Spine Deformity

www.spine-deformity.org

Spine Deformity 5 (2017) 27−36

Strain in Posterior Instrumentation Resulted by Different Combinations of Posterior and Anterior Devices for Long Spine Fusion Constructs

Christopher J. Kleck, MD*, Damian Illing, MD, Emily M. Lindley, PhD, Andriy Noshchenko, PhD, Vikas V. Patel, MD, Cameron Barton, MD, Todd Baldini, MS, Christopher M.J. Cain, MD, Evalina L. Burger, MD

Department of Orthopedics, University of Colorado, Anschutz Medical Campus, 13001 E 17th Pl, Aurora, CO 80045, USA

Received 22 February 2016; revised 18 July 2016; accepted 19 September 2016

Abstract

Study Design: Clinically related experimental study.

Objective: Evaluation of strain in posterior low lumbar and spinopelvic instrumentation for multilevel fusion resulting from the impact of such mechanical factors as physiologic motion, different combinations of posterior and anterior instrumentation, and different techniques of interbody device implantation.

Summary of Background Data: Currently different combinations of posterior and anterior instrumentation as well as surgical techniques are used for multilevel lumbar fusion. Their impact on risk of device failure has not been well studied. Strain is a well-known predictor of metal fatigue and breakage measurable in experimental conditions.

Methods: Twelve human lumbar spine cadaveric specimens were tested. Following surgical methods of lumbar pedicle screw fixation (L2−S1) with and without spinopelvic fixation by iliac bolt (SFIB) were experimentally modeled: posterior (PLF); transforaminal (TLIF); and a combination of posterior and anterior interbody instrumentation (ALIF+PLF) with and without anterior supplemental fixation by anterior plate or diverging screws through an integrated plate. Strain was defined at the S1 screws, L5−S1 segment of posterior rods, and iliac bolt connectors; measurement was performed during flexion, extension, and axial rotation in physiological range of motion and applied force.

Results: The highest strain was observed in the S1 screws and iliac bolt connectors specifically during rotation. The S1 screw strain was lower in ALIF+PLF during sagittal motion but not rotation. Supplemental anterior fixation in ALIF+PLF diminished the S1 strain during extension. Strain in the posterior rods was higher after TLIF and PLF and was increased by SFIB; this strain was lowest after ALIF+PLF, as supplemental anterior fixation diminished the strain during extension, in particular, cages with anterior screws more than anterior plate. Strain in the iliac bolt connectors was mainly determined by direction of motion.

Author disclosures: CJK (reports grants from DePuy/Synthes Inc, during the conduct of the study; grants from Medtronic Sofamor-Danek, grants from Aesculap, grants from SI Bone, grants from Vertiflex, grants and personal fees from Medicrea, grants from Orthofix, grants from Integra Life Sciences Corporation, grants from Pfizer, grants from Spinal Kinetics, grants from MTF, grants from National Institutes of Health, grants from Globus, outside the submitted work); DI (reports grants from DePuy/Synthes Inc, during the conduct of the study); EML (reports grants from DePuy/Synthes Inc, during the conduct of the study; grants from Medtronic, grants from SI Bone, outside the submitted work); AN (reports grants from Synthes, during the conduct of the study); VVP (reports grants from Synthes, during the conduct of the study; grants from Aesculap, grants from Stryker, grants from SI Bone, grants from National Institutes of Health, grants from Medtronic, grants from Musculoskeletal Transplant Foundation, outside the submitted work); CB (reports grants from DePuy/Synthes Inc, during the conduct of the study); TB (reports grants from DePuy/Synthes Inc, during the conduct of the study; grants from Stryker Endoscopy, SMV Scientific, and Acumed outside the submitted work); CMJC (reports grants from DePuy/Synthes Inc, during the conduct of the study; personal fees from DePuy/Synthes Inc, grants from Medtronic, grants from Aesculap, grants from Medicrea, grants from Vertiflex, grants from AOSpine, outside the submitted work); ELB (reports grants from Synthes, during the conduct of the study; grants from Medtronic, grants from Aesculap, grants from SI Bone, grants from Vertiflex, grants from Medicrea, grants from Synthes, grants from Orthofix, grants from Integra LifeSciences, grants from Anschutz Foundation, grants from OREF, grants from OMeGA, from null, from null, outside the submitted work).

The authors give permission to reproduce copyrighted materials or signed patient consent forms.

Research grant funding and instrumentation were provided by DePuy/Synthes.

*Corresponding author. 12631 E. 17th Ave., Mail Stop B202, Aurora, CO 80045, USA. Tel.: (303) 724-8309; fax: (303) 724-1593.

E-mail address: christopher.kleck@ucdenver.edu (C.J. Kleck).

http://dx.doi.org/10.1016/j.jspd.2016.09.045

Conclusions: Different devices modify strain in low posterior instrumentation, which is higher after transforaminal and posterior techniques, specifically with spinopelvic fixation.
Level of Evidence: N/A.

Keywords: Iliac fixation; ALIF; Pseudoarthrosis; Thoracolumbar fusion

Introduction

Currently long multilevel posterior instrumented fusion with spinopelvic fixation is widely used for surgical correction of spine deformity [1-6]. However, this treatment is quite expensive, having typical cumulative two-year costs ranging from $40,000 to $54,000, not including reoperation [7-9]. Reoperation with device replacement can more than double these expenses [7,10]. The cumulative rate of reoperation reaches 15% to 17% at the four-to five-year follow-up [11]. Around 30% to 40% of the reoperations are caused by device failure, including rod and/or screw fracture [11,12], having significant association with nonunion at the level of failure [13]. Clinical studies have shown that fixation to the sacrum and/or the pelvis is associated with different complications requiring additional treatment, including rod and screw failure [5,6,13,14]. Enhancing of the spinal correction and the construct stability can be reached by combining posterior instrumentation with anterior interbody devices. It improves the construct stiffness and decreases strain in the S1 pedicle screw [15]. Unfortunately, the impact of common, currently used devices on strain in posterior instrumentation has not been studied.

It has been shown in clinical studies that combination of posterior instrumentation with an interbody implant does not guarantee stable correction at long-term follow-up, in particular, corrected lumbar lordosis tends to decrease correlating with the interbody height loss [12,16]. It suggests loss of anterior support, which may increase stress within the rigid posterior instrumentation, and correspondingly increase the risk of failure. This effect can be explained by the fact that vertebral bone density is relatively low, and endplate is quite soft, with a stiffness that is significantly less than the stiffness of implants, causing subsidence [17]. Supplemental anterior fixation can decrease or eliminate this negative effect. In posterior transforaminal approaches, unilateral dissection of facet joint decreases mechanical function of the posterior spinal column [18]. Also, transforaminal fusion requires use of different cages with smaller footprints and absence of stiff fixation. It can decrease anterior support, increasing stress in posterior instrumentation and correspondingly risk of failure.

It was previously shown that strain, which is an index of micro-motion under the applied force, is a good predictor of metal fatigue and correspondingly risk of breakage [19]. This index is measured as a ratio of dislocation to the initial status, and can be applied to define the impact of different mechanical factors on the risk of device failure in experimental studies. The purpose of the current study is evaluation of strain in the S1 screw, the rod between L5 and S1, and the iliac connectors/rod between the S1 and the iliac screws impacted by physiologic motion with various anterior and posterior fixation techniques.

Materials and Methods

Specimen description and preparation

Twelve cadaveric human lumbar spines with intact pelvis were obtained from Lonetree Medical Donation (Littleton, CO) and stored frozen at −20°C prior to surgical preparation and instrumentation. There were six male and six female donors; mean age was 67 (standard deviation, 10.4) and ranged from 41 to 79 years at death (Table 1). Before testing, the specimens were thawed and muscular tissues were removed, but ligamentous structures were left intact. The pelvises were potted in Smooth-Cast 321 (Smooth-On, Inc., Easton, PA) deep enough to cover the pubic crest but shallow enough to leave the sacrum unfixed and free to move. The proximal spine was also potted at L1 in the same epoxy resin for attachment to the test apparatus. The spines were instrumented as described below (using the current operative technique we employ with our operative cases), and 10 tests with different combination of posterior and anterior devices were performed consequently.

Test 1: for all 12 specimens, posterior instrumentation (PLF) with two 6.0-mm-diameter titanium rods and 6.0-mm-diameter pedicle screws (Pangea Spine System,

Table 1
Tested lumbar specimens.

Specimen ID	Sex	Age (year)	Height (cm)	Weight (kg)	40% of weight (N)
C110106	F	71	165.1	66.738	261.9
C110079	F	69	177.8	90.8	356.3
C101542	F	66	162.56	80.812	317.1
C110110	F	78	165.1	68.1	267.2
C110126	F	79	165.1	149.82	587.9
LMD00090	F	41	172.72	68.1	267.2
C110104	M	75	172.72	81.72	320.7
C110108	M	56	180.34	102.15	400.8
C110128	M	64	182.88	77.18	302.9
C110080	M	67	182.88	136.2	534.4
LMD00033	M	73	165.1	66.738	261.9
LMD00098	M	67	180.34	93.524	367.0