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Biomechanics

Preventing Instrumentation Failure in Three-Column Spinal Osteotomy: Biomechanical Analysis of Rod Configuration

Zachary S. Jager, MD, Serkan İnceoğlu, PhD, Daniel Palmer, BS, Yusuf T. Akpolat, MD, Wayne K. Cheng, MD*

Department of Orthopaedic Surgery, Loma Linda University, School of Medicine, 11406 Loma Linda Dr, Suite 213, Loma Linda, CA 92354, USA

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Abstract

Study Design: Biomechanical analysis.

Objectives: To show the role of additional rods and long-term fatigue strength to prevent the instrumentation failure on three-column osteotomies.

Summary of Background Data: Three-column osteotomy such as pedicle subtraction osteotomy (PSO) and vertebral column resections are surgical correction options for fixed spinal deformity. Posterior fixation for the PSO involves pedicle screw—and rod-based instrumentation, with the rods being contoured to accommodate the accentuated lordosis. Pseudarthrosis and instrumentation failure are known complications of PSO.

Methods: Unilateral pedicle screw and rod constructs were mounted in ultra-high-molecular-weight polyethylene blocks using a vertebrectomy model with the rods contoured to simulate posterior fixation of a PSO. Each construct was cycled under a 200 N load at 5 Hz in simulated flexion and extension to rod failure. Three configurations (n = 5) of titanium alloy rods were tested: single rod (control), double rod, and bridging rod. Outcomes were total cycles to failure and location of rod failure.

Results: Double-rod and bridging-rod constructs had a significantly higher number of cycles to failure compared with the single-rod construct ($p < .05$). Single-rod constructs failed at or near the rod bend apex, whereas the majority of double-rod and bridging-rod constructs failed at the screw—rod or rod—connector junction.

Conclusions: Double-rod and bridging-rod constructs are more resistant to fatigue failure compared with single-rod constructs in PSO instrumentation and could be considered to mitigate the risk of instrumentation failure.

Keywords: Sagittal imbalance; Pedicle subtraction osteotomy; Spinal rod failure; Double rod; Bridging rod

Introduction

Fixed sagittal imbalance of the spine is a disabling condition resulting from lumbar degenerative kyphosis [1,2] or failure of prior lumbar surgeries [3-5]. Classically, it is described as "flatback syndrome." Patients typically exhibit painful loss of lumbar lordosis, forward inclination of the trunk, and inability to stand erect with the knees extended [5,6].

One of the surgical correction options for this deformity is pedicle subtraction osteotomy (PSO). PSO involves a posteriorly based three-column closing wedge osteotomy in the lumbar spine [2,7]. PSO can typically provide an approximately 30 to 35 degree increase in lumbar lordosis [3-5,8,9], which translates into correction of sagittal balance and more upright posture. Posterior fixation for PSO involves pedicle screw—and rod-based instrumentation [4,5,7], with the rods being contoured to accommodate the accentuated lordosis. Pseudarthrosis and instrumentation failure are known complications of PSO [2-4,10-16]. It has been reported that moderate [17] and excessive [18] lordotic contouring may predispose the rod to reduced stiffness and poor fatigue performance (Fig. 1).

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*Corresponding author. Department of Orthopaedic Surgery, Loma Linda University, School of Medicine, 11406 Loma Linda Dr, Suite 213, Loma Linda, CA 92354, USA. Tel.: (909) 558-6444; fax: (909) 558-6118.

E-mail address: md4spine@yahoo.com (W.K. Cheng).

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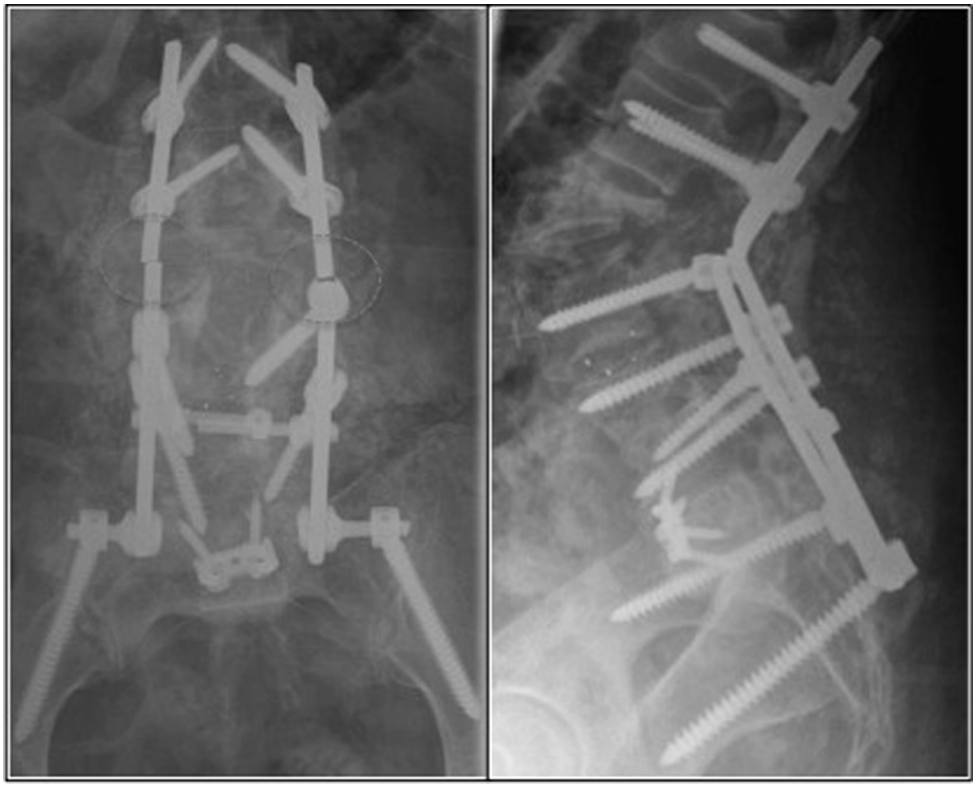

Fig. 1. X-ray image of a broken single-rod construct, AP (left) and lateral (right) view.

Clinical comparison of standard two-rod constructs to multiple-rod constructs for fixation across three-column spinal osteotomies has been recently reported by Hyun et al. [19]. In this study, the author strongly recommended using a multiple-rod construct during the initial osteotomy as a safe, simple, and effective method to prevent implant failure and symptomatic pseudarthrosis. Salvage constructs for fractured PSO instrumentation by additional rods to the

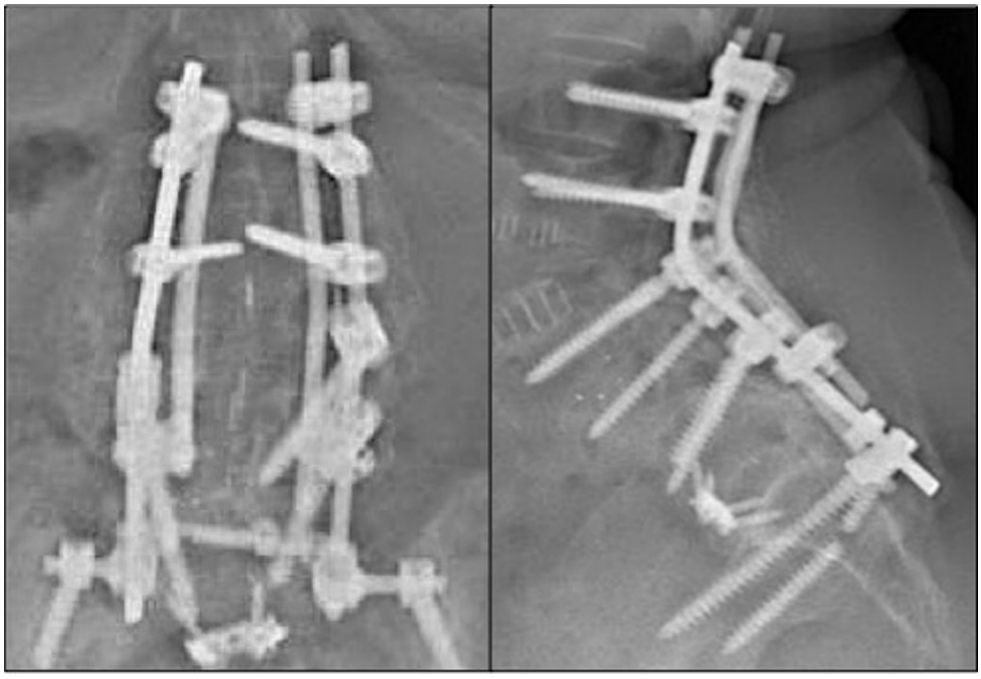

Fig. 2. X-Ray image of a double-rod construct, AP (left) and lateral (right) view.