Biomechanics of Two Fusionless Scoliosis Correction Techniques- Rigid Staple vs. Flexible Tether

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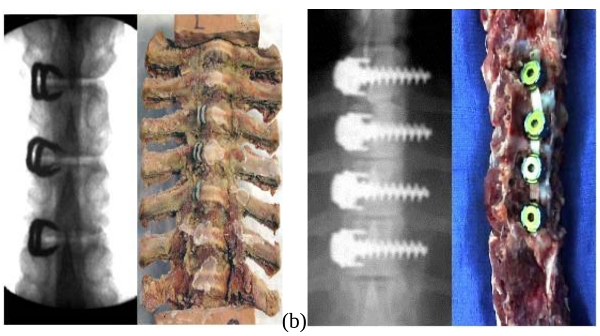
INTRODUCTION:

Currently, there are two clinically relevant, fusionless surgical treatments that utilize growth modulation for scoliosis deformity correction. The first treatment incorporates the use of two parallel Nitinol staples and the second treatment uses a flexible, ultra-high molecular-weight polyethylene (UHMWPE) tether. Both techniques have been shown to successfully modulate spinal growth,[1,2] harnessing the growth potential of the spine, with the clinically relevant benefits of correcting three-dimensional deformities without requiring arthrodeses. The purpose of this study was to perform a comparative analysis of biomechanical stiffness and range of motion (ROM) in a porcine model of these two fusionless scoliosis correction techniques and compare them to intact (control) spines.

METHODS:

Twenty porcine thoracic spines were obtained. The ends of each specimen were embedded in polyester resin (3M, St. Paul, MN), creating a rigid connection between the specimen and testing apparatus. Nine of the spines were tested prior to instrumentation and served as the control goup. Four of the spines were stapled across three adjacent motion segments on the right anterolateral thoracic spine. Two Nitinol staples (Medtronic, Memphis, TN) were instrumented parallel to each other on each level across the adjacent motion segments. Staples spanned the entire disc and adjacent vertebral endplates and growth plates (Figure 1a). In seven spines, laterally directed anterior vertebral body screws (DePuy Spine, Raynham, MA) were placed into each of four adjacent vertebrae. A flexible, UHMWPE-tether was secured to the screws, spanning three motion segments (Figure 1b).



(a) (b)

Figure 1: Spines were prepared with either Nitinol staples (a) or with a flexible, UHMWPE tether across three adjacent motion segments (b).

Each specimen was prepared by rigidly attaching Kirschner wires in the midline of each vertebral body parallel to the plane of motion. Retro-reflective markers were then attached to the end of each wire. All deformation was assumed to occur in the soft tissue (discs), so that the vertebral bodies acted as rigid bodies.

Non-destructive biomechanical testing was performed in flexion–extension, lateral bending, and axial rotation using a MTS 858 Bionix testing apparatus (Eden Prairie, MN). Specimen stability was evaluated by determining their rotation behavior based on the biomechanical stiffness and ROM. All calculations were performed using a custom-designed MATLAB (MathWorks Inc., Natick, MA) program.

Multiple comparisons (Bonferroni post hoc) of the stiffness (Nm/deg) of the entire construct and the range of motion (degrees) were used for analysis among the three groups. Statistical significance was set at a critical alpha value of $p < 0.05$.

RESULTS:

Axial ROM was significantly restricted with staple (p=0.000, 40% of normal AX) and tether (p=0.035, 67% of normal AX) introduction (Figure 2). Staples significantly increased stiffness in lateral bending (2-fold, p=0.024), flexion/extension (5-fold, p=0.064) and axial rotation (AX) (3-fold, p=0.000) compared to the control group (Figure 3). The stapled group was significantly stiffer than the tethered group in axial rotation (3-fold, p=0.000) with no difference in lateral bending and approaching significance for flexion/extension (1.5-fold, p=0.055).

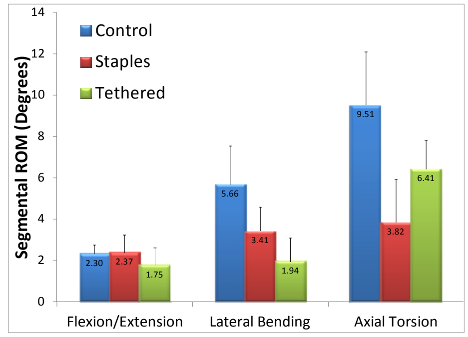


Figure 2: The average ROM between two adjacent motion segments (± SD) for the three groups

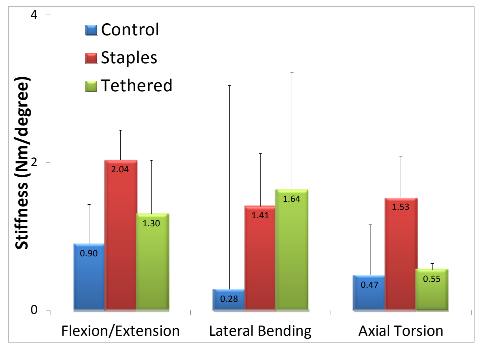


Figure 3: The average stiffness (± SD) for the three groups

DISCUSSION:

Studies evaluating the motion flexibility and spinal unit stiffness in fusionless scoliosis correction management have been limited. For the first time, the biomechanics of two clinically relevant fusionless techniques was compared. The use of an animal model and the *in vitro* study experimental setup are limitations of the study. It is to be expected that the stiffness in porcine spines will be higher than in a human adolescent spine, as humans possess a greater range of motion and flexibility than many animal models. However, the same testing procedure was implemented on both control and treated spines, so that the percental change in motion and stiffness by the insertion of the staples or the tether can be assessed. Another study limitation is that all constructs were tested at the time of initial implantation. A logical next step would be to implant both instruments in a growing animal model and evaluate them after a given time period.

The data from this study may be useful in determining the treatment that is more physiologically correct and which restricts the spinal motion only minimally, presuming that both treatments have an equal effect on scoliosis correction. The clinical implications of this study are significant since one of the major complications associated with the fusion surgeries is subsequent disc demobilization and degeneration. The theoretical benefit of fusionless techniques is that they correct scoliosis and/or stop progression without fusing the affected levels.

REFERENCES:

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2. Newton PO, et al. Spinal growth modulation with use of a tether in an immature porcine model. J Bone Joint Surg Am 2008;90:2695-706.