Journal **ARTICLE**

Fatigue Characterization of Anterior Screw/ Rod Constructs in Axial Compression

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Introduction:

Zielke anterior spinal instrumentation revolutionized scoliosis surgery in the 1970's, allowing powerful correction and stabilization of the anterior column of the spine. However, recent studies have shown significant instances of rod breakage and/or loss of correction with this instrumentation. Harms modified the Zielke system with polyaxial screws to give the instrumentation more degrees of freedom, but used a similar threaded rod. The Texas Scottish Rite Hospital (TSRH) anterior system elected to use a solid 4.75mm diameter rod and larger diameter screws (6.5)mm) instead of the 6mm screws and 3.2mm or 4mm threaded rods of the Zielke system, believing that this would minimize instrumentation failure and loss of correction while providing a stiffer construct. The Synergy anterior system also uses a solid 4.75mm rod and has a variety of screw options including 6mm and 6.5mm diameter screws in open and closed designs. The purpose of this study is to compare fatigue endurance limits (FEL) and dynamic stiffness of Zielke, Harms, TSRH and Synergy screw/rod constructs.

Materials and Methods:

All constructs were assembled according to manufacturer specifications and conducted under ambient conditions. A minimum of six constructs from each design were tested in dynamic axial compression. Each construct consisted of two UHMW polyethylene pucks simulating vertebral bodies, two screws and one rod (Figure 1). The constructs were tested under cyclic fatigue to develop load/ moment vs. number of cycles curves, and dynamic stiffness was determined within the first 1000 cycles of each test by capturing peak and valley points from both force and displacement sine waves. Differences were evaluated for statistical significance for dynamic stiffness in the standard manner (p=0.05), and for FEL by determining if the 95% confidence limits fitted to each curve overlapped. The designs tested were Zielke 6 x 40mm polyaxial screws on a 4mm threaded rod, Synergy 6 x 40mm closed screws on a 4.75mm rod, TSRH 6.5 x 40mm goalpost screws on a 4.75mm rod, Synergy 6.5 x 40mm open screws on a 4.75mm rod, and Synergy 6.5 x 40mm closed screws on a 4.75mm rod.

Results:

The load and moment vs. number of cycles curves for the 6mm screw constructs (Figure 2A -B) show significant differences in FEL between the Synergy Open and Closed screw construct and the Zielke and Harms constructs. The Synergy Open screw construct developed a double curve with a screw breaking at the higher loads and the rod breaking at the lower loads. The 6.5mm screw fatigue curves (Figure 3A-B) show differences in FEL between the Synergy Open and Closed screw constructs and the TSRH construct, with all three significantly higher than the Zielke value.

The dynamic stiffness values for 6mm screw constructs (Figure 4) show differences between the Synergy Open and Closed screw constructs and the Zielke and Harms constructs, while the 6.5mm screw constructs (Figure 5) show differences between the Synergy Open and Closed screw constructs and the TSRH construct. Typical failure modes for the different designs tested are shown in (Figure 6A-F).

Conclusions:

Stiffness and FEL's have improved as anterior screw/rod instrumentation for spinal deformity has evolved. The increases appear to be primarily due to enhanced rod and cancellous thread geometries (Figure 7A-C), and improved screw to rod clamping mechanisms (Figure 8A-B). Of clinical relevance, these increases should lead to reduced occurences of instrumentation failure and loss of correction, and may contribute to higher rates of fusion.

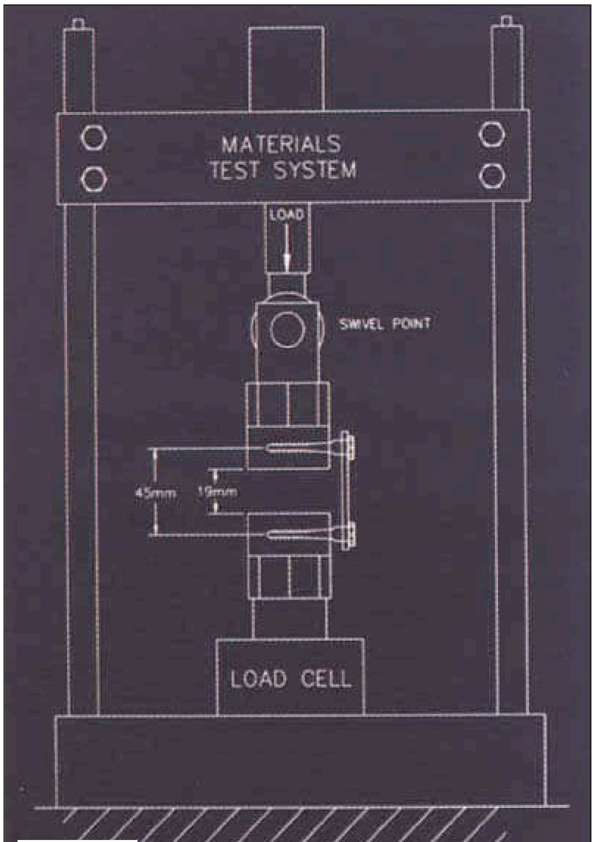

Fig. 1

Fig. 2A-B

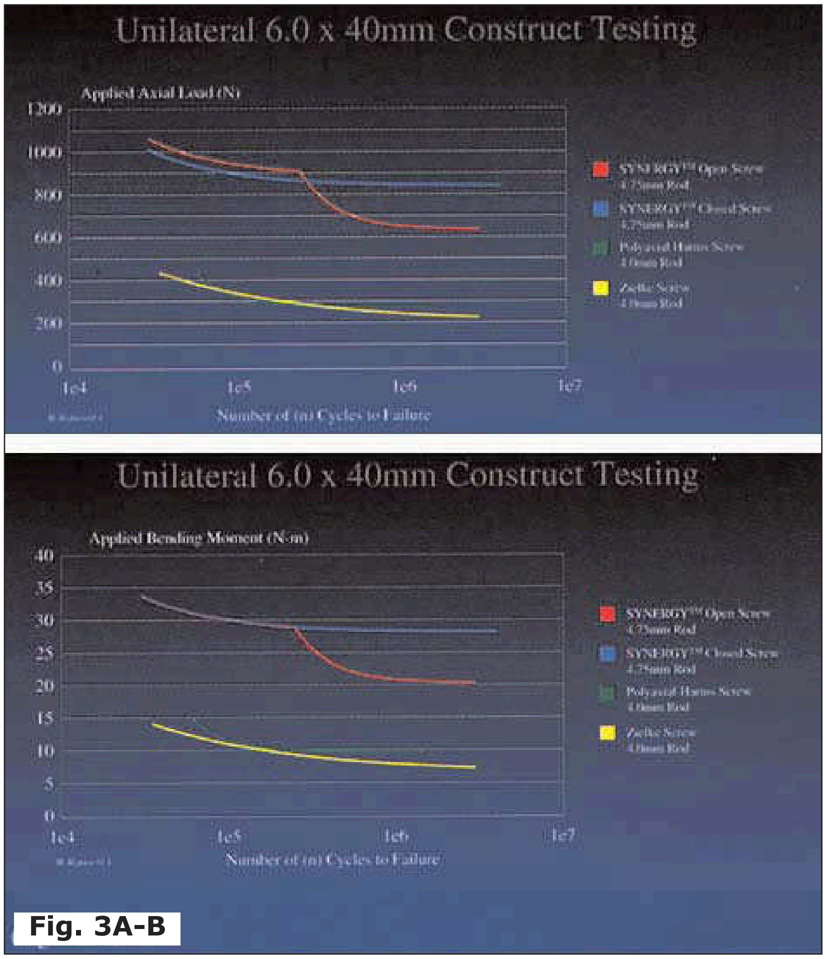

Fig. 3A-B

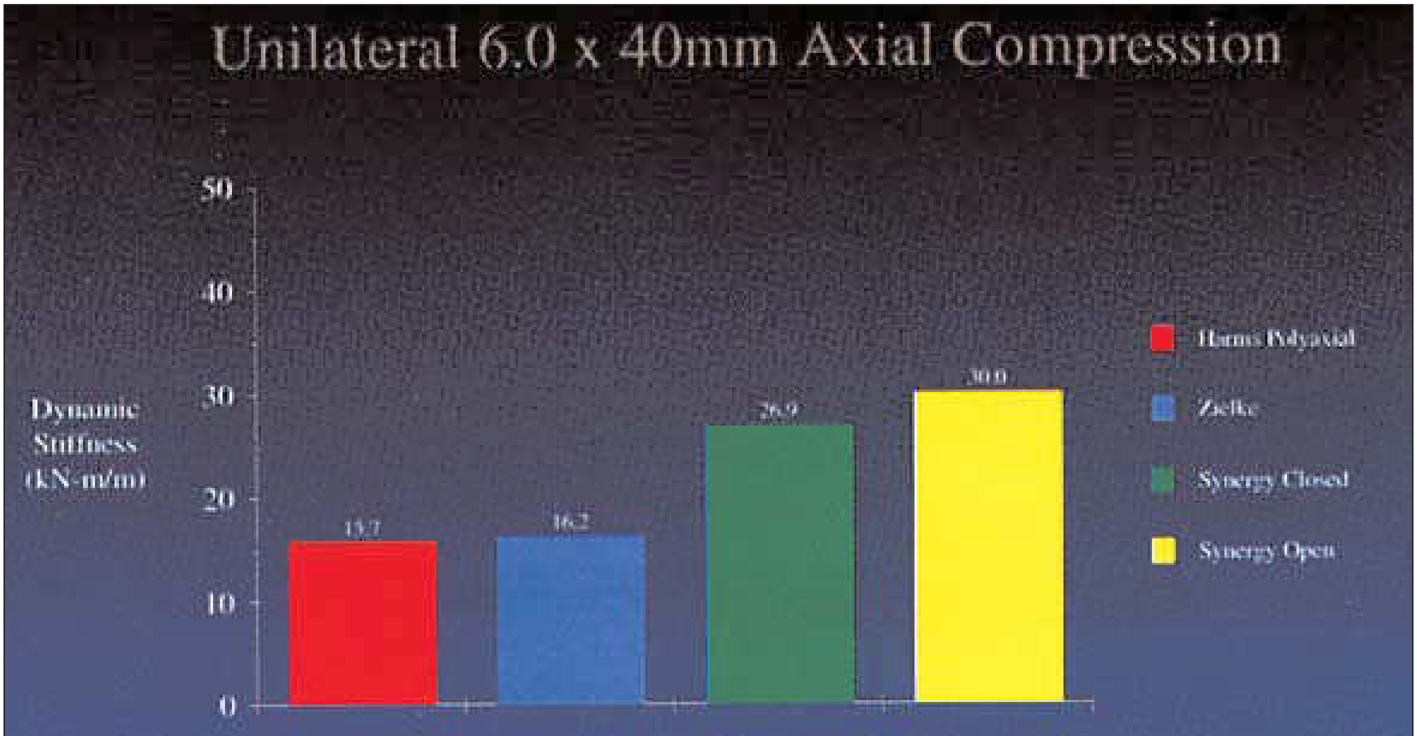
Unilateral 6.0 x 40mm Axial Compression
Dynamic Stiffness (kN-m/m)
50
40
30
20
10
0
15.7
16.2
26.9
30.0
🟥 Harms Polyaxial
🟦 Zielke
🟩 Synergy Closed
🟨 Synergy Open

Fig. 4

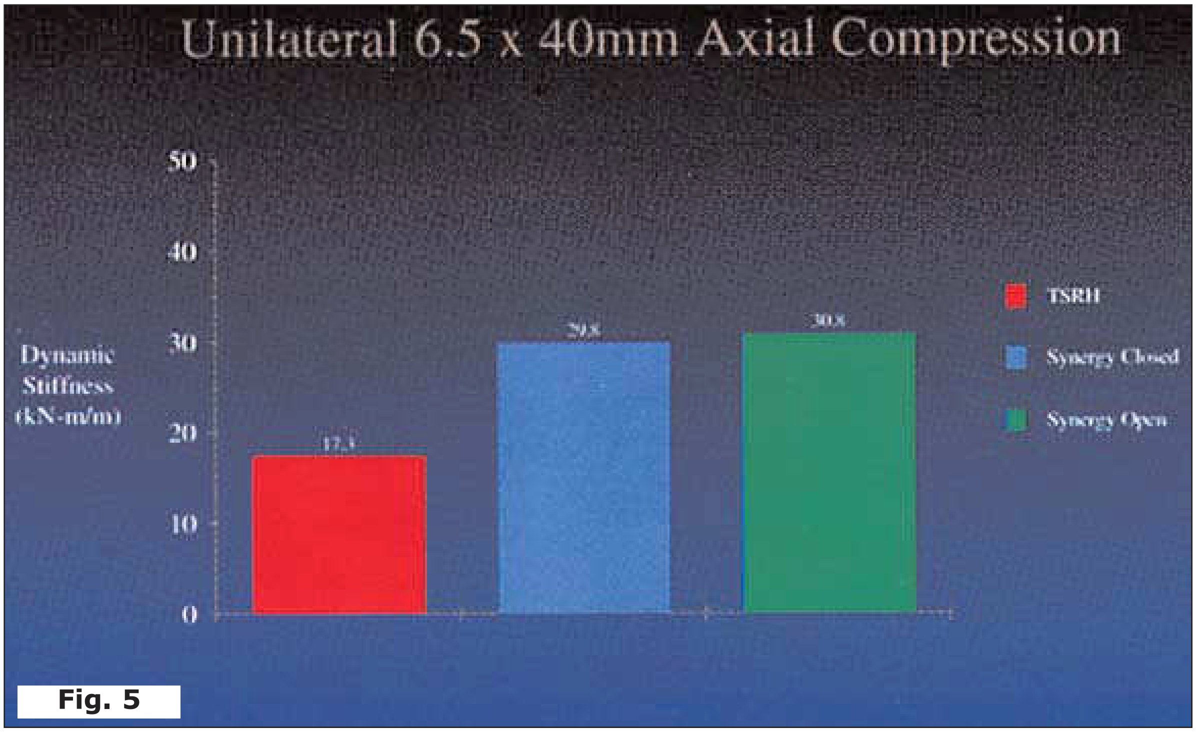
Unilateral 6.5 x 40mm Axial Compression
Dynamic Stiffness (kN-m/m)
50
40
30
20
10
0
17.3
29.8
30.8
🟥 TSRH
🟦 Synergy Closed
🟩 Synergy Open

Fig. 5

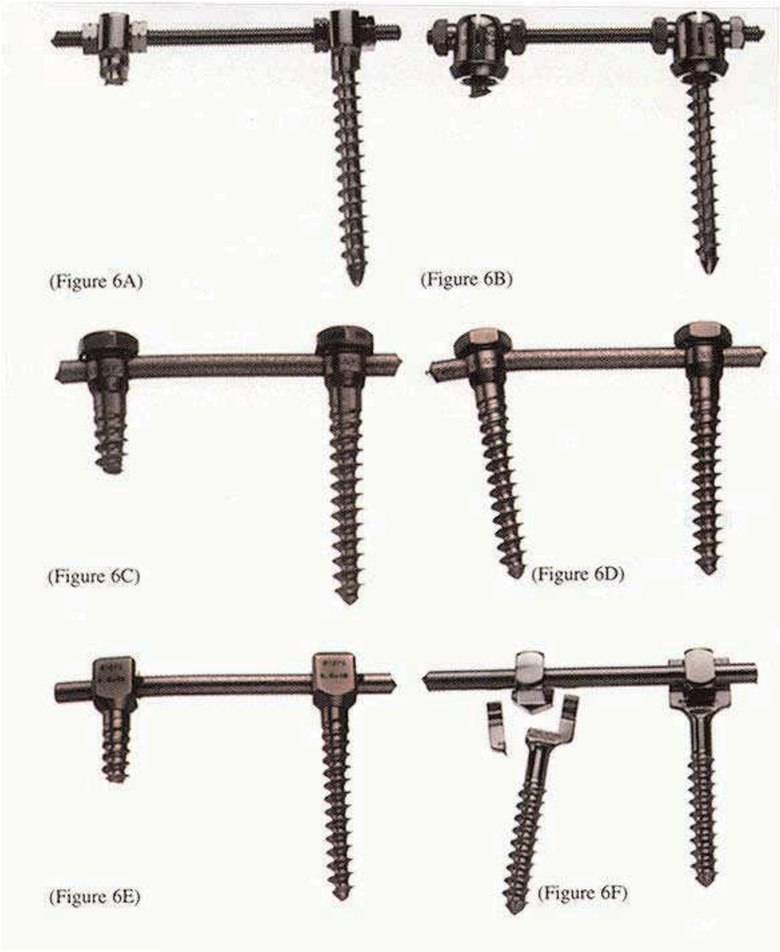

Fig. 6

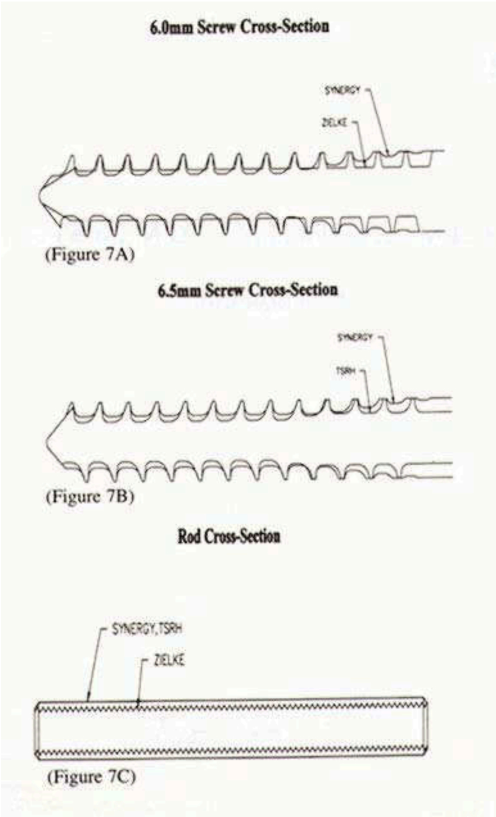

Fig. 7

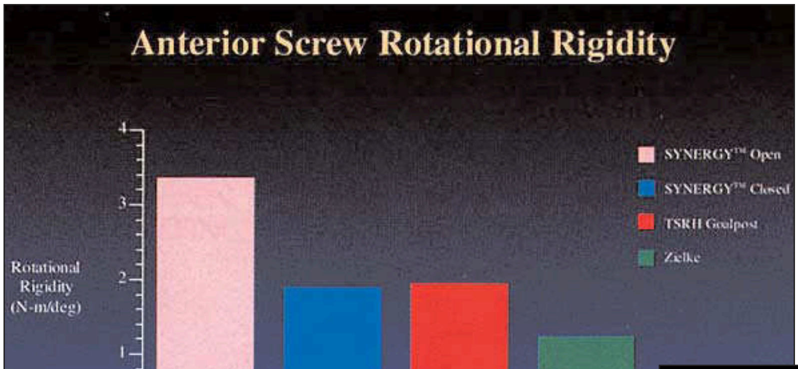

Fig. 8A

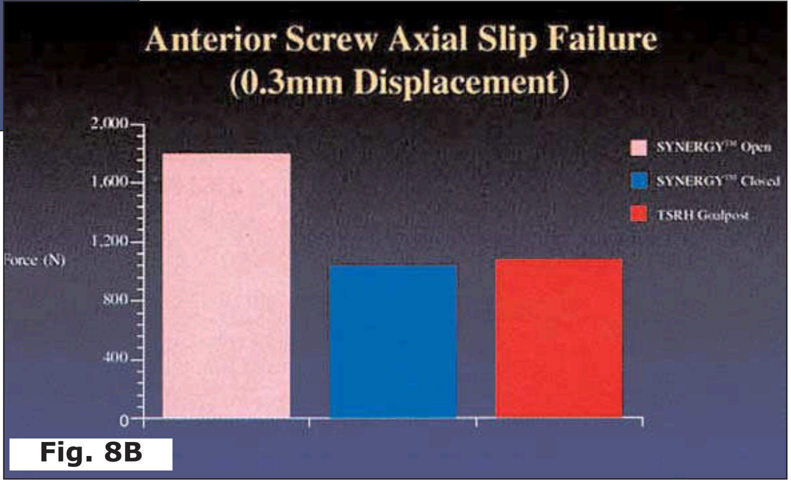

Fig. 8B