Cyclic Testing of a Growing Rod System for Scoliosis Reconstructions

[1]Shufflebarger, H, [2]Kaimrajh, D, [3]Serhan, H, [4]Leger, G, [2]Milne, E, + [2, 5]Latta, L
[1]Miami Children's Hospital, Coral Gables, FL, + [2]Max Biedermann Instit. Biomech., Miami Beach, FL,
[3]DePuy Spine, Raynham, MA, [4]Univ. de Tech. de Troyes, Troyes, France, [5]Univ. of Miami, Miami, FL

INTRODUCTION:

Long constructs of the thoracic spine involve a great deal of motion when loaded in flexion-extension, therefore, they cannot be rapidly cyclically loaded. It is impractical to test cadavers for several days, so synthetic models have been developed for long term testing. Such a model has been published[1] but the short term biomechanical behavior has not been validated by comparison to cadaver testing. The objective of this study was to validate a synthetic model for long thoracic constructs and cycle test to 150,000 cycles to evaluate component loosening and wear debris in a growing rod construct.

METHODS:

Three fresh cadaver spines from T1 – T10 were stripped of ribs and muscles leaving all joints intact. The fused section of thoracic spine had pedicle screws locked to 6 N·m, while the other screws were tightened to 6 N·m, while maintaining a 5 mm gap at the screw rod interface to allow sliding, see Fig. 1. Each was loaded from 5 N·m flexion to 5 N·m extension while the structural stiffness was measured, see Fig. 2. Next each spine was then loaded in axial torque, ±5 N·m. Then each spine was instrumented with pedicle screws and rods in a typical scoliosis construct and the loading repeated. A UHMWPE model of the thoracic spine was then tested with the same loading conditions, stiffness measured, then instrumented with the same construct and retested. The synthetic model was far less rigid than the cadaver spines, so the model was doubled in size and the tests repeated.

Following the static validation tests, the construct with instrumentation was loaded in fatigue for 150,000 cycles to determine propensity for failure, tendency for jamming while sliding and integrity of the locking mechanism.

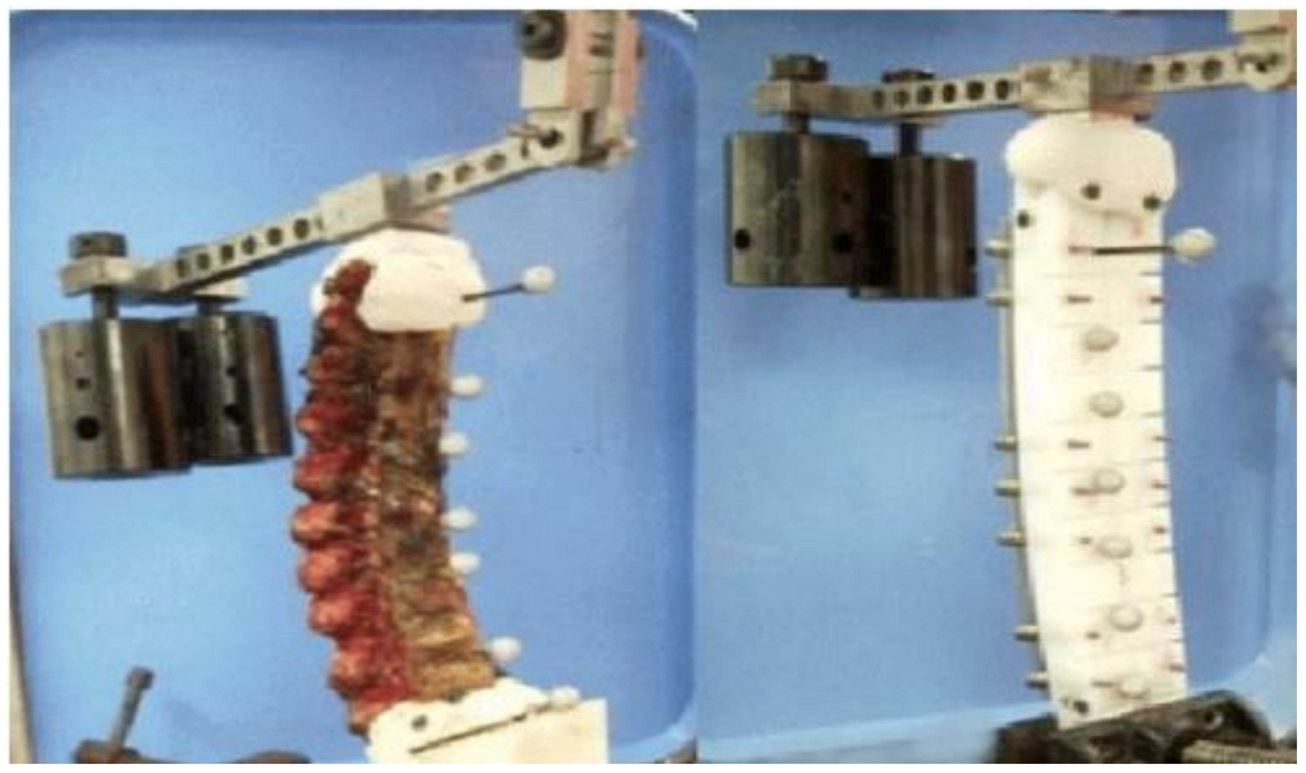

FIGURE 4 – Flexion/Extension constructs

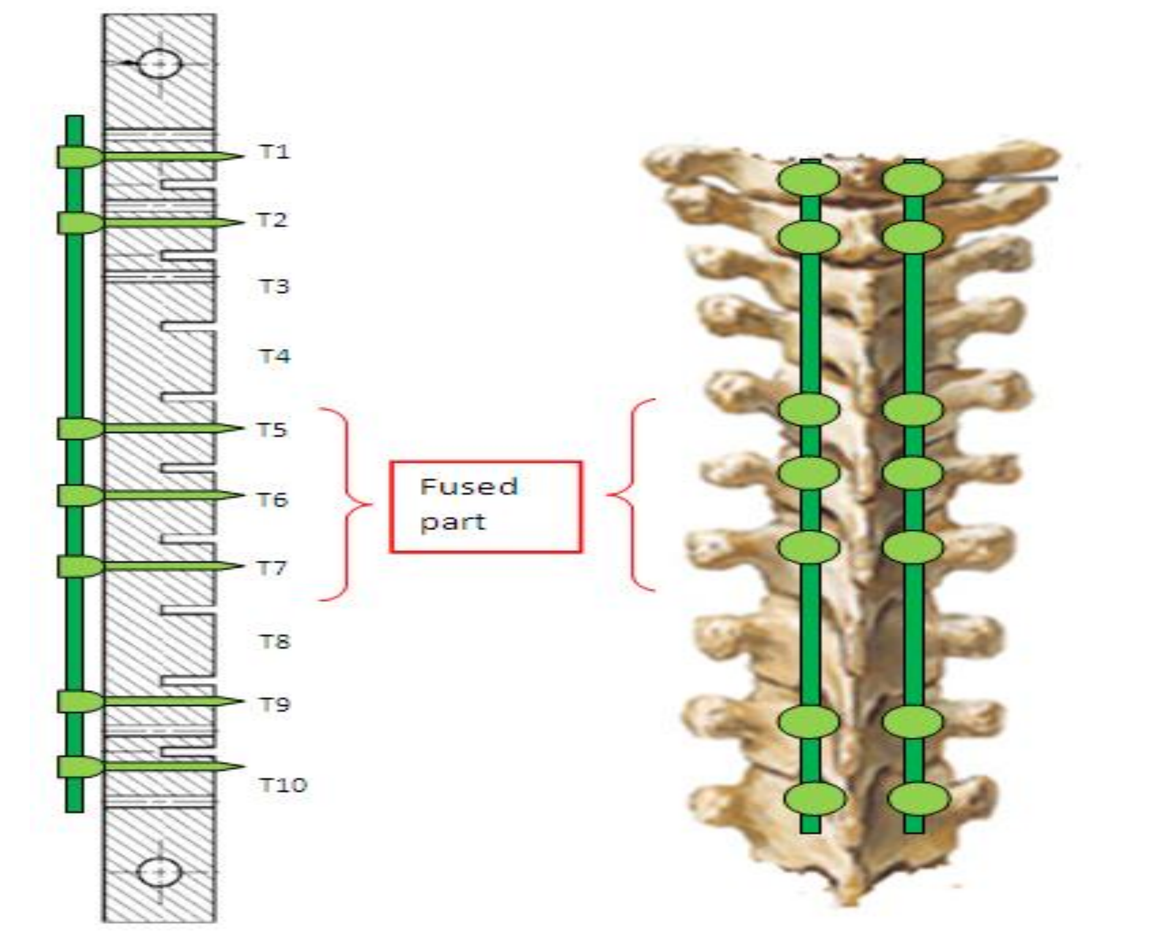

FIGURE 1 – Construct and screw placement

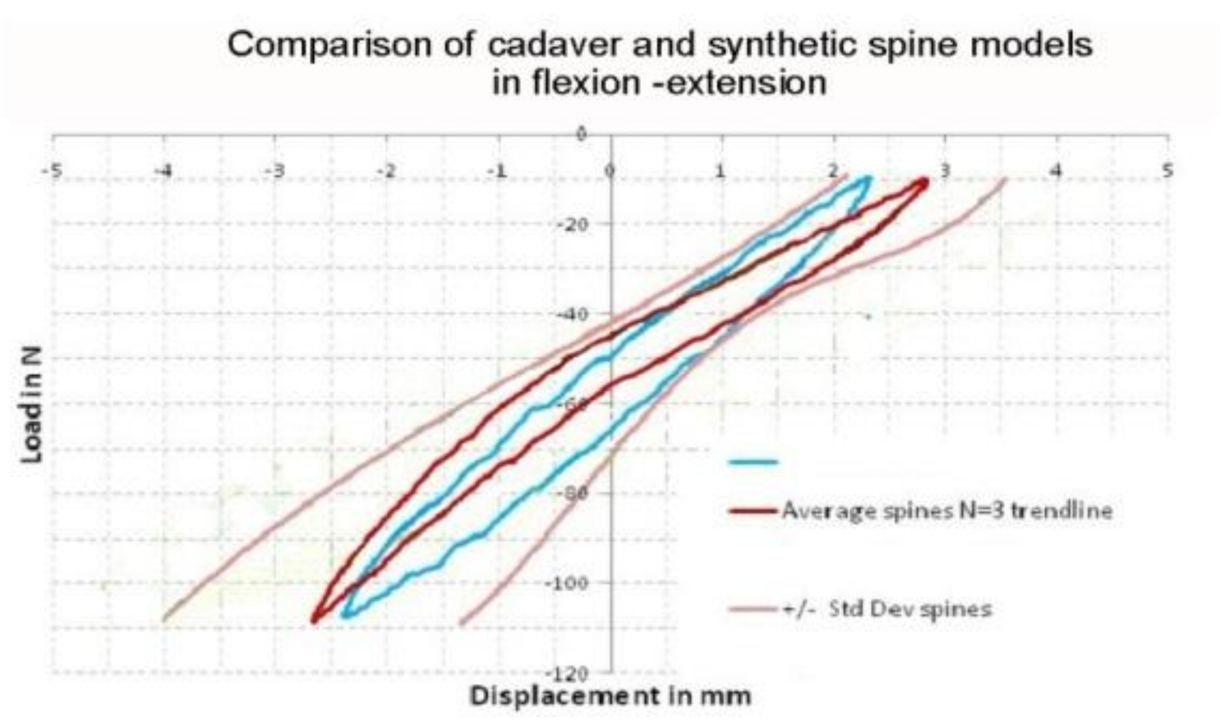

FIGURE 2 – Flexion/extension curves

FIGURE 3– Wear Debris from testing 150,000 cycles

RESULTS:

The average torsional stiffness was significantly less with the synthetic model than with the cadaver spines both with and without instrumentation, so this loading condition was dropped from the study. The flexion-extension stiffness for the models without instrumentation was 5.5 N/mm for the synthetic model and 4.4 N/mm (4.0 – 5.5) for the cadaver spines. With the instrumentation, the cadaver spines averaged 18.1 N/mm (15.1 – 20.0) and the synthetic model, 16.7 N/mm. Thus the synthetic model was within the 95% confidence limit of the cadaver models in flexion-extension which validates this model for cyclic test for the growing rods, see Fig. 3. Cycle testing to 150,000 cycles showed no evidence of component loosening but did show evidence of wear where the rods moved through the screw head and minimal wear debris, see Fig. 4.

DISCUSSION:

The synthetic model as described in the literature, doubled in size to simulate a full thoracic spine, was a valid model of a cadaver spine for flexion-extension loading as long as comparisons between instrumentation are made, but was not valid for axial torsion loading. Also, the model did not have a neutral zone which is commonly seen in spine biomechanical testing.

A simple model has been validated to simulate the stiffness in flexion-extension loading of cadaver spines with long thoraco-lumbar constructs. Long constructs of this nature do not lend themselves to rapid cyclic loading for fatigue testing, thus rendering it impossible to use cadaver models for long term cyclic testing. With this model, it is possible to operate the model in a variety of environments for long periods of time to simulate long constructs in fatigue conditions.

REFERENCES: 1) Serhan, H: J Spinal Disord Tech, Vol. 23(7), pp. e31-e36, Oct 2010

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