Biomechanical Comparison of Translaminar Screw Versus Pedicle Screw Supplementation of Anterior Femoral Ring Allografts in One-Level Lumbar Spine Fusion

Afshin E. Razi, M.D., Jeffrey M. Spivak, M.D., Frederick J. Kummer, Ph.D., David S. Hersh, M.D., and Jeffrey A. Goldstein, M.D.

Abstract

Pedicle screws (PS) can provide initial stabilization of anterior interbody femoral ring allograft (FRA) lumbar constructs. Translaminar screws (TLS) have also been advocated for this procedure. The objective of this study was to use an in vitro human cadaveric model to compare the stability of one-level anterior interbody lumbar constructs stabilized with PS and those stabilized with TLS. Five human cadaveric spinal motion segments (L4-S2) were biomechanically evaluated in the intact condition and using the following methods of stabilization: anterior interbody fusion with FRA, anterior FRA supplemented with PS, and anterior FRA supplemented with TLS. Stability was determined for each construct by measuring construct displacement as a function of applied load under the following conditions: compression, flexion, extension, lateral bending to each side, and axial torsion. There were no statistically significant differences in construct stability between FRA supplemented with PS and FRA supplemented with TLS under any of the loading conditions. In selected cases, supplementation of anterior femoral ring allograft with translaminar screws is a viable alternative to supplementation with pedicle screws.

Simultaneous combined anterior and posterior lumbar fusion has become an accepted operative procedure for the treatment of patients with disabling low back pain. Hodgson and Wong were among the first to perform a combined anterior and posterior fusion, and demonstrated that this combined approach achieves more stability than either procedure alone.1,2 Currently, combined anterior and posterior lumbar fusion often involves anterior interbody fusion (using either autograft or allograft) and posterior fixation. Instrumentation systems for posterior fixation include pedicle screw and translaminar screw constructs. Pedicle screw fixation systems are most useful when correcting degenerative conditions for which the spinous processes and laminae have been removed for neural decompression. The use of pedicle screw fixation has become popular because it allows for stable attachment to a vertebra despite resection of the posterior elements. In addition, pedicle screws allow for segmental control of the vertebrae, providing an opportunity for distraction or compression along the length of the spinal fusion.

Zdeblick and colleagues3 showed that the use of pedicle screw instrumentation results in higher fusion rates than bone grafting alone. However, the complication rate is also higher and includes device-related osteoporosis, pain, infection, and nerve root injury. Pedicle screw insertion requires significant muscle dissection and retraction resulting in greater morbidity. Furthermore, the cephalad screws of a pedicle screw plate or rod construct may cause mechanical compromise of the facet joint above the fused level.

Translaminar screw (TLS) fixation represents an alternative to pedicle screw constructs. Translaminar screws allow for good stabilization of the segment with minimal soft tissue injury.6,7 It is well known that excessive movement at the bone-implant interface will lead to fibrous tissue formation; minimizing movement at the interface theoretically increases the fusion rate. A number of studies have evaluated the biomechanical characteristics of translaminar facet screw fixation in the absence of anterior interbody fusion.12-15 Subsequently, Volkman and associates16 demonstrated that the supplementation of anterior lumbar interbody arthrodesis with transfacet screw fixation results in an increase in...
stiffness of the motion segment. However, few studies have
directly compared the biomechanical properties of pedicle
screws with those of translaminar screws as a means of
supplementing anterior interbody fusion.

Therefore, this biomechanical study was designed to
compare the stability of one-level anterior interbody lumbar
constructs stabilized with either translaminar screw fixation
or pedicle screw fixation. Our hypothesis was that there is
no difference in initial stability between the two forms of
posterior fixation when used as a supplement to an anterior
femoral ring allograft construct.

Materials and Methods

Specimen Preparation
Five motion segments (L4-S2) from fresh human cadavers
were obtained. Each specimen was radiographed to ensure
that no major structural abnormalities were present. Bone
density was not performed on these specimens. All speci-
mens were frozen to -20° C and stored until the day before
testing, when they were allowed to thaw slowly to room
temperature. Each lumbar motion segment was carefully
stripped of muscle, with care taken to preserve all ligaments,
joint capsules, discs, and the bone structure. The proximal
(L4) and distal (S2) ends of each specimen were then fixed
to the centers of aluminum plates (15 x 15 x 0.5 cm), using
surgical bone cement (Stryker, Rutherford, NY). Care was
taken to ensure that the disc and the facet joints were clear
of the cement and easily accessible.

Biomechanical Testing
Nondestructive biomechanical testing was performed.
During each test, load was applied to the superior plate at a
defined center with a ball bearing (Fig. 1). The inferior end
plate was clamped to the activator of a mechanical testing
machine (MTS, Canton, MA). After a cyclic compression-
conditioning period (500 N ± 150 N, at 1 Hz, for 1000
cycles), the motion segment was biomechanically tested
corresponding to the following loading sequence. At each step,
the load was applied three times and a load-deformation
curve was obtained each time.

The center of rotation was established for the intact
motion segment in the manner described by Volkman and
colleagues.16 Each specimen was then loaded in pure com-
pression at a displacement rate of 0.25 cm/min. A load of
up to 900 N was applied at the center of rotation. Previous
studies showed that this maximum load allowed repeated
cycles without causing irreversible damage to the interver-
tebral joint.17,18

Each specimen was then loaded in flexion, extension,
right lateral bending, and left lateral bending. A load of
900 N was applied 2 cm anterior, posterior, right, or left of
the center of rotation, respectively, to produce a maximum
bending moment of 18 Nm. The specimen was never flexed
more than 7° to prevent permanent deformity. As the last
step in the loading sequence, axial torsion was applied. The
specimen was first compressed to 900 N and then an axial
torque was applied in a clockwise motion, to a maximum
of 10 Nm. The angle of displacement was measured using
a goniometer.

The loading sequence was initially performed on each of
the intact motion specimens. The loading sequence was then
sequentially tested on each of the specimens after placement
of the following constructs: anterior femoral ring allograft
(FRA), anterior FRA with posterior pedicle screw fixation,
and anterior FRA with posterior TLS fixation.

For each individual test (except for torsion), a load-
deformation curve was obtained. The stiffness of the motion
segment was derived as the slope of the curve (from 450 N
to 900 N).

Surgical Procedure
An anterior interbody fusion was performed for each
specimen. The anterior longitudinal ligament and nucleus
pulposus of L5-S1 were excised. An interbody femoral ring
allograft (MTF, Synthes, Jessup, PA) was inserted via an
anterior approach, and was centered within the disc space. A
fully threaded screw with a washer was used anteroinferiorly
to secure the graft.

Posterior pedicle screw fixation was then performed for
each specimen. After proper identification of the entry point,
four 6.2 mm self-tapping pedicle screws (Synthes Spine
LTD, Paoli, PA) were placed according to the manufacturer’s
protocol. The motion segment was then stabilized with two
pre-cut rods. No cross-link was used. Following testing, the screws were removed.

Next, posterior TLS fixation was performed for each specimen. A long 3.2 mm drill was used to create a hole extending from the base of the spinous process transversely across the contralateral lamina to transfix the facet joint. A 4.5 mm fully threaded self-tapping cortical screw (Synthes, Monument, CO) of 48 mm length was then inserted. A contralateral screw was inserted after pre-drilling in a similar manner.

Statistical Analysis
A repeated measures analysis of variance (ANOVA) was conducted to compare the displacement of the intact specimens and the displacement of each of the other constructs. Significance was set at p < 0.05.

Results
Of the specimens, 3/5 (60%) had severe degenerative changes of the L5-S1 segment and the remaining 2/5 (40%) had minimal to mild changes.

In compression, extension, and lateral bending, the intact specimens demonstrated the least amount of displacement. In flexion, the intact specimen demonstrated slightly more displacement than the specimen with FRA alone, but less displacement than the specimens with FRA and pedicle screws or FRA and translaminar screws. There was no statistically significant difference in displacement when the intact specimens were compared with the instrumented constructs.

In torsion-loading, the intact specimen exhibited more displacement than the instrumented constructs. The specimen with anterior interbody femoral ring allograft and pedicle screw fixation demonstrated the least displacement. However, there was no significant difference between any two conditions (p > 0.05).

Supplementation with pedicle screw fixation produced greater stiffness and stability than with translaminar screw fixation in compression, lateral bending, and axial torsion. Conversely, supplementation with translaminar screw fixation provided greater stability in flexion and extension. However, there was no significant difference in displacement between pedicle screw fixation and translaminar screw fixation (p > 0.05) (Fig. 2).

Discussion
Our study demonstrated a very slight increase in intervertebral displacement when the intact specimens were compared with the femoral ring allograft constructs under all loading conditions except for torsion. However, there were no statistically significant differences in stability under any of the loading conditions. These findings are consistent with those of Rathonyi and coworkers\textsuperscript{17} and Lund and colleagues\textsuperscript{19} who found a slight increase in the range of motion of the unit after anterior or posterior interbody implantation, respectively.

Moreover, Volkman and associates\textsuperscript{16} reported a decrease in stiffness in both flexion and extension when stand-alone anterior interbody cages are used. Tencer and coworkers\textsuperscript{20} found similar results, although they were not statistically significant. Upon insertion of the anterior femoral ring allograft, the implant rests on the endplate and relies on friction in order to resist shear; therefore, the increase in displacement may be due to insufficient compressive force or insufficient friction. Under torsion loading, on the other hand, specimens with FRA constructs demonstrated less displacement than the intact specimens, although the differences were not statistically significant. These findings are consistent with those of Brodke and colleagues\textsuperscript{21} who showed that under axial torsion, stiffness increased by 50% with the insertion of a titanium basket into the interbody space. This may be due to the natural orientation of the facets, which provides an intrinsic resistance to torsion, as described by Eskander and associates\textsuperscript{22}.

Previously, Volkman and associates\textsuperscript{16} showed that supplementation with transfacet screw fixation increases motion stiffness, especially in extension, compared to anterior interbody reconstruction (using a cage) alone. Rathonyi and coworkers\textsuperscript{17} similarly demonstrated that cage fixation alone provides good stability in flexion and lateral bending, but that translaminar fixation improves stabilization, particularly in extension and axial rotation. Lund and colleagues\textsuperscript{19} demonstrated similar results for transpedicular fixation. Upon comparing the supplementation of anterior FRA with these two techniques, our study found only minimal differences in intervertebral displacement under all loading conditions except for torsion. Under torsion loading, supplementation with translaminar screw
fixation resulted in greater intervertebral displacement and therefore less stability than supplementation with pedicle screws. However, there were no statistically significant differences in stability under any of the loading conditions, which may be due to our small sample size. These results are consistent with those of Eskander and associates,23 whose findings implied that pedicle screw supplementation of anterior FRA provides greater stiffness than translaminar screw supplementation, although statistical significance was not demonstrated.

This study has several limitations. The active physiological loads on the spine are not fully understood. We applied 900 N (or 10 Nm in the torsion sequence) as this was used and studied by previous investigators. However, greater or lesser loads may exist in vivo. Another limitation is inherent to biomechanical studies using cadaveric motion segments (i.e. the lack of stabilization provided by the surrounding spinal musculature in vivo). Furthermore, three out of five of the motion segments were found to have severe degenerative changes at the L5-S1 segment. Significant anterior degenerative changes may have altered the properties of the intact spine segment, while posterior degenerative changes may have specifically affected intervertebral displacement in sequences such as extension and lateral bending. Additionally, it appeared that our specimens were harvested from rather elderly subjects and were thus osteopenic. This may have possibly caused undetected subsidence of the graft. However, since all specimens acted as their own controls, and had similar loading sequences and conditions, the results are comparable.

Of note, this study addresses only the immediate stability of various implant configurations. The effect of time on stability, fusion rates, and the maintenance of disc height was not evaluated. It is possible, therefore, that the immediate stability shown in our study is a worst-case scenario, and that stability may increase as bony fusion occurs.

**Conclusion**

Pedicle screw fixation can be useful as a means of augmenting anterior interbody grafting. However, the use of the pedicle screw entails considerably more cost, operative time, and intra-operative risk as compared to translaminar screw fixation. Our results show no statistically significant differences between pedicle screw versus translaminar screw supplementation of an anterior interbody femoral ring allograft in vitro. Therefore, translaminar screw fixation may be an effective alternative in selected cases.

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**Disclosure Statement**

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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