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Do facet screws provide the required stability in lumbar fixation? A biomechanical comparison of the Boucher technique and pedicular fixation in primary and circumferential fusions

Amit Agarwala [a], Brandon Bucklen [b,*], Aditya Muzumdar [b], Mark Moldavsky [b], Saif Khalil [b]

[a] Panorama Orthopedics & Spine, 660 Golden Ridge Road, Suite 250, Golden, CO 80401-9522, USA
[b] Globus Medical, Inc., Valley Forge Business Center, 2560 General Armistead Ave, Audubon, PA 19403, USA

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ABSTRACT

Background: Transfacet pedicle screws are scarcely used in primary posterior fixation, and have limited use unilaterally or with existing anterior instrumentation. Nevertheless, the incomplete literature suggests equivalent or better performance of ipsilateral, bilateral, facet screws compared to bilateral pedicle screws.
Methods: Two groups of seven human cadaver spines (L3–S1) were tested under pure moments of 6 Nm. Each specimen was tested in a primary and circumferential fixation (Spacer, Spacer + Plate) environment. Both transfacet and bilateral pedicle screws were used as posterior fixation, in separate groups. Motion was obtained at L4–L5 for single-level constructs in flexion–extension, lateral bending and axial rotation modes.
Findings: In primary fixation, both transfacet and bilateral pedicle screws reduced motion below intact levels. Statistically, the level of circumferential fixation (anterior, posterior, or both) proved to be more influential than the type of posterior fixation. Incorporating a spacer and plate with pedicle screws provided a greater relative gain in stability than with facet screws. The interpretation is explained through a model describing the location of fixation with respect to the center-of-rotation of the vertebral bodies. In lateral bending and axial rotation, bilateral pedicle screw constructs were stiffer than transfacet pedicle screw constructs as a trend.
Interpretation: Transfacet pedicle screws provided similar fixation to bilateral pedicle screws in primary and circumferential fixations during flexion–extension. In the other modes, transfacet screw rigidity is, on average, less than bilateral pedicle screws when used alone, but with the addition of other anterior instrumentation the differences are minimized. Therefore, facet screws are warranted based on the surgical effect desired, and in the presence of additional anterior fixation.

1. Introduction

Spinal fusion may be used in the treatment of disabling back pain arising from a failed motion segment (Brodsky et al., 1989; Guyer et al., 1987; O'Brien et al., 1986; Ogilvie and Schendel, 1986; Olerud et al., 1986). Recently, transfacet pedicle screw (TFPS) fixation of the facet joint, and translaminar transfacet screw fixation (TLTF) have been investigated as alternatives to standard bilateral pedicle screw (BPS) and rod fixation systems in the lumbar spine in two ways; 1) as an adjunctive minimally invasive posterior surgery following an anterior lumbar interbody fusion (ALIF); and 2) as a stand-alone form of fixation to traditional posterior techniques (posterolateral fusion).

Pedicle screw fixation is the standard method for stabilization of the lumbar spine. Nevertheless many studies have addressed concerns regarding such issues as screw breakage, sub-optimal fixation, and neurological injuries. Perhaps the most compelling argument against pedicle screws is the invasiveness of the open procedure which requires excessive muscle dissection and damage to the paraspinous muscle (Ferrara et al., 2003). In the situation where anterior approaches are indicated, bone-on-bone fusions and stand-alone anterior spacers are often insufficient in buffering the mechanical forces across the failed motion segment. Studies have shown an increase in range of motion (RoM) in the neutral zone of cadaver spines instrumented with stand-alone cages and exceptionally poor performance in extension and axial rotation (Hanley and David, 1999; Kandziora et al., 2005). Additionally, the rate of pseudarthrosis following ALIF without fixation has been reported as high as 25% (Benzel, 1999). Supplemental posterior fixation, while necessary in these cases, carries with it the complication of an additional surgery. These concerns have sparked interest in percutaneous, minimally invasive fixation techniques such as translaminar facet fixation and transfacet pedicle screw fixation.

There are distinct differences between the two facet fixation techniques described in the literature. The Boucher technique (1959) utilized a facet screw entering into the inferior articular process just

* Corresponding author.
E-mail addresses: aagarwala@panoramaortho.com (A. Agarwala), bbucklen@globusmedical.com (B. Bucklen), amuzumdar@globusmedical.com (A. Muzumdar), mm638@drexel.edu (M. Moldavsky), skhalil@globusmedical.com (S. Khalil).

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medial to the joint, crossing the joint into the ipsilateral articular surface (TFPS). Magerl's technique, a deviation of the Boucher technique, maximizes the length of the screw by moving the insertion point to the contralateral side of the lamina (TLTF), through the facet to be restricted (Best and Sasso, 2006; Ferrara et al., 2003). Both fixation techniques directly restrict facet motion, but the length of the screw and angle of insertion are notably different.

There are obvious clinical advantages to both translaminar and transfacet pedicle fixations. The rate of neurological deficit and cerebrospinal fluid leakage associated with TLTF fixation has been reported as 25% to 50% that associated with BPS fixation (Benzel, 1999; Grob et al., 1992; Tuli et al., 2007). Wound infection rates of TLTF are also described as being 10% that of BPS fixation. Additionally, blood loss, operation time, and surgical cost are all less than that of BPS screw fixation (Best and Sasso, 2006). Similar results can be expected for TFPS fixation. Nevertheless, there are conflicting long-term patient data when directly comparing facet screw and pedicle fixation clinical outcomes. In one study, it was found that in a patient pool of 67 patients undergoing circumferential fusions of the lumbar spine (24 BPS, 43 TLTF), 37.5% of BPS cases underwent secondary operations, while only 4.7% of TLTF cases required similar measures, supporting the use of TLTF fixation (Best and Sasso, 2006). In conflicting results of a separate study, 77 patients underwent interbody ALIF or PLIF fusions (33 BPS, 40 TLTF), 27% of BPS cases required a secondary operation, and 32.5% of TLTF required secondary surgeries. Moreover, the mean time to reoperation was higher for BPS (4.35 yrs) than TLTF (2.94 yrs) cases (Tuli et al., 2007), supporting the use of pedicle screws. The clinical outcomes of transfacet pedicle screws, as per the Boucher technique (TFPS) have not been compared directly to traditional pedicle screw fixation techniques in the literature, but several studies have corroborated favorable outcomes. El Masry et al. (2003) concluded that 92% of patients had good or excellent results after undergoing posterolateral primary fusion with TFPS. Margulies and Seimon (2000) reported similar outcomes with 91% of patients achieving an excellent rating.

The goal of this study was to further the biomechanical knowledge of transfacet pedicle screw (TFPS) fixation using the Boucher technique. While the medical community has adopted Magerl's translaminar transfacet (TLTF) technique, the procedure is more technically demanding and offers no confirmed biomechanical advantage, despite the perceived mechanical robustness achieved through an increased screw length (Ferrara et al., 2003). The authors are aware of only four biomechanical studies comparing traditional BPS and TFPS in the presence of anterior grafts, and no biomechanical studies examining TFPS as a means of primary posterior fixation. Kandziora et al. (2005) compared all three types with anterior cages in one study and found that BPS fixation was stiffer than TLTF and TFPS in flexion and rotation, but not in extension and in lateral bending. Nevertheless, both TLTF and TFPS compensated successfully for the stiffness decrease usually observed in extension and axial rotation due to an anterior cage. In contrast, Beaubien et al. (2004) found that BPS and TFPS significantly reduced RoM below ALIF alone, but that there was no significant difference between BPS and TFPS. Similarly Mahar et al. (2006) found no differences in anterior column loading and stiffness between BPS and TFPS. In one study, the effect of pullout strength was measured to be higher for transfacet (694 N) versus pedicle screws (670 N) (Liu et al., 2008). The most comprehensive study found that TFPS was significantly stiffer than BPS fixation in flexion. No statistical difference was observed in extension, bending, or axial rotation between pedicle screws and transfacet screws. Moreover, the longevity of TFPS was tested over 180,000 cycles and it was found that the stiffness remained uncompromised in repetitive loading (Ferrara et al., 2003).

The reason behind the limited use of facet fixation as a primary fixation technique or in combination with an ALIF procedure is not known, but may arise from a perceived stigma of incomplete mechanical fixation passing through an articulating joint. The literature nevertheless suggests no biomechanical difference (RoM or stiffness) between pedicle screw (BPS) and facet screw fixation techniques. Moreover, the limited use of the Boucher technique (TFPS) when compared to Magerl's technique (TLTF) is further unjustified from a biomechanical perspective, but requires more study. In this protocol, a comprehensive analysis of single-level spines fixated using TFPS is compared biomechanically to pedicle screw fixation.

2. Methods

2.1. Specimen preparation

All spines were radiographed in both the anteroposterior and lateral planes to ensure the absence of fractures, deformities and any metastatic disease. The spines were stripped of paravertebral musculature while preserving the spinal ligaments, joints and disk spaces. Subsequently, they were mounted at L3 rostrally and S1 caudally in a three-to-one mixture of Bond Auto Body Filler and fiberglass resin [Bondo MarHyde Corp, Atlanta, GA, USA]. Plexiglas markers, each having three infrared light-emitting diodes, were secured rigidly to each vertebral body via bone screws to track motion using the Optotrak Certus (NDI, Waterloo, Canada) motion analysis system. The location of the markers (denoting a rigid body) was approximately aligned sagitally along the curvature of the spine. The Optotrak Certus software was able to superimpose the coordinate systems of two adjacent vertebral bodies in order to inferentially determine the relative Eularian rotations in each of the three planes. The spine was then affixed to a six degree-of-freedom (6DoF) testing apparatus via magnetization, and pure unconstrained bending moments were applied in the physiologic planes of the spine at room temperature using a multidirectional “load-controlled” flexibility protocol. The 6DoF machine applied unconstrained loading through application of three cephalad stepper motors placed in each of the three physiological rotation axes. Moreover, the supports are mounted on air bearings to provide near frictionless resistance to the natural kinematics of the spine.

2.2. Test groups

Two groups of seven fresh frozen human cadaver lumbar spines (L3–S1) were tested by applying pure moments of ± 6 Nm. Range of motion (RoM) was obtained at L4–L5 for single-level experiments in flexion–extension, lateral bending and axial rotation modes. Each specimen in both groups was tested in a primary fixation environment and subsequently in a circumferential fusion environment in the following modes: 1) Intact; 2) PF alone; 3) PF and radiolucent interbody fusion using CONTINENTAL™ ALIF Spacer [Globus Medical, Audubon, PA, USA]; 4) PF and interbody spacer with a two hole anterior plate CITADEL™ [Globus Medical]; 5) Interbody spacer and plate alone; 6) Interbody spacer alone; and 7) Injured (anterior discectomy L4–L5). Transfacet pedicle screws, ZYFUSE™ [Globus Medical] and traditional pedicle screws, REVERE® [Globus Medical], were used as PF in groups A and B, respectively (Fig. 1). The use of two distinct test groups was to avoid overlapping screw path trajectories between TFPS and BPS groups. Not all test groups are clinically relevant, but were included to know the relative contribution of each device or instrumentation.

2.3. Data interpretation

Within group comparisons were made using a repeated measures analysis-of-variance (ANOVA) to evaluate any statistical differences in constructs 1–7 for BPS separately from TFPS (Table 1). This was in accordance with the test methodology which required two separate groups. Two factors were identified as likely to effect the RoM and were termed “posterior fixation type” (facet screws vs. pedicle screws)

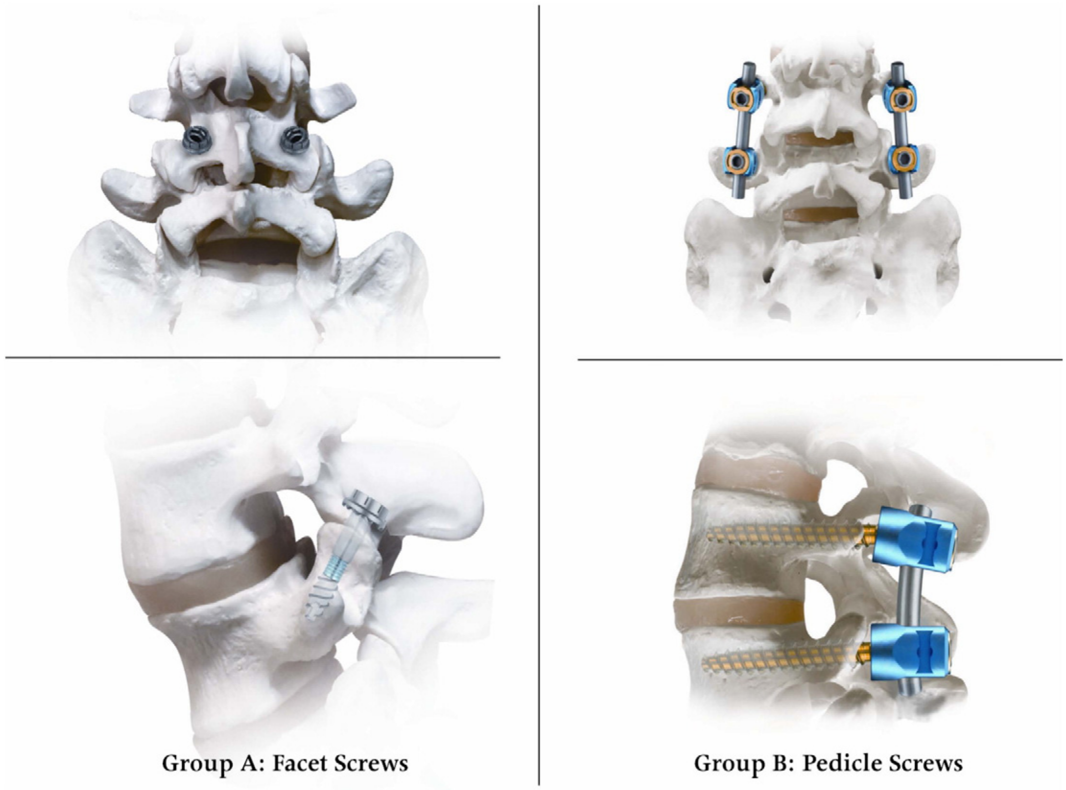


Fig. 1. Group A (TFPS) facet screws, left, and group B (BPS) pedicle screws and rods, right, in an L4–L5 segment.

and "instrumentation amount" (Posterior Fixation alone, Posterior Fixation + Spacer, Posterior Fixation + Spacer + Plate). Subsequently, a two-factor split-plot ANOVA was used to evaluate the effect of two factors and their interaction for posterior fixation groups 2–4. Therefore, the analysis was able to tell if the level of circumferential fusion or the posterior fixation type, or a confounded interaction of the two influenced the resultant RoM. In all cases to alleviate inhomogeneity of variance, log transforms in the form of $\log_{10}(\text{raw\_data}+1)$ were applied to the raw data. Comparisons were made with a probability of type I error, $\alpha = 0.05$, using Tukey's post-hoc comparison. Graphical presentation of data was normalized to the L4–L5 intact level on a per group basis by percentage.

Table 1
RoM summary and repeated measures intragroup analysis A/B with significances.

Group A: PF = TFPS							
	Intact (a)	TFPS (b)	TFPS + Spacer (c)	TFPS + Spacer + Plate (d)	Spacer + Plate (e)	Spacer (f)	Injured (g)
Flexion–extension	Mean 100 (SD 34) (b, c, d, e, g)	Mean 20 (SD 14) (a, d, e, f, g)	Mean 21 (SD 16) (a, d, e, f, g)	Mean 10 (SD 9) (a, b, c, e, f, g)	Mean 53 (SD 21) (a, b, c, d, f, g)	Mean 85 (SD 29) (b, c, d, g)	Mean 175 (SD 67) (a, b, c, d, e, f)
Lateral bending	Mean 100 (SD 43) (b, c, d, e)	Mean 37 (SD 34) (a, f, g)	Mean 29 (SD 27) (a, e, f, g)	Mean 24 (SD 27) (a, e, f, g)	Mean 59 (SD 40) (a, c, d, g)	Mean 85 (SD 46) (b, c, d)	Mean 127 (SD 57) (b, c, d, e)
Axial rotation	Mean 100 (SD 28) (b, c, d, e, g)	Mean 41 (SD 22) (a, f, g)	Mean 40 (SD 28) (a, f, g)	Mean 22 (SD 22) (a, e, f, g)	Mean 53 (SD 30) (a, d, f, g)	Mean 126 (SD 47) (b, c, d, e, g)	Mean 207 (SD 63) (a, b, c, d, e, f)
Group B: PF = BPS							
	Intact (a)	BPS (b)	BPS + Spacer (c)	BPS + Spacer + Plate (d)	Spacer + Plate (e)	Spacer (f)	Injured (g)
Flexion–extension	Mean 100 (SD 34) (b, c, d, e, g)	Mean 24 (SD 11) (a, d, f, g)	Mean 16 (SD 9) (a, f, g)	Mean 8 (SD 5) (a, b, e, f, g)	Mean 31 (SD 21) (a, d, f, g)	Mean 74 (SD 46) (b, c, d, e, g)	Mean 204 (SD 54) (a, b, c, d, e, f)
Lateral bending	Mean 100 (SD 35) (b, c, d, e, f, g)	Mean 22 (SD 7) (a, f, g)	Mean 17 (SD 11) (a, e, f, g)	Mean 15 (SD 10) (a, e, f, g)	Mean 40 (SD 23) (a, g)	Mean 60 (SD 35) (a, b, c, d, g)	Mean 170 (SD 49) (a, b, c, d, e, f)
Axial rotation	Mean 100 (SD 41) (b, c, d, e, g)	Mean 34 (SD 15) (a, f, g)	Mean 26 (SD 17) (a, f, g)	Mean 18 (SD 18) (a, f, g)	Mean 31 (SD 22) (a, f, g)	Mean 67 (SD 35) (b, c, d, e, g)	Mean 187 (SD 60) (a, b, c, d, e, f)

a: significant w.r.t. *Intact*.
b: significant w.r.t. *PF*.
c: significant w.r.t. *PF + Spacer*.
d: significant w.r.t. *PF + Spacer + Plate*.
e: significant w.r.t. *Spacer + Plate*.
f: significant w.r.t. *Spacer*.
g: significant w.r.t. *Injured*.

3. Results

3.1. Facet screws versus pedicle screws

The two groups were combined in order to compare pedicle screw fixation and facet screw fixation in an ALIF and non-ALIF model (Fig. 2). Transfacet pedicle screws (TFPS) resulted in reduced motion (20%) when compared to BPS (24%) in flexion–extension in the non-ALIF model, but had an increased RoM in lateral bending (37% vs. 22%) and axial rotation (41% vs. 34%). In the ALIF model, TFPS exhibited larger average motions than BPS with a spacer (FE: 21% vs. 16%, LB: 29% vs. 17%, AR: 40% vs. 26%) and with a spacer and plate (FE: 10% vs. 8%, LB: 24% vs. 15%, AR: 22% vs. 18%).

The results of split-plot, two-factor ANOVA showed a significant difference between instrumentation amount (primary vs. circumferential) in flexion–extension ($F>F_{crit}=16.8>3.40$, df = 24), lateral bending ($F>F_{crit}=10.8>3.40$, df = 24), and axial rotation ($F>F_{crit}=12.2>3.40$, df = 24). There was no statistical difference between posterior fixation type or any interaction between instrumentation amount and posterior fixation type. Post-hoc analysis indicated that in flexion–extension, there was no difference in the means of PF or PF + Spacer, but there was a significant difference between PF and PF + Spacer + Plate as well as PF + Spacer and PF + Spacer + Plate (Fig. 2). This trend was mirrored in axial rotation. In lateral bending, post-hoc analysis showed no difference in group means between PF + Spacer and PF + Spacer + Plate, while there was a difference in PF alone with both groups.

The within-group repeated-measures analysis (Table 1) of all surgical groups revealed that all constructs (other than injured and spacer) were statistically less than the intact condition. The addition of an interbody spacer to BPS decreased RoM 8%, 5%, and 8% in flexion–extension, lateral bending, and axial rotation, respectively. The addition of an interbody spacer to TFPS decreased RoM −1%, 8%, and 1% in flexion–extension, lateral bending, and axial rotation, respectively. There was no statistical difference between TFPS and BPS (split-plot ANOVA), but as a trend BPS restricted motion more than TFPS in every complementary comparison (PF, PF + Spacer, PF + Spacer + Plate) in every loading mode, with one exception: posterior fixation alone in flexion–extension.

The stabilizing effect of facet screws and pedicle screws was measured in primary fusion by calculating the motion reduction (PRR) through the type of PF when compared to intact, defined as follows:

$$PRR = \left|\frac{RoM(intact) - RoM(PF)}{RoM(intact)}\right| \times 100,$$

where RoM(PF) is the RoM of the TFPS constructs in group A, or BPS constructs in group B. In general, transfacet pedicle screws tended to provide greater stabilization than pedicle screw fixation in flexion–extension (80% vs. 73%), but less in lateral bending (65% vs. 73%) and axial rotation (59% vs. 62%) (Fig. 3). There were no statistical differences between strengthening of PF types in any loading modes. The stabilizing effect of adding an ALIF (in this case a Spacer + Plate) construct to a primary fusion (creating a circumferential fusion) was measured by calculating the motion reduction through the type of PF when compared to the primary fusion case as follows:

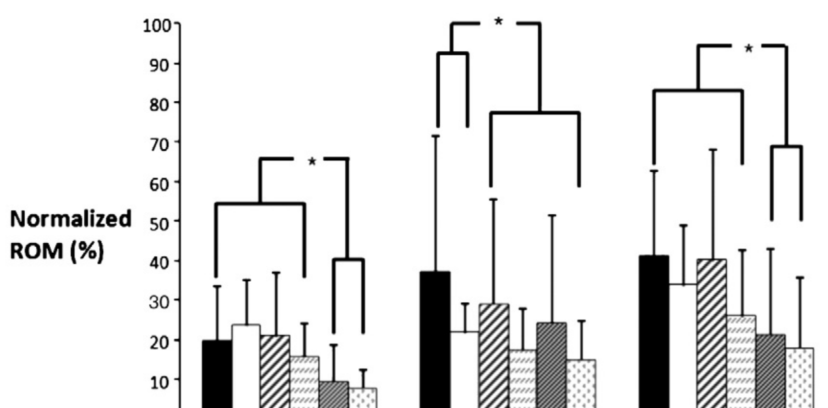
$$PRR = \left|\frac{RoM(PF + Spacer + Plate) - RoM(PF)}{RoM(PF)}\right| \times 100.$$

The reduction in motion (PRR) when adding ALIF to the TFPS was less in all loading directions than that of adding ALIF to BPS (flexion–extension: 49% vs. 64%, lateral bending: 31% vs. 37%, axial rotation: 42% vs. 54%).

4. Discussion

The purpose of this study was to ascertain the relative strength of transfacet pedicle screws compared to bilateral pedicle screws, with and without supplemental ALIF (Spacer, Spacer + Plate).

The TFPS construct reduced motion more than the BPS construct in primary fusion procedures without ALIF in flexion–extension, but not in lateral bending or axial rotation (Fig. 2). In circumferential fusions, BPS + Spacer + Plate reduced motion more than TFPS + Spacer + Plate in all directions to some degree. These were observed trends, but none of the comparisons was significant. Statistically speaking, there was no difference between TFPS and BPS groups, but statistical power may have been less for the between-group factor “posterior fixation type”, when compared to the within-group factor “instrumentation amount”. It was unfortunately unavoidable to have BPS and



	Flexion-Extension	Lateral Bending	Axial Rotation
TFPS	20±14	37±34	41±22
BPS	24±11	22±7	34±15
TFPS + Spacer	21±16	29±27	40±28
BPS + Spacer	16±9	17±11	26±17
TFPS + Spacer + Plate	10±9	24±27	22±22
BPS + Spacer + Plate	8±5	15±10	18±18

Fig. 2. Range-of-motion and two-factor ANOVA significances of fixated level normalized to intact group (100%). TFPS = transfacet pedicle screws, BPS = bilateral pedicle screws.

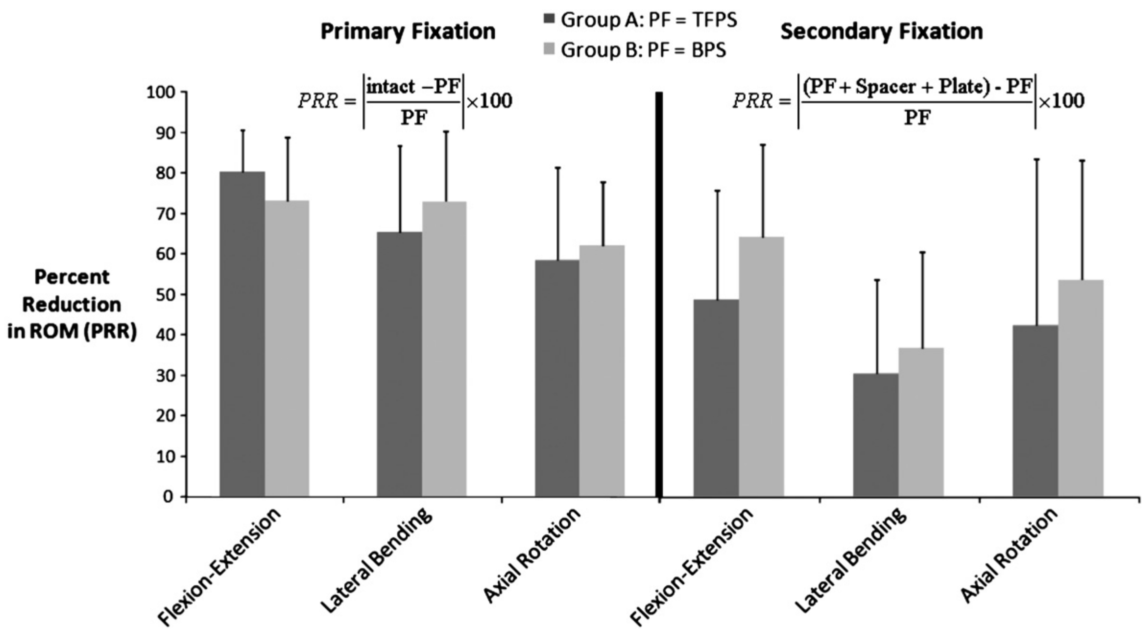


Fig. 3. Strengthening of facet and pedicle screws in primary and circumferential fixations with spacer and plate, demonstrated by percent reduction in RoM.

TFPS in the same specimen group due to the overlapping trajectories of facet screws into the pedicle path. This study is corroborated by previous work by Beaubien et al. Their study reported higher RoM for facet screws with a spacer when compared to pedicle screw constructs with a spacer in flexion–extension (15% vs. 9%) and lateral bending (37% vs. 19%). However, the current study cannot confirm their finding of equivalent performance in axial rotation (39%), but shows BPS + Spacer motion to be less than that of TFPS + Spacer (Beaubien et al., 2004). In comparison to Ferrara et al., this work corroborates two of three of their short-term flexibility conclusions. Their data suggests that TFPS + Spacer RoM is less than BPS + Spacer RoM in flexion–extension, where our data do not. However, we confirm their findings in lateral bending and axial rotation (Ferrara et al., 2003). Kandziora et al. (2005) exactly mirror the trends we find in the comparison of TFPS + Spacer and BPS + Spacer in all loading directions, but their data used a potentially smaller interference screw, with an unspecified length.

The addition of an interbody spacer affects facet screw constructs differently than pedicle screw constructs. In flexion–extension and axial rotation, the addition of an interbody spacer has a negligible effect on stabilization of TFPS (−1%, 1%), but has some effect on the stabilization of BPS (8%, 8%). In lateral bending, both TFPS and BPS constructs are stabilized to some degree by a spacer (8%, 5%). There was no interaction effect between “posterior fixation type” and “instrumentation amount” ($F<F_{crit}=1.33<3.40$, df = 24) in flexion–extension, or axial rotation. Therefore, there was no difference in group means between PF and PF + Spacer in these modes. Both PF and PF + Spacer allowed more RoM than PF + Spacer + Plate. In lateral bending, the opposite trend was observed. There was no difference in RoM for PF + Spacer and PF + Spacer + Plate, and both of these groups provided better fixation than PF alone (Fig. 2). In this light, the addition of a spacer to posterior fixation may provide an incomplete stabilization to the patient in flexion–extension and axial rotation, but is probably sufficient in lateral bending. For this reason the addition of a plate to the circumferential fusion is paramount.

The stabilization effect of these constructs in primary and secondary fixation (spacer and plate) environments was examined (Fig. 3). Interestingly, transfacet pedicle screws outperformed bilateral pedicle screws as a primary fixation method in flexion–extension. Therefore, the use of posterolateral fusions may warrant a more minimally invasive facet screw. In secondary fixations, the strengthening effect was accentuated more by a spacer and plate in the BPS constructs than the TFPS constructs, as previously discussed.

The only data anomaly was seen in flexion–extension, where primary TFPS fixation was superior to BPS fixation. It is the authors' opinion that the performance of BPS and TFPS constructs in the presence of ALIF is largely determined by the fulcrum relationship of an anteriorly placed spacer and plate, as well as the location of posterior fixation with regard to the instantaneous axis of rotation of the spinal segment. For example, the BPS + Spacer + Plate construct provides fixation in the extreme anterior–posterior directions of the sagittal plane, directly acting as a fulcrum around the center of rotation, which lies near the middle of the spacer and PF for flexion–extension (Fig. 4). The authors believe that this is similar to a fulcrum cantilever relationship in deformation theory, as shown in Fig. 4 which shows the expected deflection of a spinal segment utilizing posterior instrumentation with and without anterior instrumentation. In the case of circumferential fixation with posterior TFPS, the fulcrum cantilever relationship is closely balanced, while circumferential fixation with BPS will produce some skew in the deflection (location of β_1 vs. β_2 (Fig. 4)). There are several consistencies between the cantilever analogy and the experimental results. First, the flexion–extension RoM is higher for primary BPS than primary TFPS (δ_2 vs. δ_1 (Fig. 4)). Second, with the addition of a spacer and plate TFPS RoM becomes higher than BPS RoM (β_1 vs. β_2 (Fig. 4)) — an opposite trend. These results are mirrored by the beam deflection solutions (Table 2), which show the same trends based on geometry (distance from center-of-rotation, etc.). Moreover the ratio between the maximum beam deflection values of TFPS and BPS in a circumferential fixation is very small, in correspondence with the experimental observation of nearly equivalent performance of the two constructs as long as an anterior plate is included. Without the inclusion of an anterior plate, the anterior fixation cannot be assumed to be “motion-free” and the cantilever analogy of a perfectly constrained beam is no longer applicable.

There are some limitations to this study. First, common to all biomechanics evaluations, the interpretations of metrics such as range-of-motion and stability, are relevant clinically, but cannot be direct predictors of clinical outcome. Second, in group A, TFPS + Spacer, was constructed in the opposite manner as to what would occur clinically. In all probability a surgeon would choose to decompress and reestablish disk height with an interbody device before instrumentation with TFPS. This was not done because the preceding surgical construct of TFPS

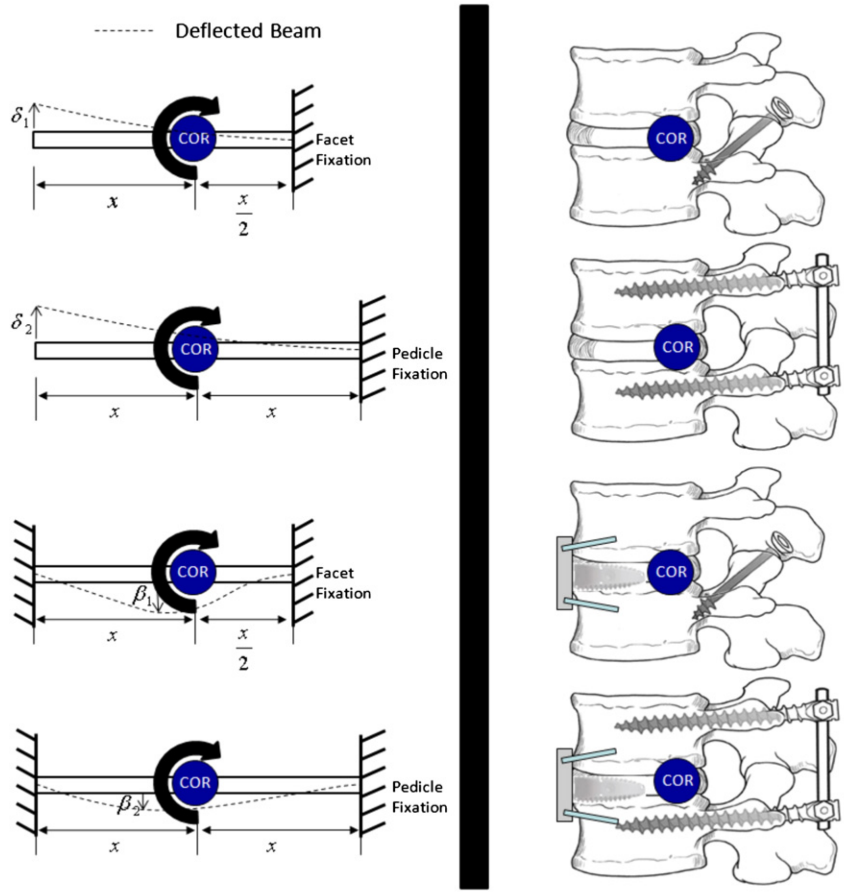


Fig. 4. Cantilever analogy of circumferential fixation. The beam deflection symbolizing RoM is shown (left) for the instrumentation configuration (right). A similar analogy can be drawn for flexion. Bony anatomy was adapted from Ferrara et al. (2003).

alone. Inserting the interbody first required removal and re-insertion of the facet screws, which would compromise the purchase, so it was not done. Lastly, as mentioned previously, the statistical power across groups is weaker because two separate groups of spines were used (which introduces another level of variability); nevertheless, this was required because of the over-lapping screw trajectories of pedicle screws and facet screws.

Transfacet pedicle screws appear to provide adequate fixation as a stand-alone device in flexion–extension. The use of an anterior spacer may further reduce RoM more in BPS than TFPS. One possible reason for this behavior is that the placement of the facet screw across the facet joint is much closer to the instantaneous center of rotation of the motion segment, and therefore any fulcrum affect due to the anterior spacer is not nearly as pronounced as with bilateral pedicle screws. Nevertheless, it should be noted that the overall fixation of bilateral pedicle screws, as a trend, was superior to that of transfacet pedicle screws in lateral bending and axial rotation.

In primary fusion, it appears as if TFPS and BPS offer a similar amount of motion reduction. Therefore, posterolateral fusion surgeries without interbody spacers could benefit from the minimally invasive advantages offered by many facet screw systems. Indeed, good clinical results have been achieved (El Masry et al., 2003). Interbody procedures, according to this study, stand to biomechanically benefit greatly through BPS constructs, yet there is no statistically significant difference between TFPS + Spacer and BPS + Spacer constructs. Even less of a disparity exists between TFPS + Spacer + Plate and BPS + Spacer + Plate constructs. Consequently, there is very little reason to believe that a circumferential fusion with an anterior plate will require the rigidity of BPS over TFPS, and the latter can be inserted posteriorly in a simpler manner. Moreover, Slucky et al. (2006) found that the novel construct of TLIF and unilateral pedicle screw with contralateral translaminar screw insertion (eliminating the need for bilateral paraspinous tissue disruption) performed biomechanically the same as BPS with TLIF, representing a compromise between a purely facet and a purely pedicle screw approach. The results of TFPS and BPS constructs used with or without the presence of ALIF indicated a statistically significant difference between intact specimens in all loading modes. This study shows TFPS constructs to be biomechanically equivalent to BPS constructs in flexion–extension for a primary fusion, with some advantages of BPS in circumferential fusions. With the circumferential fusions involving an anterior plate, discrepancies in RoM between facet and pedicle screws are minimized.

Table 2
Analytical beam deflection solutions.

	Primary fixation	Circumferential fixation
Transfacet pedicle screws (TFPS)	$\delta_1 = \frac{5}{8}\frac{Mx^2}{EI}$, at $a = 0$	$\beta_1 = \frac{1}{32}\frac{Mx^2}{EI}$, at $a = \frac{3}{4}x$
Bilateral pedicle screws (BPS)	$\delta_2 = \frac{3}{2}\frac{Mx^2}{EI}$, at $a = 0$	$\beta_2 = \frac{1}{54}\frac{Mx^2}{EI}$, at $a = \frac{2}{3}x$

M = applied moment around center-of-rotation, EI = elastic modulus * area moment of inertia of beam, and a = distance from the left side of side of beam.

5. Conclusion

The selection of a posterior fixation system is made using many factors including surgeon preference, peer recommendations, as well as the biomechanical performance of implants. While facet screws have received less attention as a method of posterior fixation due to the widespread use of pedicle screw systems, they offer a simple, minimally invasive option for fusion. Biomechanically, the performance of facet screws when compared to pedicle screws in this study resulted in similar flexibility in flexion–extension with, on average, higher flexibilities in lateral bending and axial rotation. All constructs, of either posterior fixation type, resulted in a statistically significant reduction in range of motion compared to healthy intact spines. The short-term flexibility data in this study suggest a near equivalent performance in flexion–extension of facet screw and pedicle screw systems for both primary and circumferential fusions involving an anterior plate.

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