A numerical study to compare the mechanical behavior of different surgical constructs for sternal closure repair

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Abstract

Purpose

The study evaluates how three sternal closure constructs—stainless-steel wire cerclage, titanium plate fixation, and the Circumfix Varitrax® buttress-and-band system—respond mechanically under identical physiological loading. The goal is to understand differences in stability, stress distribution, and load sharing to inform safer, more effective postoperative sternal repair strategies. The document states that "the exact same loading conditions were applied to all 3 models" to enable direct comparison.

Methods

Finite Element Analysis was performed using simplified, symmetric sternum geometries to avoid stress risers and isolate construct behavior. Each construct was assigned published material properties, including titanium (E = 120 GPa), stainless-steel wire (E = 193 GPa), and PEEK for Varitrax® (E = 3.95 GPa).
Three physiologic loading conditions were applied uniformly:

- **Lateral distraction:** 150 N total across rib pairs
- **Anterior–posterior shear:** 100 N in opposing directions
- **Rostral–caudal shear:** 100 N in opposing directions

Contact conditions reflected realistic implant–bone interactions, such as sliding interfaces for wires and bands and fixed screw–bone interfaces for plates.

Results

Mechanical behavior varied significantly by construct:

- **Stainless-steel wire** showed the **largest displacements** in all directions and produced **high stress concentrations** at the wire–bone interface due to its low

bending stiffness and reliance on high tension. The report notes that “the very thin nature of the wire… induce[s] very high concentration points at the wire/bone interface.”

- **Titanium plates** provided the **lowest displacement** and highest rigidity but demonstrated **poor load sharing**, with stresses concentrated in the implant and at the bone–screw interface. The document states that titanium constructs “concentrate most of the mechanical loads in the implant and not the bone.”
- **Circumfix Varitrax®** showed the **best balance** of stability and physiological load transfer. Its PEEK material and geometric configuration produced axial and flexural rigidity closer to bone, resulting in **higher load sharing** and **reduced stress concentration**, especially in rostral–caudal loading. The report highlights that Varitrax® “allowed for higher load sharing… and more homogeneous distribution of the mechanical loads.”

Conclusion

Each construct presents distinct mechanical trade-offs. Stainless-steel wire offers basic fixation but suffers from high displacement and localized bone stress, increasing risk of dehiscence or bone damage. Titanium plates maximize immediate postoperative stability but limit bone loading, potentially impairing long-term remodeling and risking screw-related stress risers. The Circumfix Varitrax® system provides a biomechanically favorable compromise, combining adequate stability with load sharing that aligns more closely with bone physiology and Wolff’s Law. Overall, constructs with rigidity closer to bone—such as Varitrax®—may better support long-term healing while maintaining sufficient mechanical stability.

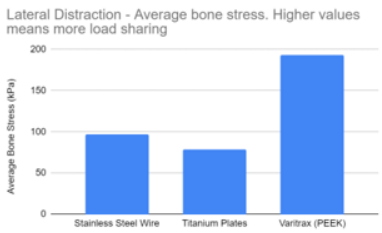


Figure 5. Comparison chart of the mechanical load sharing on each surgical construct under lateral distraction. Average bone stress was calculated by selecting 6 sample points along the midline of the sternum.

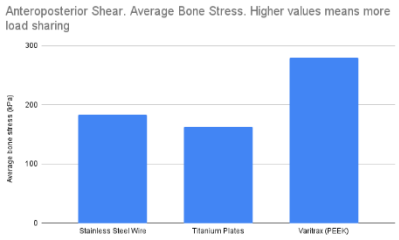


Figure 6. Comparison chart of the mechanical load sharing on each surgical construct under Anterior-Posterior shear. Average bone stress was calculated by selecting 6 sample points along the midline of the sternum.

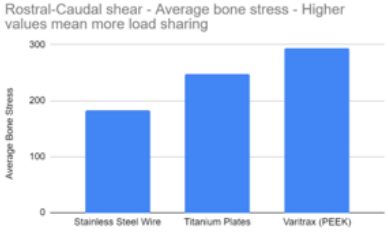


Figure 7. Comparison chart of the mechanical load sharing on each surgical construct under Rostral-Caudal shear. Average bone stress was calculated by selecting 6 sample points along the midline of the sternum.