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Basic Science

Iliac screws may not be necessary in long-segment constructs with L5−S1 anterior lumbar interbody fusion: cadaveric study of stability and instrumentation strain

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Abstract

BACKGROUND CONTEXT: Lumbosacral pseudoarthrosis and instrumentation failure is common with long-segment constructs. Optimizing lumbosacral construct biomechanics may help to reduce failure rates. The influence of iliac screws and interbody type on range of motion (ROM), rod strain (RS), sacral screw strain (SS) is not well-established.

PURPOSE: Investigate the effects of transforaminal lumbar interbody fusion (TLIF), anterior lumbar interbody fusion (ALIF), and iliac screws on long-segment lumbosacral construct biomechanics.

STUDY DESIGN: Biomechanical study.

PATIENT SAMPLE: Fourteen human cadaveric spine specimens.

OUTCOME MEASURES: Lumbosacral ROM, RS, and SS.

METHODS: Specimens were potted at L1 and the ilium. Specimens were equally divided into either an L5−S1 ALIF or TLIF group and underwent testing in the following conditions: (1) intact (2) L2−S1 pedicle screw rod fixation (PSR-S) (3) L2-ilium (PSR-I) (4) PSR-S+ALIF (ALIF-S) or TLIF (TLIF-S) (5) PSR-I + ALIF (ALIF-I) or TLIF (TLIF-I). Pure moment bending (7.5 Nm) in flexion, extension, lateral bending, axial rotation, and compressive loads (400N) were applied and ROM, SS, and RS were measured. Comparisons were performed using a one-way ANOVA ($p<.05$).

RESULTS: ALIF-S and TLIF-S provided similar decreases in ROM as TLIF-I ($p>.05$). Compared to PSR-S, PSR-I significantly decreased SS during bending in all directions ($p<.02$) but increased RS in flexion and extension ($p\leq.02$). Anterior lumbar interbody fusion-S provided similar decreases in SS as TLIF-I in all directions ($p>.40$) but had significantly less RS than TLIF-I in flexion, extension, compression ($p<.01$). TLIF-S had more SS than TLIF-I in flexion, extension, axial rotation ($p<.02$), while TLIF-S had less RS only in flexion ($p=.03$). Compared to PSR-I, ALIF-I decreased the RS ($p<.02$) but TLIF-I did not ($p>.67$).

CONCLUSIONS: Iliac screws were protective of SS but increased RS at the lumbosacral junction. Constructs with ALIF and no iliac screws result in comparable SS as constructs with TLIF and iliac screws with significantly reduced RS. If iliac screws are utilized, ALIF but not TLIF reduces the iliac screw-induced RS.

CLINICAL SIGNIFICANCE: There is a relatively high incidence of lumbosacral instrumentation failure in adult spinal deformity. Optimizing lumbosacral construct biomechanics may help to reduce failure rates. Iliac screws induce lumbosacral rod strain and may be responsible for

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instrumentation failure. Constructs with lumbosacral ALIF reduce iliac-screw induced rod strain and may obviate the need for fixation to the ilium.

Keywords: Anterior lumbar interbody fusion; Biomechanics; Iliac screws; Long-segment constructs; Lumbosacral junction; Pelvic fixation; Rod strain; Sacral screw strain; Spinal deformity; Transforaminal interbody fusion.

Introduction

Despite modern fixation techniques, achieving arthrodesis of the lumbosacral junction remains challenging with high rates of pseudoarthrosis reported for long instrumentation constructs to the sacrum [1,2]. One explanation for the high failure rates is the increased strain on sacral screws as the levels of instrumentation extend cephalad [3]. Adequate distal fixation is difficult to achieve with S1 pedicle screws alone due to the cancellous nature of the sacrum, despite efforts to augment fixation strength with bicortical or tricortical fixation [4].

One method to enhance lumbosacral fixation is by utilizing fixation to the ilium to protect sacral screws. Biomechanical studies have demonstrated increased pullout strength and reduction of sacral screw strain with supplemental iliac fixation [5,6]. However, this protective effect on the sacral screws may come at the cost of increased lumbosacral rod strain [7]. The European Spine Study Group reported a 35% incidence of mechanical complications despite distal augmentation with iliac screws [8]. Thus, iliac screw fixation alone may not provide the optimal biomechanical profile despite their ability to decrease sacral screw strain.

Anterior column support with anterior lumbar interbody fusion (ALIF) or transforaminal lumbar interbody fusion (TLIF) is another method to improve stability of the lumbosacral junction and provide circumferential fusion area to enhance arthrodesis. Anterior lumbar interbody fusion and TLIF techniques have unique clinical advantages and disadvantages. While ALIF may provide better sagittal correction than TLIF [9], it is associated with significantly higher index surgical costs and operative time [10] due to the additional approach. Biomechanical differences between the two techniques in long-segment constructs have not been fully characterized. Although it has been demonstrated that both ALIF and TLIF decrease sacral screw strain and increase stability in long-segment constructs [3,6,7], no studies have examined how anterior column support impacts instrumentation strain with iliac fixation.

The purpose of this study is to investigate the effects of TLIF, ALIF, and iliac screws on long-segment lumbosacral construct biomechanics. It is our hypothesis that ALIF is more protective against sacral screw strain (SS) and lumbosacral rod strain (RS) than TLIF. The potential clinical significance is that it might obviate the need to fixate to the ilium.

Materials and methods

Specimens

Fourteen human cadaveric L1-pelvis specimens were harvested en bloc and stored at −20°C. Donor medical history, radiographs, and direct inspection of the specimens were evaluated to exclude specimen with spinal pathology that would impact biomechanical testing. Bone mineral density ([BMD], g/cm^2) scans were conducted on L4 vertebrae and osteoporotic specimens (T-score ≤ -2.5) were excluded and replaced.

Specimens were thawed in normal saline at 21°C and muscle tissue was removed with care to not disrupt the ligaments, joint capsules, or disc spaces. The L1 vertebral body and both ilia were potted into blocks using a fast curing resin (SmoothCast 300Q, Smooth-On, Macungie, PA, USA) to allow for rigid fixation.

Instrumentation/strain gages

Polyaxial sacral screws (7.5×55 mm and 8.5×55 mm; NuVasive, Inc., San Diego, CA, USA) were instrumented with uniaxial strain gages (EA-06-031CE-350) oriented in line with the long axis of each screw. Four gages were placed circumferentially near the screw head with opposing gages wired together in half-bridge configurations. Calibration procedures were performed before implantation to obtain strain versus screw bending moment relationships [11]. Instrumented sacral screws were placed bilaterally. Polyaxial pedicle screws (6.5×45−55 mm; NuVasive, Inc., San Diego, CA, USA) were placed bilaterally from L2−L5. Iliac screws (9.5×80 mm; NuVasive, Inc., San Diego, CA, USA) were placed bilaterally in a subcrestal fashion [12].

Cobalt-chrome (5.5 mm diameter) rods were contoured to fit the screw heads to minimize need for reduction techniques. Cobalt-chrome is a popular rod material in long-segment constructs for adult spinal deformity due to its ability to provide greater forces of correction than titanium [13]. Offset connectors between the iliac screws and the rod were utilized. Rods were instrumented with two uniaxial strain gages (CEA-06-062UW-350/P2) midway between L5 and S1, with one gage facing anteriorly and one posteriorly on each rod. The gages were attached after rod bending and were not calibrated. The anteroposterior orientation of the gages limited rod strain analysis to flexion, extension, and compression.

Group 1 specimens were instrumented with TLIF (Anterior TLIF spinal system, NuVasive, Inc., San Diego, CA, USA) at L5−S1 following a hemilaminotomy and left total facetectomy. Group 2 specimens were instrumented with ALIF (Base, NuVasive, Inc., San Diego, CA, USA) at the same level. Anterior fixation was achieved with ALIF using 3 5.0×25 mm screws (one L5 and two S1) through the integrated plate. Interbody dimensions varied based on cadaver specific anatomy with the goal of placing an interbody that fit perfectly into the native disc space height and intradiscal angle without changing alignment. Preinstrumentation and postinstrumentation radiographs were obtained to verify proper implant placement (Figs. 1 and 2). All surgical procedures were performed by a neurosurgeon.

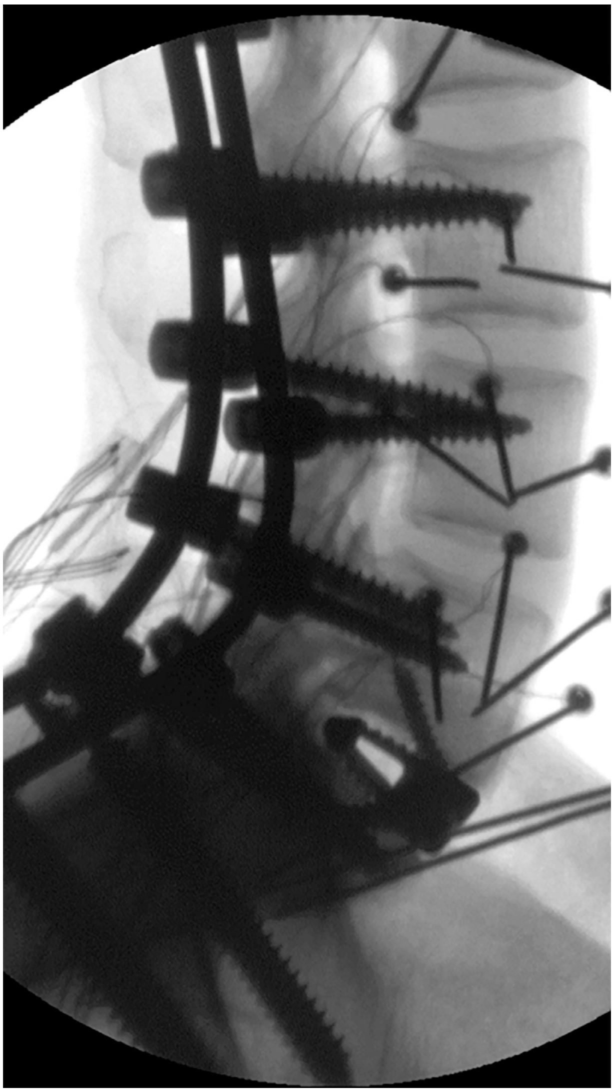

Fig. 1. Postinstrumentation lateral radiograph of lumbosacral ALIF construct. Used with permission from [blinded for review]. ALIF, anterior lumbar interbody fusion.

Fig. 2. Postinstrumentation lateral radiograph of lumbosacral TLIF construct. Used with permission from [blinded for review]. TLIF, transforaminal lumbar interbody fusion.

Testing conditions

Specimens were tested intact and evenly divided in to Group 1 and 2 based on statistical equivalence in flexion-extension range of motion (ROM), BMD, and age. Each group was subsequently tested in four instrumented conditions: (1) L2−S1 PSR-S (both Groups); (2) L2-Ilium PSR-I (both Groups); (3) L2-Ilium with interbody at L5−S1 (Group 1 TLIF-I, Group 2 ALIF-I); and (4) L2−S1 with interbody at L5−S1 (Group 1 TLIF-S, Group 2 ALIF-S). All screws and rods remained in place for all the instrumented conditions, with the L2−S1 configurations tested with the iliac screw offset connectors removed.

Biomechanical testing

Specimens were rigidly fixed caudally to the testing frame table with unconstrained lateral translation between left and right ilia, and cranially to the end effector of a previously described robotically controlled testing system [14] (Fig. 3).

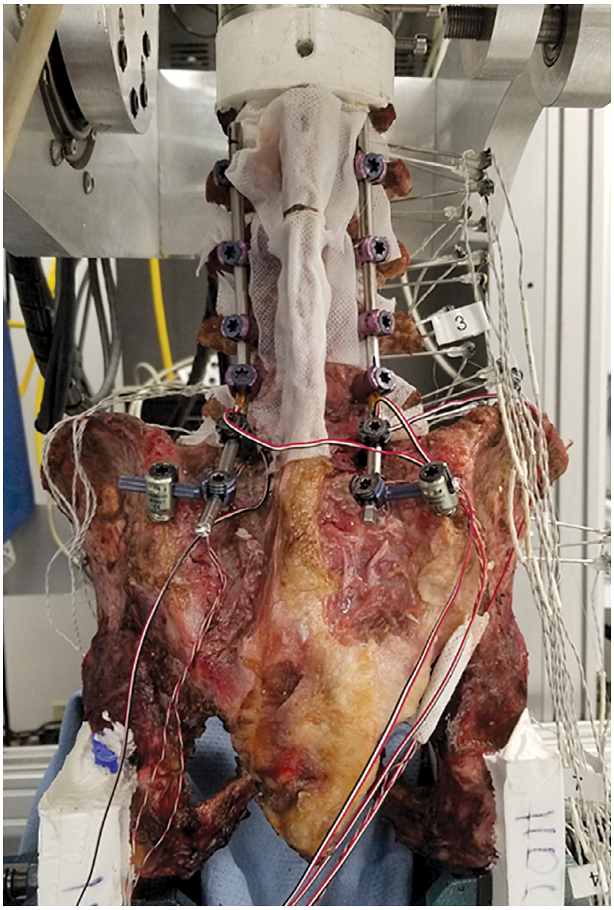

Fig. 3. Representative posterior view of a potted PSR-I specimen with infrared-emitting markers, L5−S1 rod strain gages, and sacral screw strain gages. Used with permission from [blinded for review]. PSR-I, pedicle screw rod.

Pure nondestructive moment loads (7.5 Nm), as recommended by Wilke et al. [15], were continuously applied at an approximate 1.2°/s global rotation rate to induce flexion, extension, left and right lateral bending, and left and right axial rotation motion. Specimens were loaded in pure compression (400 N) after the bending tests. Two preconditioning cycles were applied with data collected and recorded on the last cycle.

Three-dimensional specimen motion was tracked optically (Optotrak 3020 system Northern Digital, Waterloo, Ontario, Canada). Custom software converted the marker coordinates to angles about each of the anatomical axes in terms of the motion segment's own coordinate system [16]. Intervertebral spinal angles were calculated using a 3D technique that provides the most appropriate results for describing planar angles [17].

Sacral screw bending moment strain (SS) and RS during specimen loading were recorded at 10 Hz (StrainSmart system Vishay Micro-Measurements, Raleigh, NC, USA). Biplanar sacral screw bending moments were used to calculate resultant screw bending moments. The resultant screw bending moments and rod strains at peak applied loads were used for analyses in each case.

Analysis

Statistical comparisons between Group 1 and Group 2 intact ROM were performed using *t* tests to determine equivalency in ROM, BMD, and age as a prerequisite for subsequent comparisons. Lumbosacral ROM, RS, and SS were compared within each group and between groups. There were no significant differences between left and right strain outputs (screws and rods), so data from both sides were averaged. Intragroup variability was assessed using one-way RM-ANOVA (eg, within Group 1), and intergroup variability were analyzed using one-way ANOVA, both followed by paired Holm-Šidák tests, to determine whether outcomes among conditions were significantly different. Statistical significance was set at $p<.05$.

Results

Specimen

There was no statistically significant difference between groups in regard to age, BMD, L1-pelvis baseline ROM, and L5−S1 ROM ($p>.091$; Table 1).

L5−S1 ROM

Mean ROM values are presented in Table 2.

Flexion

Compared to PSR-S, ROM significantly decreased with ALIF-S, TLIF-S, and PSR-I ($p<.005$). Anterior lumbar interbody fusion-S and TLIF-S provided similar decreases in flexion ROM to TLIF-I ($p>.810$). Anterior lumbar interbody fusion-I ROM was similar to ALIF-S ($p=.514$).

Extension

Anterior lumbar interbody fusion-S, TLIF-S, and PSR-I did not significantly decrease ROM compared to PSR-S ($p>.127$). Anterior lumbar interbody fusion-S and TLIF-S provided similar decreases in ROM to TLIF-I ($p>.816$). Anterior lumbar interbody fusion-I ROM was similar to ALIF-S ($p=.284$)

Lateral bending

There was no significant difference in right lateral bending between any of the conditions ($p>.050$). PSR-I decreased left lateral bending ROM compared to PSR-S ($p=.007$) but ALIF-S and TLIF-S were comparable to PSR-S ($p>.566$). Anterior lumbar interbody fusion-S and TLIF-S had similar ROM to TLIF-I in lateral bending in both directions ($p>.050$). Anterior lumbar interbody fusion-I was comparable to ALIF-S in both directions ($p>.050$).

Axial rotation

Anterior lumbar interbody fusion-S significantly decreased axial rotation ROM to either side compared to PSR-S ($p<.048$). TLIF-S and PSR-I did not decrease ROM to either side compared to PSR-S ($p>.192$). Anterior

Table 1
Specimen data

Group	Specimen #	Gender	Age (years)	DEXA (t-score)
1	1	F	49	1.156
1	2	M	34	1.066
1	3	M	52	0.76
1	4	F	55	1.202
1	5	M	45	0.86
1	6	M	60	0.668
1	7	F	43	0.633
2	8	F	53	0.633
2	9	F	53	0.744
2	10	M	50	1.118
2	11	M	53	0.68
2	12	M	55	0.949
2	13	M	64	0.568
2	14	M	57	0.68

	Mean (SD) Group 1	Group 2	p value
DEXA (t-score)	0.906 (0.235)	0.767 (0.196)	.561
Age (years)	48.3 (8.6)	55.0 (4.5)	.091
L1-pelvis ROM (degrees)	47.3 (10.7)	44.3 (11.5)	.623
L5-sacrum ROM (degrees)	12.6 (5.7)	11.7 (3.2)	.713

ROM, range of motion; SD, standard deviation.

lumbar interbody fusion-S and TLIF-S demonstrated comparable decreases in bilateral axial rotation ROM as TLIF-I (p>.644). Anterior lumbar interbody fusion-I had similar ROM to ALIF-S (p>.946).

Sacral screw bending moment strain

Mean SS values are presented in Table 3.

Flexion

Mean SS was highest with PSR-S. PSR-I and ALIF-S significantly decreased SS (p<.001) compared to PSR-S, but TLIF-S did not provide a significant decrease in SS (p=.098). Anterior lumbar interbody fusion-S provided comparable decreases in SS to TLIF-I (p=.800); TLIF-I significantly diminished SS compared to TLIF-S (p<.001). Anterior lumbar interbody fusion-I had comparable SS to ALIF-S (p=.730).

Extension

Mean SS was highest with PSR-S. PSR-I and ALIF-S significantly decreased SS in extension (p<.001) compared to PSR-S while TLIF-S did not demonstrate a significant decrease in SS (p=.693). Anterior lumbar interbody fusion-S provided comparable decreases in SS to TLIF-I (p=.663); TLIF-I significantly diminished SS compared to TLIF-S (p<.001). Anterior lumbar interbody fusion-I had similar SS to ALIF-S (p=.413).

Lateral bending

Mean SS in the ipsilateral and contralateral screws was highest in the TLIF-S condition. Compared to PSR-S, PSR-I significantly diminished lateral bending SS in both screws (p<.019) but ALIF-S and TLIF-S had no significant effect on SS (p>.888). Both ALIF-S and TLIF-S provided SS protection comparable to TLIF-I (p>.054). Anterior lumbar interbody fusion-I had similar SS to ALIF-S in both screws (p>.095).

Axial rotation

Ipsilateral SS was highest in PSR-S and contralateral SS was highest in TLIF-S. Compared to PSR-S, ALIF-S, and PSR-I significantly decreased ipsilateral and contralateral SS (p<.001) but TLIF-S had similar SS (p>.993). TLIF-I had significantly less SS than TLIF-S (p<.001) but TLIF-I and ALIF-S were comparable (p>.955). Anterior lumbar interbody fusion-I had similar SS to ALIF-S in both screws (p>.127).

Compression

Mean SS was highest in the PSR-S construct. PSR-I and ALIF-I decreased SS compared to PSR-S (p<.001); TLIF-S had comparable SS to PSR-S (p=.863). Compared to TLIF-I, ALIF-S, and TLIF-S had similar SS in compression

Table 2
L5−S1 ROM

	Flexion	Extension	Lateral bending Left	Lateral bending Right	Axial rotation Left	Axial rotation Right
PSR-S	0.52 (0.30)*	0.50 (0.35)*	0.23 (0.17)	0.25 (0.17)	0.52 (0.28)	0.48 (0.20)
PSR-I	0.24 (0.11)†	0.27 (0.17)	0.07 (0.06)†	0.12 (0.08)	0.33 (0.15)	0.38 (0.16)
TLIF-S	0.20 (0.16)†	0.26 (0.14)	0.20 (0.11)	0.21 (0.08)	0.41 (0.22)	0.42 (0.18)
TLIF-I	0.09 (0.08)†	0.13 (0.05)†	0.15 (0.04)	0.13 (0.04)	0.28 (0.12)	0.38 (0.17)
ALIF-S	0.15 (0.14)†	0.22 (0.26)	0.14 (0.15)	0.19 (0.24)	0.15 (0.20)†	0.23 (0.17)†
ALIF-I	0.02 (0.09)†	0.03 (0.15)†	0.01 (0.06)†	0.08 (0.07)	0.16 (0.13)†	0.22 (0.13)†

* p value <.05 compared to TLIF-I.
† p value <.05 compared to PSR-S.
All values shown are given in degrees as the mean (SD).
ROM, range of motion.

Table 3
Sacral screw bending moment

	Flexion	Extension	Lateral bending		Axial rotation		Compression
			Ipsi	Contra	Ipsi	Contra	
PSR-S	1.11 (0.51)*	1.13 (0.49)*	0.29 (0.16)	0.26 (0.16)	1.30 (0.49)*	1.28 (0.51)*	1.79 (0.86)*
PSR-I	0.25 (0.13)†	0.22 (0.13)†	0.14 (0.09)†	0.14 (0.08)†	0.72 (0.29)†	0.69 (0.28)†	0.90 (0.45)†
TLIF-S	0.78 (0.38)*	0.96 (0.46)*	0.30 (0.20)	0.30 (0.21)	1.26 (0.46)*	1.30 (0.50)*	1.54 (0.68)
TLIF-I	0.12 (0.08)†	0.17 (0.08)†	0.17 (0.10)	0.15 (0.11)	0.69 (0.29)†	0.71 (0.30)†	0.75 (0.31)†
ALIF-S	0.31 (0.16)†	0.36 (0.17)†	0.28 (0.19)	0.29 (0.22)	0.68 (0.33)†	0.71 (0.37)†	0.60 (0.41)†
ALIF-I	0.11 (0.07)†	0.09 (0.05)†	0.15 (0.14)	0.14 (0.14)	0.38 (0.19)†	0.38 (0.20)†	0.43 (0.18)†

* p value <.05 compared to TLIF-I.
† p value <.05 compared to PSR-S.
All values shown are given in Newton meter (Nm) as the mean (SD).

Table 4
Rod strain

	Flexion	Extension	Compression
PSR-S	152 (96)	203 (125)	386 (155)
PSR-I	270 (109)*	335 (129)*	539 (178)
TLIF-S	85 (51)†	131 (58)	333 (125)
TLIF-I	219 (78)	317 (105)	519 (184)
ALIF-S	52 (41)†	72 (65)†	144 (60)*,†
ALIF-I	128 (78)	167 (105)	236 (118)†

* p value <.05 compared to PSR-S.
† p value <.05 compared to TLIF-I.
All values shown are given in microstrain (uE) as the mean (SD).

(p>.068). Anterior lumbar interbody fusion-I had similar SS to ALIF-S (p=.812).

Rod strain

Mean RS values are presented in Table 4.

Flexion

Mean RS was highest in the PSR-I construct. Compared to PSR-S, PSR-I significantly increased RS (p=.010) while ALIF-S and TLIF-S did not significantly decrease RS (p>.115; Fig. 4). Anterior lumbar interbody fusion-S and

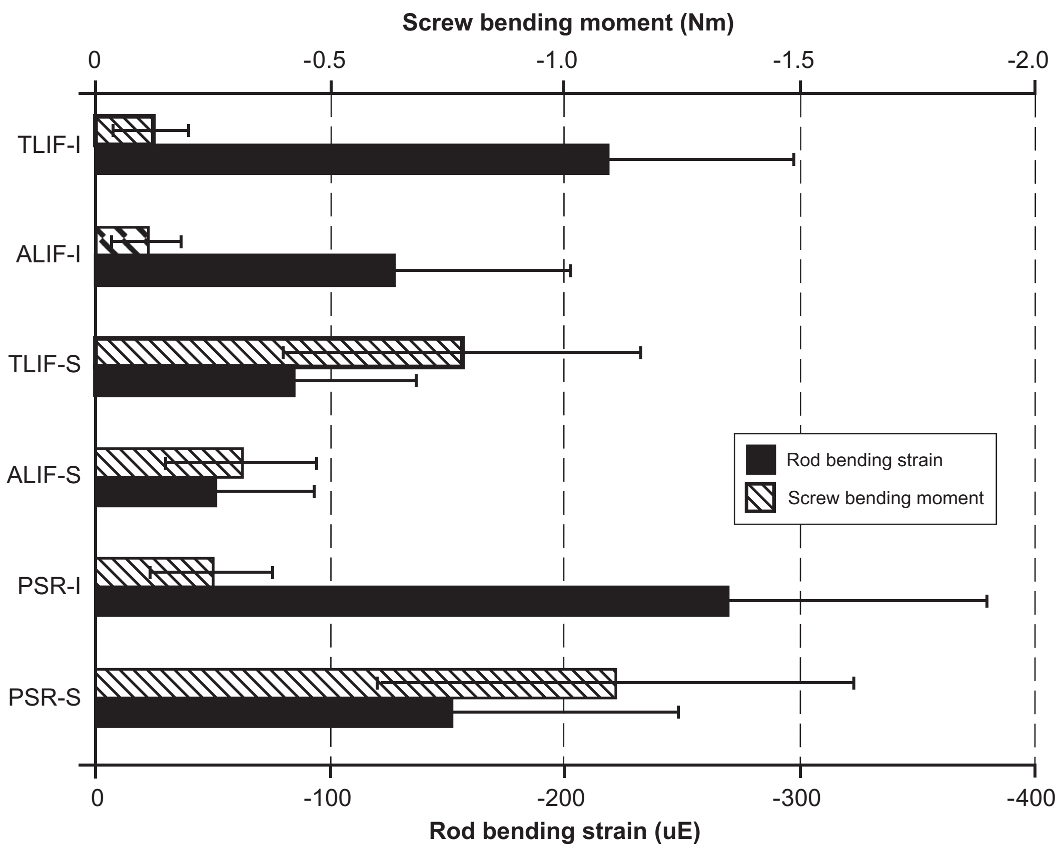

Fig. 4. Graph depicting flexion sacral screw strain and rod strain in different conditions tested. Used with permission from [blinded for review].

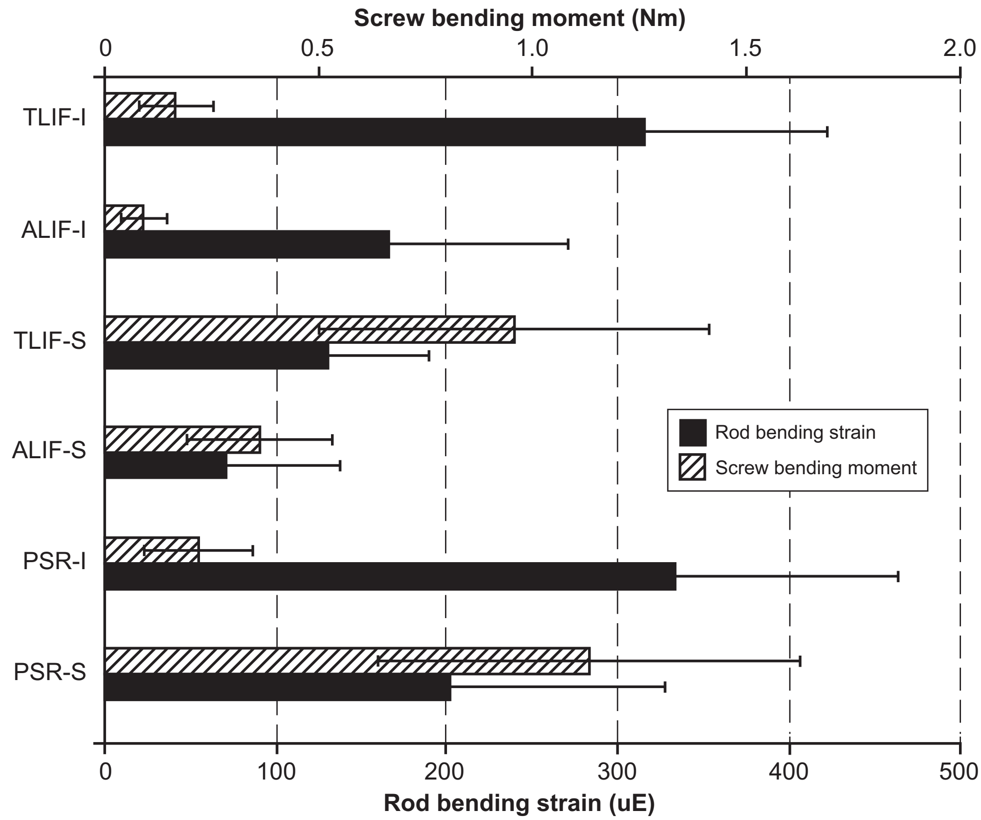

Fig. 5. Graph depicting extension sacral screw strain and rod strain in different conditions tested. Used with permission from [blinded for review].

TLIF-S had significantly less RS than TLIF-I (p<.031). Anterior lumbar interbody fusion-I significantly diminished RS compared to the PSR-I construct (p=.007) while TLIF-I did not decrease the RS (p=.871). Anterior lumbar interbody fusion-I had similar RS to ALIF-S (p=.509).

Extension

Mean RS was highest in the PSR-I construct. Compared to PSR-S, PSR-I significantly increased RS (p=.024) while ALIF-S and TLIF-S did not significantly decrease RS (p>.067; Fig. 5). Anterior lumbar interbody fusion-S had significantly less RS than TLIF-I (p=.007) but TLIF-S did not (p=.096). Anterior lumbar interbody fusion-I significantly diminished RS compared to the PSR-I construct (p=.016) while TLIF-I did not decrease the RS (p=.734). Anterior lumbar interbody fusion-I had similar RS to ALIF-S (p=.458).

Compression

Mean RS was highest in the PSR-I construct. Anterior lumbar interbody fusion-S significantly decreased RS compared to PSR-S (p=.013) while TLIF-S and PSR-I had no significant impact (p>.076). Anterior lumbar interbody fusion-S resulted in significantly less RS than TLIF-I (p=.003) while TLIF-S was comparable to TLIF-I (p=.461). Compared to the PSR-I construct, ALIF-I significantly decreased the iliac screw induced RS (p<.001) but TLIF-I failed to significantly decrease the RS (p=.663). Anterior lumbar interbody fusion-I had similar RS to ALIF-S (p=.646).

Discussion

The high mechanical demand of the lumbosacral junction makes it the most common site for pseudoarthrosis in the adult spinal deformity population [18]. Methods to augment lumbosacral fixation include interbody fusion and/or iliac screw fixation. Our current understanding of the relative importance of these different augmentation strategies on lumbosacral biomechanics is limited. Kleck et al. recently conducted a study examining the impact of various lumbosacral constructs on instrumentation strain [19]. However, results from that study should be interpreted with caution given concerns with study design and methodology [20]. The purpose of the current study was to evaluate, in a more scientifically rigorous fashion, the impact of anterior column support and iliac screws on the complete lumbosacral biomechanical profile and to directly compare clinically relevant constructs.

Attenuating range of motion is critical in achieving successful arthrodesis. Anterior lumbar interbody fusion with integrated fixation, TLIF, and iliac screws all decreased ROM in flexion. Anterior lumbar interbody fusion was the only supplemental fixation that significantly decreased ROM in axial rotation while iliac screws were the only supplemental fixation to decrease ROM in lateral bending. There was no difference in ROM between constructs with Anterior lumbar interbody fusion, TLIF, or iliac screws. Therefore, impact on ROM should not influence which type of supplemental fixation is utilized.

Iliac screw placement has become the gold standard for distal fixation in long-segment constructs in order to reduce sacral screw failure. Our study demonstrated that iliac screws significantly decreased screw strain in flexion, extension, lateral bending, axial rotation, and compression. Anterior lumbar interbody fusion with integrated fixation significantly diminished strain in all movements except lateral bending while TLIF had no protective effect on sacral screw strain. These results confirm that iliac screw fixation is an effective strategy for decreasing sacral screw strain.

Recent biomechanical studies have demonstrated that although iliac fixation is protective of sacral screw strain, they induce rod strain. Harimaya et al. reported that rod breakage at L5−S1 was only seen in patients with fixation distal to S1 [21]. The results of our study were congruent with these findings. Iliac screws dramatically increased rod strain in flexion and extension. An important finding in our study was that interbody support with an ALIF with integrated fixation reduced the iliac screw induced rod strain while a TLIF did not. Thus, if iliac screws are placed without an ALIF, the rod may be susceptible to failure at the lumbosacral junction. Future clinical and biomechanical research should evaluate alternative means to diminish rod strain in the event an ALIF is not feasible or indicated. A four-rod construct across the lumbosacral junction is one method that may diminish rod strain from a posterior only approach [22].

One of the goals of this study was to directly compare constructs with anterior column support (ALIF or TLIF) and sacral screws only to a clinically relevant posterior only construct with TLIF and iliac screws. TLIF-I was chosen as a comparison rather than PSR-I due to several studies advocating circumferential fixation/fusion of the lumbosacral junction as the standard in long-segment constructs [23−25]. Our study demonstrated that ALIF with integrated fixation and sacral screws only provided comparable stability and protection of sacral screw strain to TLIF with supplemental iliac screws. However, rod strain was significantly higher in the TLIF-I construct compared to the ALIF-S. Anterior column support with TLIF and sacral screws only failed to provide similar results when compared to TLIF-I. While TLIF-S and TLIF-I provided similar stability, TLIF-S had significantly more sacral screw strain in flexion, extension, and axial rotation. Rod strain was significantly less in TLIF-S in flexion only. Thus, anterior column support with ALIF (ALIF-S) may provide a more favorable biomechanical profile than TLIF-I. However, TLIF-S performance was inferior to TLIF-I specifically with protection of sacral screws from strain.

Our results must be tempered with the understanding that iliac screws are not solely utilized for stability and protection of sacral screws. Iliac screws serve as the foundation of the long-segment construct and may allow for more aggressive deformity corrective maneuvers without compromise of the proximal instrumentation. Furthermore, patients with pelvic obliquity may demand iliac fixation for correction of the obliquity [26]. However, iliac screws have their drawbacks including pain from implant prominence [27] and theoretical risk of sacroiliac joint dysfunction secondary to immobilization of the joint without fusion. The risk/benefit ratio of iliac screw fixation should be carefully analyzed. Nonosteoporotic patients with deformity correction achieved via interbodies and/or positioning may not necessitate fixation to the pelvis given the favorable biomechanical profile of ALIF with sacral screws only.

The main limitation of this study is one inherent to all biomechanical studies, which is significance in the laboratory may not translate to clinical significance. Nevertheless, this study provides important findings regarding sacral screw and rod strain in various long-segment constructs, providing the biomechanical foundation for future clinical research. An additional limitation to this study is that loading to construct failure was excluded from the protocol to allow for testing of more conditions and to mitigate concerns regarding testing order. Thus, long term durability and prediction of construct failure is limited. Another limitation is that these findings may differ in osteoporotic patients due to inadequate screw fixation. Cadavers in this study were screened and replaced if found to be osteoporotic. Thus, these results may not apply to patients with poor bone quality with inadequate sacral fixation.

Conclusions

Constructs with ALIF and integrated fixation may obviate the need for iliac screws and provide comparable stability and protection of sacral strain with significantly less rod strain than a posterior only construct with TLIF and iliac screws. If iliac screws are necessary due to osteoporosis, corrective maneuvers, or pelvic obliquity it is important to understand that they are protective of sacral screw strain but induce rod strain at the lumbosacral junction. Anterior column support with ALIF but not TLIF is protective and significantly reduces the iliac screw induced rod strain.

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