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Basic Science

Spinal growth modulation with posterior unilateral elastic tether in immature swine model

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Abstract

BACKGROUND CONTEXT: Fusionless scoliosis surgery is frequently performed in children. Many studies have analyzed the effects of spinal growth modulation by tethering the anterior and anterolateral aspects of the spine in animal models. However, few studies have reported the disc health and spinal motion in spines with posterior unilateral elastic tethering.

PURPOSE: To analyze the regional radiography, biochemistry, and histology of spinal motion segments fixed by posterior unilateral elastic tethering.

STUDY DESIGN: A randomized controlled trial.

OUTCOME MEASURES: Preoperative and postoperative radiographs of the spines were taken. After an 8-week recovery period, the spines were harvested en bloc and underwent radiographic, biochemical, and histologic analyses.

METHODS: Fifteen 3-month-old swine were randomly divided into three groups. Instrumentation was performed posteriorly in the swine. In the elastic fixation (EF) group, five swine were instrumented on the left side of the lumbar vertebrae from L1 to L5 with pedicle screws that were connected with a unilateral elastic tether with tension to produce a curve on the spine. The same surgery was performed in the five animals of the metal rod fixation (MF) group, in which the screws were connected with metal rods and curves were established. In the control group, five animals were instrumented with five screws with no connecting cable.

RESULTS: Scoliosis and lordosis were created in the coronal and sagittal planes in both the EF and MF groups. On average, the Cobb angles were $12.16^\circ \pm 1.37^\circ$ and $9.10^\circ \pm 2.02^\circ$ ($p=.023$) in the coronal plane and $17.44^\circ \pm 11.29^\circ$ and $5.32^\circ \pm 3.06^\circ$ ($p=.049$) in the sagittal plane in the two groups, respectively. The vertebrae and discs wedged on the tethered side in the two groups showed no significant differences ($p>.05$). The thickness of end-plate epiphysis on the fixed side was significantly decreased in the two groups ($p=.032$ and $p=.024$). No apparent change was found in the gross morphology of the discs in the two groups. The distribution of collagen types I and II decreased and that of matrix metalloprotease-3 (MMP-3) increased in both the EF and MF groups. Additionally, the proteoglycan synthesis decreased in the two groups.

CONCLUSIONS: Unilateral elastic tethering resulted in vertebral wedging and scoliosis. Although changes in collagen and MMP-3 distribution, proteoglycan synthesis, end-plate epiphysis, and disc thickness were observed, the tethered discs and end plates did not demonstrate gross morphologic signs of degeneration.

Keywords: Elastic tether; Growth modulation; Scoliosis; Animal model; Asymmetric tether; Swine model

FDA device/drug status: Not applicable.

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Introduction

Instrumented spinal fusion is the surgical standard for treating patients with idiopathic scoliosis. However, this treatment is not optimal for young children with scoliosis because it would restrict the longitudinal growth of the spine and may result in the ''crankshaft phenomenon'' [1] and thoracic insufficiency syndrome [2], especially in early-onset scoliotic patients [3–5]. Fusionless scoliosis surgery offers many advantages over standard fusion surgery, including preservation of the longitudinal growth and few effects on the height of patients [6]. Although there are good effects with regard to the correction of the children's scoliosis, many surgeries are needed as the spine grows and many complications with this treatment have been reported [7]. Thus, many new fusionless surgical methods have been investigated in animal models during the past few years.

Newton et al. [8] determined the effect of a flexible cable attached to the anterolateral aspect of the thoracic spine in an immature bovine model and found that anterolateral tethering of the spine could create kyphosis and scoliosis and that the total lateral bending motion would return to control levels in the motion segments after removal of the tether. Braun et al. [9] analyzed the effect of two different fusionless scoliosis treatment techniques on a scoliotic animal model and found that attachment of the tether to the spine could modestly correct scoliosis in the coronal plane, and the result was better than that in the stabled group. Hunt et al. [10] analyzed the regional biochemistry and histology of spinal motion segments in animals treated with fusionless scoliosis implants. Although obvious disc degeneration was not observed, the implications of the cellular and histologic changes are not known. However, most of the previous studies were focused on anterior and anterolateral tethering of the spine, and few studies had reported the effects of posterior tethering on the spine.

The objective of this study was to analyze the regional radiography, biochemistry, and histology of tethered intervertebral discs and end plates in swine spines with posterior unilateral elastic tethering. It was hypothesized that a more elastic fusionless implant (elastic tether) would produce fewer degenerative changes in the disc and end plate compared with a more rigid implant (metal rod).

Materials and methods

After approval from the ethical committee of the hospital, fifteen 3-month-old Tibetan swine were divided into three groups. In Group 1 (elastic fixation [EF] group), five swine received posterior unilateral instrumentation on the left side of the spine from L1 to L5. Pedicle screws (2.5 mm in diameter and 15 mm in length; Sanyou, Shanghai, China) were placed in each vertebra and connected with a polyester elastic tether (Zimmer Spine, Minneapolis, MN, USA). The elastic tethers were tensioned with the same force in each swine to produce a curve on the left side of the lumbar spine (Fig. 1). Group 2 (metal rod fixation [MF] group, n=5) received the same surgery on the lumbar spine, but the pedicle screws were connected with a metal rod (Sanyou). The same force was used to create a curve on the left side of spine in each swine. Group 3 was the control group and received the same surgery on the left side of spine. Pedicle screws were placed in each vertebra but with no connecting cable. During implantation, care was taken to avoid damage to the intervertebral discs and epiphyseal growth plates. All swine survived for 8 weeks. The lumbar spines were then harvested en bloc to include the vertebral bodies and discs from L1 to L5. The specimens were flexed anteriorly, extended posteriorly, and bent laterally by the same person with the same force to test the flexibility of the spine that the elastic and metal rods were still in place in each group.

Radiographic analysis

For each animal, anteroposterior and lateral radiographs of the lumbar spine were taken preoperatively, immediately after the surgery, postoperative, and after harvesting (Fig. 2). The vertebral bodies and disc heights of both the left and right sides were measured. The magnitude of coronal and sagittal deformity was measured over the tethered lumbar segments using standard Cobb angle techniques.

Biochemical analysis

The L2–L3 segments from each group were used for biochemical analysis of the intervertebral discs. Immediately after harvesting, the vertebral bone on either end of the disc was removed to the growth plate, keeping the disc and the adjacent epiphyses intact (Fig. 3). The L2–L3 discs from each spine were split at the midcoronal plane with an osteotome, and digital photographs were taken to grade the intervertebral discs using the method described by Thompson et al. [11].

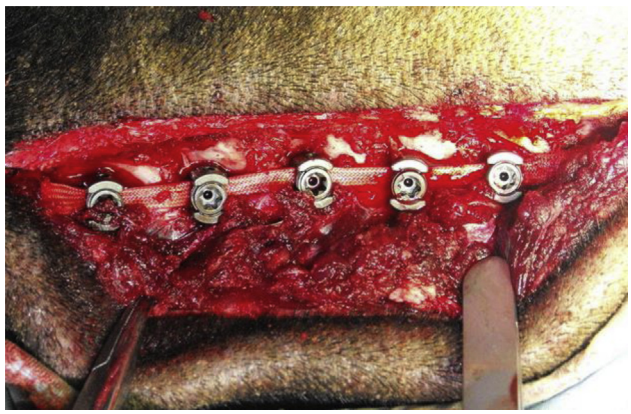

Fig. 1. Surgical photograph of a swine spine in the elastic fixation group. Posterior unilateral instrumentation was conducted on the left side of the spine from L1 to L5, and the screws were connected with a polyester elastic tether.