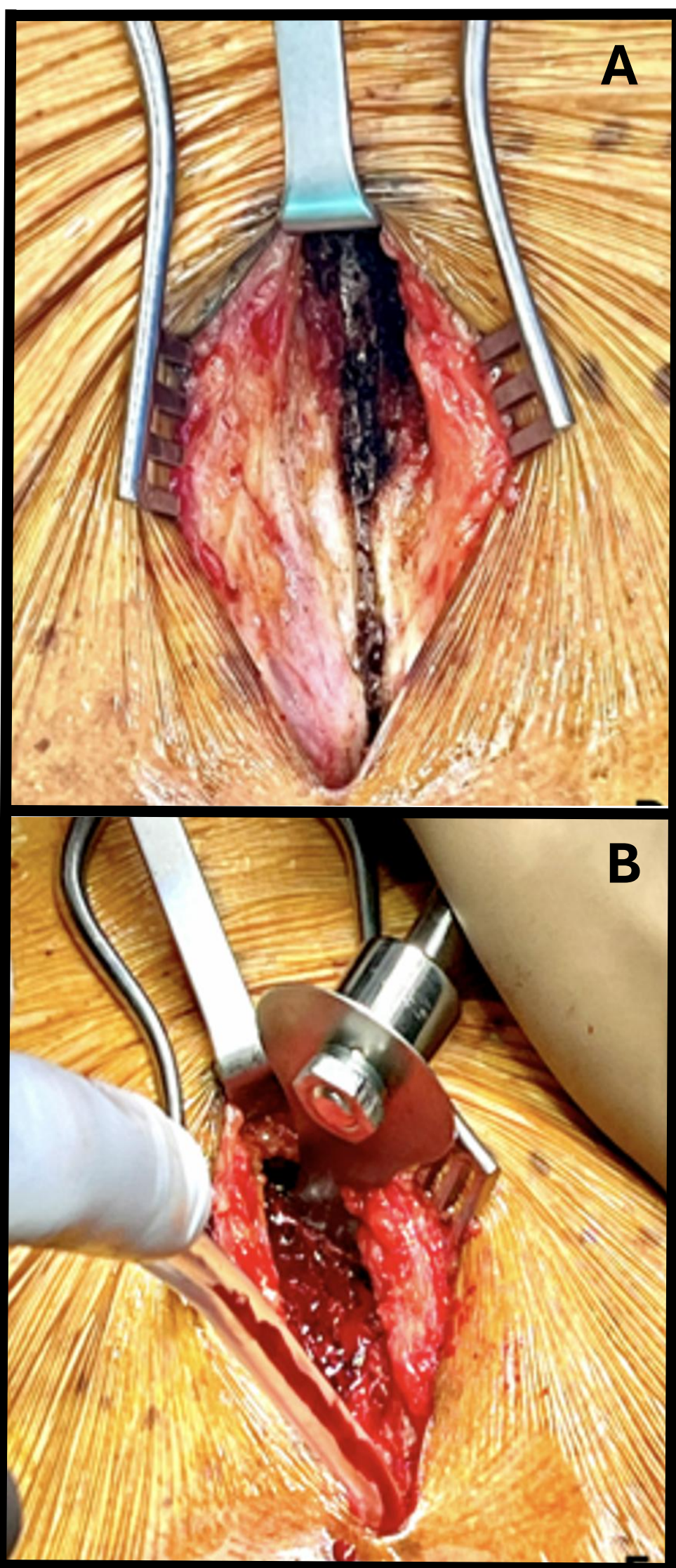


Figure 2. Intra-operative views of the Arrow-type J sternotomy. (A) Completed osteotomy with its distal triangular notch before sternal retraction. (B) Oscillating saw creating the angled cut through the third intercostal space

Sternotomy Type	Cut Surface Area (mm ²)	Area Comparison	Peak von Mises Stress (MPa)	Stress Comparison
Arrow Type J sternotomy	1692	11.4% larger area	1613.708	14.3% lower stress
Conventional J sternotomy	1519	Baseline	1882.507	Baseline
T sternotomy	1600	5.3% larger area	2243.391	19.1% higher stress

Figure 3. Cut-surface area and simulated peak von Mises stress for three sternotomy configurations. Triangular J, conventional J, and T sternotomies were modeled in CAD; areas are expressed in mm² and compared to the smallest cut (baseline), while stresses are given in MPa and compared to the conventional J baseline.

Methods

This section describes our methodology for creating and quantifying stress simulations used to compare sternotomy techniques:

- Human sternum is drawn in Form workspace of Autodesk Fusion 360 Software (Autodesk, San Francisco, CA) using anonymized Computational Tomography scans as reference. (Figure 1)
- Static stress simulations were performed again in the same application on three virtual sternotomy models identical except the sternotomy techniques: triangular J, conventional J, and T.
- Each model incorporated the material properties of average human cortical bone (*density* $2.0 \times 10^{-6} \text{ kg mm}^{-3}$, *Young's modulus* 17 GPa, *tensile strength* 150 MPa) drawn from Xiaodu Wang's characterization of age- and sex-matched specimens.
- Sternal wires were represented as steel for simulations (*Young's modulus* 210 GPa, *tensile strength* 345 MPa).
- A single directional load vector was applied across the manubrium to mimic the inspiratory forces that act on the sternum during the early postoperative period.
- Von Mises stress distributions were extracted for each construct.
- To assess potential gains in exposure, cut-surface areas were calculated directly from the CAD geometries after each virtual osteotomy; all three cuts terminated at the same intercostal level.

Conclusions

The triangular modification of the J sternotomy introduces an angled distal extension that mitigates two drawbacks of the conventional technique:

- First, by converting the distal curve into a triangular notch, the cut edges interlock under distraction, creating a self-reinforcing geometry that resists separation during respiration. Consistent with that premise, **the triangular J model registered the lowest peak von Mises stress (1 614 MPa) compared with the conventional J (1 883 MPa) and T (2 243 MPa) constructs**, suggesting a lower propensity for postoperative dehiscence. (Figure 1, Figure 3)
- Second, the triangular extension enlarges the bony window without lengthening the skin incision or sacrificing another rib. The **calculated cut-surface area reached 1 692 mm², surpassing both the conventional J (1 519 mm²) and the T sternotomy (1 600 mm²)** (Figure 3).

In the operating room this translates into easier retraction and superior access to inferior and posterior mediastinal targets, critical for procedures such as aortic valve replacement and multi-vessel coronary bypass, while preserving the cosmetic and biomechanical advantages of a shorter incision. Together, the biomechanical and geometric gains argue that the triangular J sternotomy may offer a safer, more versatile alternative to existing limited-access midline approaches.

References

- Svensson, L. G. (2007). Minimally invasive surgery with a partial sternotomy “J” approach. *Seminars in Thoracic and Cardiovascular Surgery*, 19(4), 299–303. <https://doi.org/10.1053/j.semtcvs.2007.10.004>
- Wang, X. (2012). Cortical bone mechanics and composition: Effects of age and gender. In M. J. Silva (Ed.), *Skeletal aging and osteoporosis* (Studies in Mechanobiology, Tissue Engineering and Biomaterials, Vol. 5, pp. 53–85). Springer. https://doi.org/10.1007/8415_2011_108