

Biomechanical Comparison of a Novel Percutaneous Transfacet Device and a Traditional Posterior System for Single Level Fusion

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Abstract: Posterior spinal fusions are indicated for a variety of spinal disorders. Transfacet fixation minimizes soft tissue disruption and preserves the adjacent facet joint. This technique is uncommon due to concerns with biomechanical stability and proper implant placement. For these reasons, a length adjustable implant may obviate the clinical concerns but necessitates biomechanical study. This study evaluated the in vitro biomechanical stability between a novel transfacet fixation device compared with standard pedicle screws during cyclic physiologic loading in a human cadaveric model. Cadaveric L4-L5 lumbar motion segments from 16 human spines were tested in cyclic flexion/extension, lateral bending, and torsion after insertion of either transfacet fixation devices or 5.5 mm pedicle screw instrumentation. A load cell was used to measure the compressive forces on the anterior column during testing. Motion segment stiffness and anterior column compression were analyzed with a 1-way analysis of variance ($P < 0.05$). The transfacet device demonstrated a statistically similar stiffness when compared with the pedicle screw system for each test direction. For anterior column loading during physiologic testing, there were no biomechanical differences between stabilization systems. Percutaneous transfacet fixation is an attractive surgical option for single-level spinal fusions. A biomechanical evaluation of a novel device for this application demonstrated similar stability to a pedicle screw system. The length adjustability of the device may alleviate concerns for precise device placement and the biomechanical stability may produce similar rates and quality of posterior spinal fusions.

Key Words: posterior spinal stabilization, transfacet fixation, biomechanics, anterior column load, spinal fusion

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Posterior spinal fusions are indicated for a variety of spinal disorders such as degenerative disc disease, trauma, and tumor. During spinal fusion procedures, it is desirable to minimize soft tissue trauma and retain the normal anatomy of the facets. Minimally invasive approaches to spinal fusion tend to reduce the exposure area and its associated morbidities such as blood loss, perioperative pain, and potential for infection. The technique of direct facet fixation provides an attractive option in this regard. Facet fixation can be performed percutaneously using the Boucher technique.¹ This method of fixation avoids injury to the adjacent facet above the fused segment, which may decrease the incidence of adjacent segment disease. Although there have been concerns regarding the biomechanical stability of transfacet fixation, recent biomechanical studies have demonstrated that both short-term and long-term cycling of motion segments instrumented with bilateral facet fixation had equivalent biomechanical performance to standard pedicle screw instrumentation.² In a more recent study, Kandziora et al³ found that a translamina screw and a facet interference screw were biomechanically equivalent, but both less stable than a pedicle screw system. Thus, the stability issues related to facet fixation remain unclear. A novel transfacet device has been developed for these reasons. The device is cannulated to allow percutaneous insertion using guide wires. The device length is adjustable in situ, allowing precise placement of the screw and compression at the fusion site. Finally, a double helical thread design along with the ability for axial compression increases the biomechanical stability of the bone-implant interface.⁴ The purpose of this study was to compare this new transfacet device with standard pedicle screw instrumentation for single-level posterior lumbar fusions.

METHODS

Sixteen human cadaveric L4-L5 single motion segments (9 male, 7 female, average age: 70 ± 11 y) were stripped of soft tissue saving the ligamentous structures. Each motion segment was inspected to ensure there were no gross abnormalities. Motion segments were randomly assigned to either 4.5 mm transfacet fixation (BONE-LOK Transfacet Fixation System, Triage Medical, Inc)

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FIGURE 1. Mechanical design of the transfacet fixation device.

(Fig. 1) or 5.5 mm polyaxial pedicle screw groups (CD Horizon, Medtronic Sofamor Danek) (n = 8/group).

The technique for implantation of the transfacet device is described below. The implantation of the transfacet devices was performed using an instrument kit provided by the manufacturer. An incision is made in the skin and fascia to allow adequate exposure to gain proper alignment for facet screw placement, as indicated by thorough preoperative examination. Once adequate alignment is achieved, a guide wire is placed to be used as a guide for drilling and device insertion. A device path is created by power drilling over the guide wire and the path is then hand tapped with the appropriate sized instruments. The device is installed using a custom driver. The distal tip of the device is placed as desired and its position confirmed using fluoroscopy (typically). The collar mechanism of the device is then advanced using a custom compression tool. The retaining ring is locked to the outer barrel and achieves compression by stepping down the ratchet on the inner shaft. Once compression across the facet joint is achieved, the compression tool is removed and the device stability may be checked by hand. After confirmation of proper position and adequate stabilization, the guide wire is removed, as is the redundant pin mechanism that is used as part of the compression process.

Transfacet fixation followed the technique described by Boucher,¹ although the technique was slightly modified in its trajectory to obtain thread purchase within the pedicles of the inferior vertebral body (Figs. 2A, B). Motion segments were tested intact and after posterior instrumentation and anterior interbody lumbar fusion. To simulate an anterior body cage, a compression load cell (Model no.: AL322, Sensotec, Columbus, OH) was inserted between 2 custom machined, anodized aluminum plates (diameter = 25 mm) (Fig. 3). The load cell was factory calibrated to be within 0.5% of full range, with a full-scale measurement range of 0 to 500 N. When necessary, additional plates were used to ensure that each cage experienced a press fit within the anterior column. Mechanical testing involved physiologic moments applied in flexion (5 Nm), extension (5 Nm), lateral bending (5 Nm), and axial torsion (2 Nm + 100 N axial load) over 5 cycles using an MTS858 servohydraulic biaxial test frame (MTS, Co, Eden Prairie, MN). These loading levels approximated those previously used for in vitro investigation of transfacet fixation stability.^{2,3} System stiffness

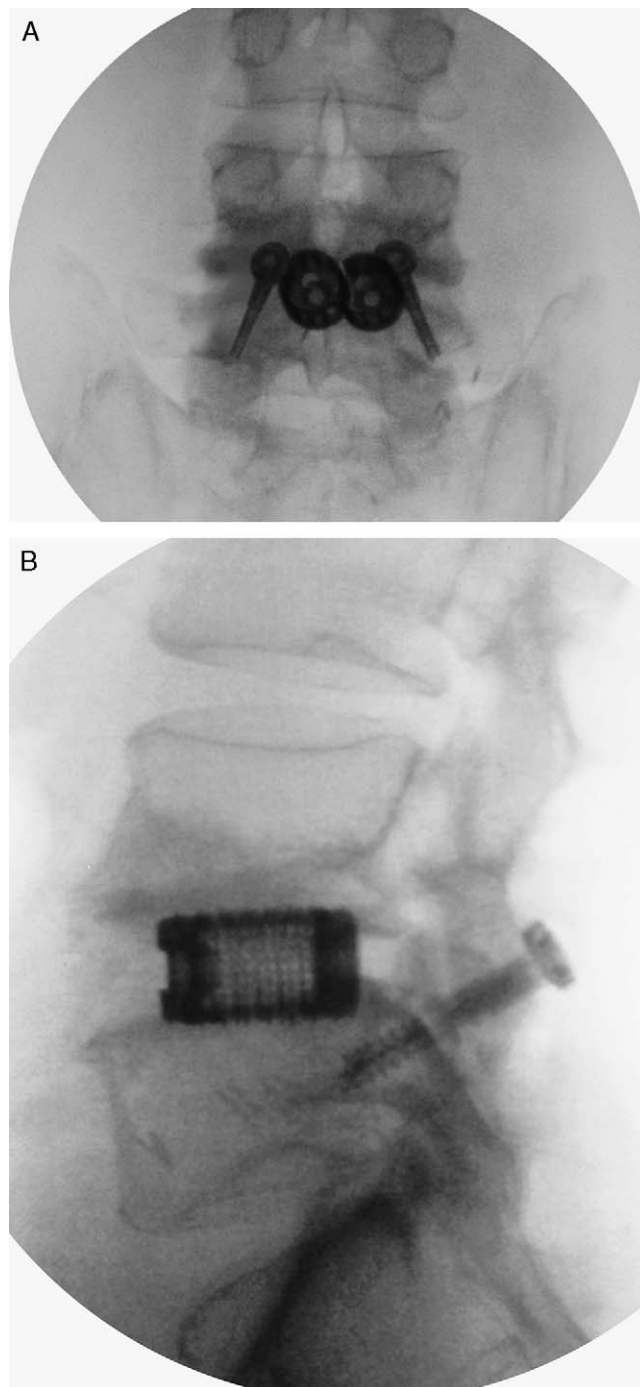


FIGURE 2. A/B, Radiograph of anteroposterior and lateral views of transfacet fixation.

(Nm/degree) was calculated between 0.5 Nm and the end load. The compression load cell within the simulated anterior body cage provided real time changes in the compressive force between vertebral bodies. These fluctuations in load (N) within the anterior column were calculated as the range from maximum to minimum for each cycle for each test (thus combining data for each



FIGURE 3. Assembled anterior column load cell simulating an interbody cage.

direction of loading). For each test, the first 3 cycles were used to condition the specimens and data analyzed over the last 2 cycles. The statistical analysis occurred in 2 stages. Because no data could be collected for anterior column loading during the intact condition, the first analysis compared the stiffness and loading differences between constructs without any normalization to the intact state. The second stage of statistical analysis compared only the stiffness of each construct after normalization to the intact state, enabling each spine to act as its own control. For all comparisons, data were statistically analyzed using a 1-way analysis of variance ($P < 0.05$).

RESULTS

Stiffness

No differences were found between groups for testing of intact specimens in any direction. This indicated adequate randomization of specimens. For flexion stiffness, there were no significant differences between transfacet (2.0 ± 1.1 Nm/degree) and pedicle screw (1.4 ± 0.7 Nm/degree) fixation methods (Fig. 4). After

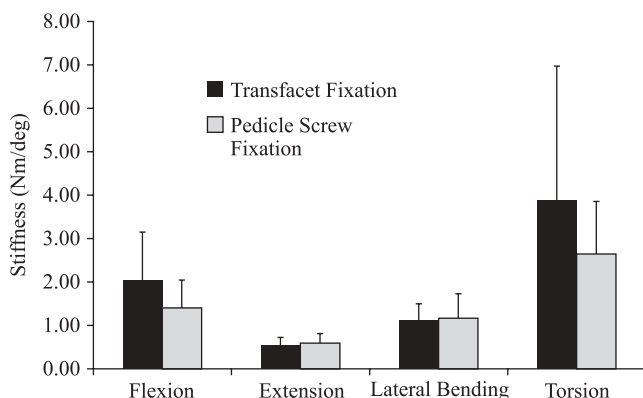


FIGURE 4. Construct stiffness for all testing.

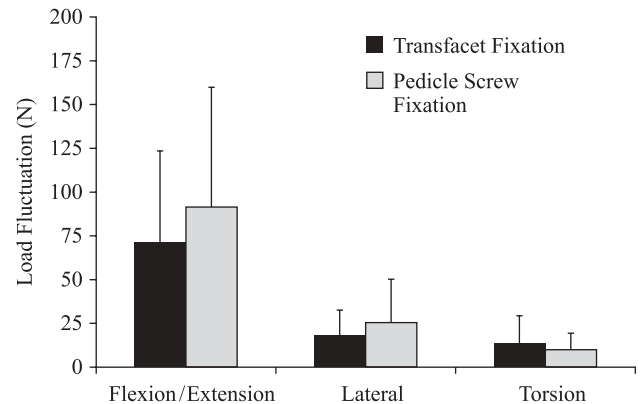


FIGURE 5. Load fluctuation for all testing.

normalizing stiffness to the intact condition, both systems were found to be stiffer than the intact condition. There were no significant differences between transfacet ($+71 \pm 54\%$) and pedicle screw ($+40 \pm 68\%$) systems ($P = 0.3$). For extension stiffness, there were no significant differences between transfacet (0.5 ± 0.2 Nm/degree) and pedicle screw (0.6 ± 0.2 Nm/degree) fixation methods. After normalizing to the intact data, both systems were found to be less stiff than the intact state. No significant differences were found between transfacet fixation ($-36 \pm 29\%$) and the pedicle screw system ($-42 \pm 25\%$) ($P = 0.4$). Lateral bending stiffness did not report significant differences between transfacet (1.1 ± 0.4 Nm/degree) and pedicle screw (1.2 ± 0.6) constructs. After normalization, both systems reported slightly stiffer data than the intact. No significant differences were reported between transfacet fixation ($+9 \pm 37\%$) and the pedicle screw construct ($+22 \pm 57\%$) ($P = 0.6$). For torsion stiffness, there were no significant differences between the transfacet (3.9 ± 3.1 Nm/degree) and pedicle screw (2.6 ± 1.2 Nm/degree) constructs. After normalization, both systems were found to be stiffer on average than the intact condition. There were no differences between the transfacet construct ($+84 \pm 177\%$) compared with pedicle screws ($+59 \pm 123\%$) ($P = 0.7$).

Anterior Column Loads

The load fluctuations during flexion/extension were not significantly different between the transfacet (71.3 ± 51.9 N) and pedicle screw systems (91.1 ± 68.4) (Fig. 5). These data were not significantly different between systems for lateral bending, with the load fluctuation for the transfacet system being slightly lower for the transfacet system (17.7 ± 14.6 N) compared with the pedicle screw system (25.2 ± 24.8 N). The load fluctuations during torsion testing demonstrated the lowest magnitude of loading change during testing. As before, there were no significant differences between transfacet (13.4 ± 15.7 N) and pedicle screw (9.6 ± 9.5 N) constructs.

DISCUSSION

The Boucher technique of facet fixation is simple and effective. The description of the technique was first reported in 1959.¹ Since then, several clinical reports have demonstrated the efficacy of this procedure. Stonecipher and Wright⁵ reported on 35 patients treated with posterior lumbar interbody fusion with facet fixation, with successful fusions and satisfactory outcomes in 34 patients. Margulies and Seimon⁶ reported on 57 patients undergoing single-level and 2-level posterolateral fusions. Overall, good to excellent results were found in 50 patients (88%).⁶ El Masry et al⁷ reported on 38 patients undergoing posterolateral fusion with Boucher screw fixation. All patients had a successful fusion and 89% had good to excellent results.⁷⁻⁹ Recently, Ferrara et al² performed a mechanical comparison of Boucher screw fixation to pedicle screw fixation. For both short-term and long-term cyclic testing, facet screw fixation was comparable to pedicle screw fixation.² Most recently, Kandziora et al³ compared lumbar facet interference screws, translamina screws and pedicle screw systems (each employing interbody structural support). The pedicle screw system was significantly stiffer in flexion and torsion compared with either facet system, but they attributed this to the type of pedicle screw system tested (Universal Spine System, Mathys, Inc). However, no dimensions were provided for that particular instrumentation which would help better understand its influence on construct stiffness.

There is clear interest in using facet fixation for posterior stabilization, although it is unclear why it has not gained more surgical popularity. One possibility is that the technique requires significant precision in terms of screw position and screw length. The transfacet system used in this study addresses these issues by using a cannulated system allowing insertion over a guide wire. The precise length of the device is adjustable in situ allowing for precise placement of the screw tip. At that stage, if further facet compression is desirable, a ratchet-gun mechanism allows the surgeon to compress the facets without danger of advancing the screw tip. The slight modification to the original Boucher technique also allows the surgeon to obtain thread purchase in the pedicle of the inferior vertebral body.

An important limitation of this study is the lack of bone density measurements at the time of testing. Differences in bone density in either the facet/pedicle area or in the anterior column may affect bone/implant stability. However, all specimens were assessed for preexisting osteoporotic fractures or other issues that

could have affected the results. Only specimens that cleared this examination were used in testing. Intact specimens were also analyzed before random allocation to ensure that there were no significant biomechanical differences between groups. Furthermore, our conclusion that these constructs are mechanically equivalent is based on the absence of statistically significant differences between the transfacet and pedicle screw constructs. Power calculations (~ 0.5) indicated that a large number of additional specimens would be needed to detect relatively small differences. Owing to limitations of specimen availability, this was not considered possible.

Transfacet fixation for posterior spinal fusions is an attractive surgical option as the devices may be delivered percutaneously, potentially limiting morbidities associated with open or miniopen procedures. However, this benefit can only be achieved in the presence of equivalent stabilization compared with standard pedicle screw constructs. Data from the current study indicate that a novel transfacet fixation device demonstrates similar mechanical stiffness and anterior column loading compared with a pedicle screw system when tested in different planes of motion with physiologic loads. However, this in vitro information should be considered carefully when selecting potential patients and clinical studies should be pursued to verify fusion rates and quality of fusions using this new system.

REFERENCES

1. Boucher HH. A method of spinal fusion. *J Bone J Surg Br.* 1959; 41-B:248-259.
2. Ferrara LA, Secor JL, Jin BH, et al. A biomechanical comparison of facet screw fixation and pedicle screw fixation: effects of short-term and long-term repetitive cycling. *Spine.* 2003;28:1226-1234.
3. Kandziora F, Schleicher P, Scholz M, et al. Biomechanical testing of the lumbar facet interference screw. *Spine.* 2005;30:E34-E39.
4. Cachia VV, Culbert B, Warren C, et al. Mechanical and structural characteristics of the new BONE-LOK cortical-cancellous internal fixation device. *J Foot Ankle Surg.* 2003;42:15-20.
5. Stonecipher T, Wright S. Posterior lumbar interbody fusion with facet-screw fixation. *Spine.* 1989;14:468-471.
6. Margulies JY, Seimon LP. Clinical efficacy of lumbar and lumbosacral fusion using the Boucher facet screw fixation technique. *Bull Hosp Jt Dis.* 2000;59:33-39.
7. El Masry MA, McAllen CJ, Weatherley CR. Lumbosacral fusion using the Boucher technique in combination with a posterolateral bone graft. *Eur Spine J.* 2003;12:408-412.
8. Jang JS, Lee SH, Lim SR. Guide device for percutaneous placement of translamina facet screws after anterior lumbar interbody fusion. Technical note. *J Neurosurg.* 2003;98(Suppl):100-103.
9. Thalgott JS, Chin AK, Ameriks JA, et al. Minimally invasive 360 degrees instrumented lumbar fusion. *Eur Spine J.* 2000;9(Suppl): S51-S56.