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Basic Science

Biomechanical stability of transverse connectors in the setting of a thoracic pedicle subtraction osteotomy

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Abstract

BACKGROUND CONTEXT: Transverse connectors (TCs) are often used to improve the rigidity of posterior spinal instrumentation as previous investigations have suggested that TCs enhance torsional rigidity in long-segment thoracic constructs. Posterior osteotomies, such as pedicle subtraction osteotomy (PSO), are used in severe thoracic deformities and provide a significant amount of correction; as a consequence, however, PSOs also induce three-column spinal instability. In theory, augmentation of longitudinal constructs with TC after a thoracic PSO may provide additional rigidity, but the concept has not been previously evaluated.

PURPOSE: To evaluate the biomechanical contribution of TC to the rigidity of a long-segment pedicle screw-rod construct after a thoracic PSO.

STUDY DESIGN: An in vitro fresh-frozen human cadaveric biomechanical analysis.

METHODS: Seven human cadaveric thoracic spines were prepared and instrumented from T4–T10 with bilateral pedicle screws/rods and a PSO was performed at T7. Intact range of motion (ROM) testing was performed with nondestructive loading and analyzed by loading modality (axial rotation [AR], flexion/extension [FE], and lateral bending [LB]). Range of motion analysis was performed in the unaugmented construct, the construct augmented with one TC, and the construct augmented with two TCs.

RESULTS: After PSO and an unaugmented longitudinal pedicle screw-rod construct, T4–T10 (overall construct) and T6–T8 (PSO site) ROMs were significantly reduced in all planes of motion compared with intact condition (AR: 11.8° vs. 31.7°; FE: 2.4° vs. 12.3°; 3.4° vs. 17.9°, respectively, $p<.05$). Augmentation of longitudinal construct with either one or two TCs did not significantly

FDA device/drug status: Approved: Pedicle screw, Transverse connector.

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increase construct rigidity in FE or LB compared with the unaugmented construct (p>.05). In contrast, during AR, global ROM was significantly reduced by 43% and 48% at T6–T8 (1.7° and 1.2° vs. 2.38°, respectively) after addition of one and two TCs (p<.05), respectively. One TC did not significantly reduce torsional ROM from the intact state.
CONCLUSIONS: Two TCs significantly improved torsional rigidity of the entire construct and at the PSO site, with no differences in rigidity for FE and LB or with the addition of only one TC. In the setting of a PSO and long-segment pedicle screw-rod construct, augmentation with at least two TCs should be considered to improve torsional rigidity.

Keywords: Pedicle subtraction osteotomy; Transverse connector; Crosslink; Biomechanical stability; Thoracic spine; Torsional stability

Introduction

Transverse connectors (TCs), also known as crosslinks or transfixators, have frequently been used to enhance the fixation strength of modern spinal instrumentation. Although biomechanical investigations have suggested a probable role for TC in enhancing torsional rigidity [1], the exact threshold of rigidity required to improve clinical outcomes and fusion rates remains controversial and unproven. Although some authors have demonstrated a biomechanical advantage through the addition of TC to long-segment fusion constructs, their role in the management of severe sagittal/coronal imbalance after a spinal osteotomy remains largely unknown. The pedicle subtraction osteotomy (PSO) is a surgical technique indicated in patients with severe sagittal plane deformities; the PSO is one of several posterior-only spinal osteotomies that achieve correction in the sagittal plane by wedge resection of the posterior column. However, the osteotomy itself is inherently destabilizing to the spinal column and requires rigid fixation posteriorly to minimize catastrophic neurologic failure [2,3]. Although not exceptionally common, there is a subset of spinal deformity patients with fixed sagittal imbalance that require such posterior osteotomies to optimize the surgical correction of their deformities [4–9]. Transverse connectors may play a pivotal role in patients requiring a PSO for the management of a fixed sagittal deformity. Although PSO is a technique more commonly performed in the lumbar spine, recent literature has shown that thoracic PSO can be performed safely with good improvements in regional thoracic sagittal alignment, while avoiding the potential morbidity of an anterior exposure [2,3,5–8,10]. The thoracic PSO is unique, as the correction occurs through all three columns of the spine and includes the resection of the costovertebral joints at the surrounding vertebral segments, and may therefore predispose it to a degree of instability not often encountered in other clinical scenarios [2]. The reported clinical outcomes after PSO are generally very good, with favorable correction of spinal alignment and improvement in patient-related outcomes scores, but it is not uncommon for pseudarthroses to occur at different levels, which may be related to the instability that occurs after the osteotomy [5–8,11]. Although pedicle screw constructs alone have been shown to provide adequate stability in sagittal and coronal planes, they are not as effective in limiting axial torsion, particularly in long-segment instrumentation [12].

As discussed, the efficacy of TC is controversial and as such there have been conflicting results reported within the literature. A number of biomechanical investigations have demonstrated a progressive incremental increase in torsional stiffness and lateral bending (LB) [13–17]. Conversely, there are concerns regarding the efficacy of these devices, as several other studies have failed to demonstrate any appreciable clinical benefits despite the significant additional cost of each supplementary TC [18]. Another disadvantage includes instrumentation crowding, which has been proposed to result in higher rates of pseudoarthrosis secondary to an overall decrease in the surface area available for fusion [19,20].

To our knowledge, no other studies have evaluated the impact of TC in the setting of a PSO, in which three-column stability and costovertebral articulations have been violated. Although TCs are frequently used as an adjunct to enhance overall fixation strength, their application in this particular clinical setting is without precedent. As such, no clear guidelines exist to aid in determining the number and/or location for placement of TC after a PSO. Consequently, the primary objective of the current investigation was to evaluate the biomechanical contribution of TC to the rigidity of a long-segment pedicle screw construct after a PSO in the thoracic spine. Furthermore, we evaluated the role of number and location of TC in an effort to determine their impact with regard to overall biomechanical stability.

Materials and methods

Specimen preparation

Seven fresh-frozen cadaveric spines were harvested from human cadavers. The medical history for each cadaver was reviewed to exclude specimens with any underlying primary or secondary bone disease. The bone mineral density of all specimens was determined with dual-energy X-ray absorptiometry, and spines with osteoporotic bone mineral density were excluded. Each specimen was then carefully disarticulated at the T2–T3 level proximally and T11–T12 level distally, with care to preserve all native