Biomechanical Comparison of Three Sternotomy Closure Techniques: Static Lateral Distraction

Introduction

To compare the strength and stiffness of three different sternotomy closure techniques under static lateral distraction.

Methods

Anatomical sternum models (Sawbones® 20 lb/ft^3 foam, 1025-2) were selected for testing [Trumble 2002]. The sternum models were potted, divided along their midline, and fixed with three SuperCables (Kinamed®), No. 5 stainless steel surgical wires (Ethicon®), or stainless steel sternal cables (Pioneer®) as shown in Fig. 1. A simple peri-sternal wrapping technique was chosen based on clinical evidence [Khasati 2004] and because these sternum models do not contain intercostal cartilage, which can affect the stability of a figure-of-eight wrapping technique. In accordance with published methods [Cohen & Griffin 2002], the sternal halves were distracted laterally at 10 mm/min using a Chatillon LRX materials testing system until model failure occurred. The load-displacement behavior of each sternum model was graphed and the ultimate strength and stiffness of each construct was calculated.

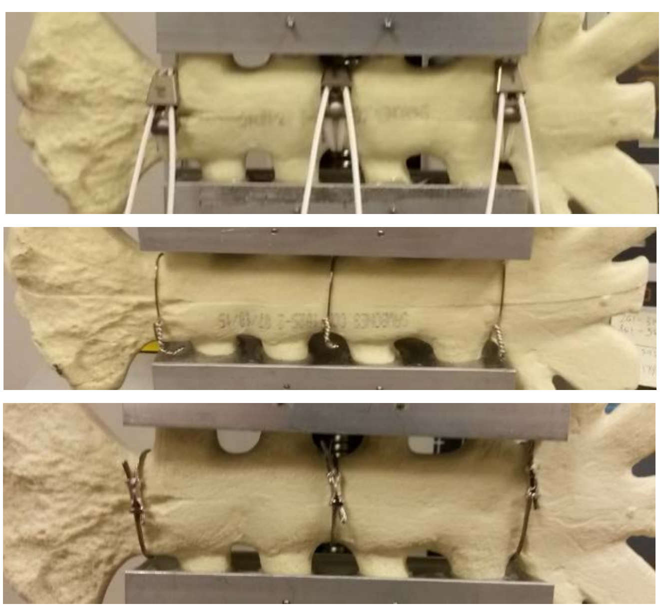

Fig 1. Anatomical sternum models divided and closed with three SuperCables (top), three No. 5 steel wires (middle), and three steel sternal cables (bottom) prior to static lateral distraction. The sternal closure and testing methods were performed in accordance with published literature [Cohen & Griffin 2002].

Results

Fig. 2 summarizes the load-displacement behavior, ultimate strength, and stiffness of each sternum construct.

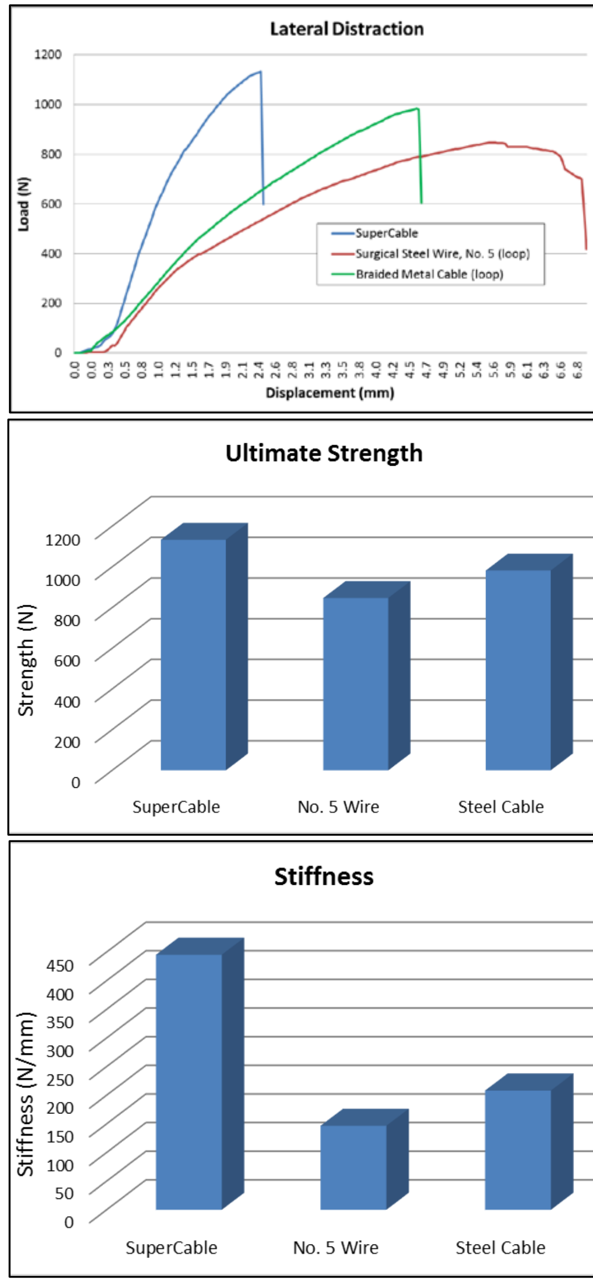

Fig 2. Load versus displacement, ultimate strength and stiffness of each sternum construct under simulated lateral distraction (loading was increased until sternum model failure occurred).

Conclusions

The SuperCable construct was 34% stronger and 3x stiffer than the Steel Wire construct. The SuperCable construct was 15% stronger and 2x stiffer than the Steel Cable construct.

Biomechanical Comparison of Three Sternotomy Closure Techniques: Cyclic Lateral Distraction

Introduction

To compare the stability of three different sternotomy closure techniques during and after cyclic lateral distraction.

Methods

Anatomical sternum models (Sawbones 20 lb/ft^3 foam, 1025-2) were selected for testing [Trumble 2002]. The sternum models were potted, divided along their midline, and fixed with four SuperCables (Kinamed®), seven No. 5 stainless steel surgical wires (Ethicon®), or four stainless steel sternal cables (Pioneer®). A simple wrapping technique was chosen based on clinical evidence [Khasati 2004] and because these sternum models do not contain intercostal cartilage, which can affect the stability of a figure-of-eight wrapping technique. Because sneezing has been shown to generate 814 Newtons of lateral distraction force on the sternum [Adams 2014], the sternal halves were laterally distracted with a cyclic force ranging from 0 to >1000 Newtons for five cycles using a Chatillon LRX materials testing system. Following cyclic loading, each sternum was statically loaded and sternal separation at the manubrium, sternal body, and xiphoid process were measured.

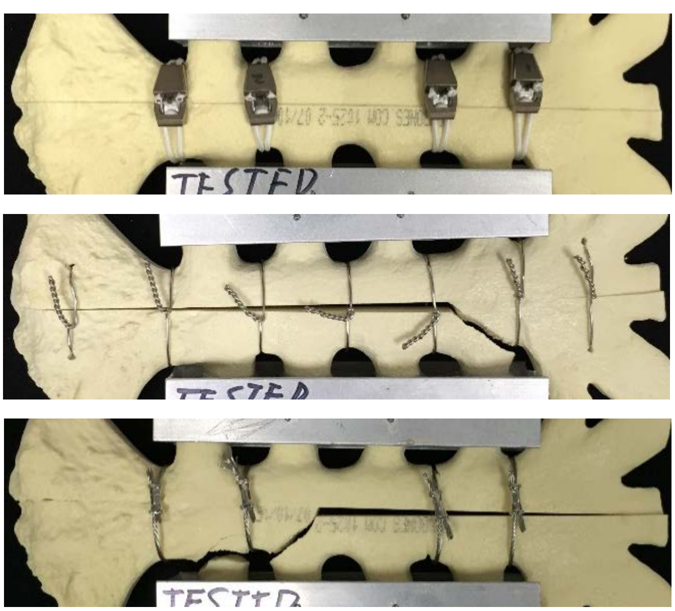

Fig 1. Anatomical sternum models divided and closed with four SuperCables (top), seven No. 5 steel wires (middle), and four steel sternal cables (bottom) after cyclic lateral distraction and under static load. The Wire construct consisted of five peri-sternal and two trans-sternal wires (Dasika 2003).

Results

The SuperCable sternotomy closure technique survived the simulated sneezing regime intact while sternum model failure occurred with both the steel wire and steel cable closure techniques (Fig. 1). Sternal separation after cyclic loading while under static load is summarized in Table 1. The ribs in the steel wire and cable constructs increasingly separated with each cycle of load, in contrast to the behavior of the SuperCable construct (Fig. 2).

	Location				
	A	B	C	D	E
SuperCable	0.00	0.50	0.64	0.64	0.25
(0 to 1216 N @ 0.9 Hz)	Sternum was intact after cyclic loading				
No. 5 Steel Wire	1.27	2.54	3.18	4.32	0.00
(0 to 1102 N @ 0.9 Hz)	Sternum partially failed during cyclic loading				
Steel Cable	N/A				
(0 to 1094 N @ 0.9 Hz)	Sternum completely failed during cyclic loading				

Table 1. Sternal separation (mm) for each construct after the sneeze simulation and final static load. Location A: Manubrium, Locations B-D: sternal body, Location E: Xiphoid. The cyclic loading parameters (average amplitude and frequency) for each closure type are listed.

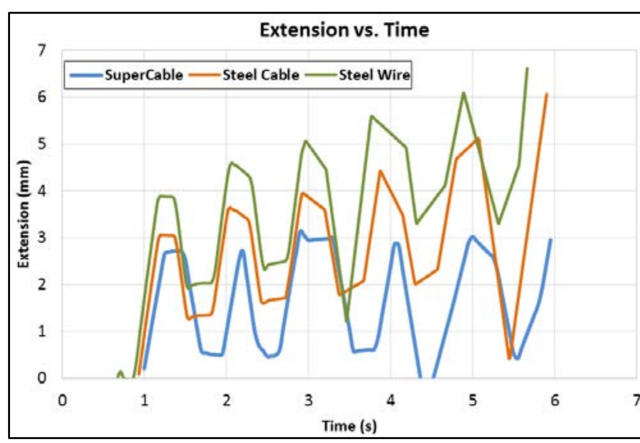

Fig 2. Extension versus time graph showing the effect of cut-through of the steel wires and steel cables into the sternum.

Conclusions

The SuperCable construct survived the cyclic loading regime intact while the Steel Wire and Steel Cable constructs experienced cut-through and structural failure. Due to its elastic properties, SuperCable is more effective than Steel Wire or Steel Cable at withstanding the cyclic loads associated with sneezing.