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Original Article

Combined transforaminal lumbar interbody fusion with posterolateral instrumented fusion for degenerative disc disease can be a safe and effective treatment for lower back pain

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Abstract

Background: Lumbar fusion is a proven treatment for chronic lower back pain (LBP) in the setting of symptomatic spondylolisthesis and degenerative scoliosis; however, fusion is controversial when the primary diagnosis is degenerative disc disease (DDD). Our objective was to evaluate the safety and effectiveness of lumbar fusion in the treatment of LBP due to DDD. **Materials and Methods:** Two-hundred and five consecutive patients with single or multi-level DDD underwent lumbar decompression and instrumented fusion for the treatment of chronic LBP between the years of 2008 and 2011. The primary outcome measures in this study were back and leg pain visual analogue scale (VAS), patient reported % resolution of preoperative back pain and leg pain, reoperation rate, perioperative complications, blood loss and hospital length of stay (LOS). **Results:** The average resolution of preoperative back pain per patient was 84% (n = 205) while the average resolution of preoperative leg pain was 90% (n = 190) while a mean follow-up period of 528 days (1.5 years). Average VAS for combined back and leg pain significantly improved from a preoperative value of 9.0 to a postoperative value of 1.1 ($P \leq 0.0001$), a change of 7.9 points for the cohort. The average number of lumbar disc levels fused per patient was 2.3 (range 1-4). Median postoperative LOS in the hospital was 1.2 days. Average blood loss was 108 ml perfused level. Complications occurred in 5% of patients (n = 11) and the rate of reoperation for symptomatic adjacent segment disease was 2% (n = 4). Complications included reoperation at index level for symptomatic pseudoarthrosis with hardware failure (n = 3); surgical site infection (n = 7); repair of cerebrospinal fluid leak (n = 1), and one patient death at home 3 days after discharge. **Conclusion:** Lumbar fusion for symptomatic DDD can be a safe and effective treatment for medically refractory LBP with or without leg pain.

Key words: Back pain, degenerative disc disease, discogenic pain, spinal fusion, spinal fusion outcomes

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INTRODUCTION

Chronic lower back pain (LBP) is a common problem that affects millions of people globally. Estimates of the financial impact of LBP reach $100 billion annually. Ineffective treatments are responsible for most of the costs to society. Effective treatments are those that are directed at the specific cause(s) of back pain. The common causes of chronic LBP have been previously described and include lumbar facet joint inflammation, discogenic pain, piriformis syndrome, sacroiliitis, fractures and lumbo-sacral strains. Discogenic pain was described by Cloward (1959) from experiments he and others did on live human subjects undergoing awake surgical procedures where he demonstrated that localized axial lumbar pain was reliably reproduced in awake test subjects via the application of blunt mechanical pressure directly onto the spinal disc's posterior annulus. The concept of discogenic pain is widely accepted today and has important implications regarding the effective treatment of chronic LBP. Discogenic pain can be cured through treatment directed specifically at the symptomatic disc(s) as demonstrated in this and other recent peer-reviewed publications.

In this study, over 200 patients with chronic discogenic back pain underwent surgical treatment directed at the source of their back pain, the painful intervertebral disc(s). The surgical procedure performed in each case included bilateral posterior osteotomy with removal of abnormal arthritic facet joint, removal of the symptomatic disc(s), interbody arthrodesis, interbody polyetheretherketone (PEEK) cage, bilateral segmental pedicle screw fixation and posterolateral arthrodesis. Patients with symptomatic stenosis underwent concomitant decompression to treat radicular symptoms. Correction of deformity was performed when necessary. Lumbar lordosis was achieved in each case by posterior element osteotomy, placement of transforaminal interbody cages and use of a "Jackson" spinal table.

MATERIALS AND METHODS

Patient selection

This prospective, cohort study included all patients treated at Deuk Spine Institute between 2008 and 2011, aged 18-85 years old with magnetic resonance imaging (MRI) or computed tomography (CT) confirmed degenerative disc disease (DDD) and discogenic LBP with or without radiculopathy who failed conservative management and underwent single incision combined anterior interbody and posterolateral fusion with instrumentation and reconstruction using interbody PEEK cage(s).

Surgical procedure

All patients underwent surgery with general anesthesia and complete neuromuscular blockade. Patients were positioned prone on a "Jackson" spinal table to optimize lumbar lordosis and minimize venous bleeding from increased abdominal pressure. The entire procedure was performed through a single posterior midline incision with subperiosteal muscle dissection using a Bovie monopolar and a wide exposure to the lateral aspect of the facet joints. Laminectomy with bilateral pars osteotomy for removal of abnormal facet joints was performed at each fused level. Through a unilateral transforaminal approach the degenerated disc was removed, the vertebral body end plates decorticated with a rasp, the disc space was partially filled with local autograft and synthetic allograft and finally a tall PEEK cage was implanted into the interbody space. Segmental, bilateral polyaxial pedicle screw rod fixation with crosslinks was placed at all levels treated using lateral fluoroscopic guidance [Figure 1]. Finally, posterolateral intertransverse fusion with local autograft and allograft was performed.

Postoperative care

All patients were prescribed a thoracolumbosacral orthosis back brace to be used for the first 6 weeks postoperative while out of bed. Lifting restrictions were 25 lbs for the first 6 weeks then 40 lbs until 3 months postoperatively. Supervised therapy was ordered for the first 6 weeks postoperative and initiated on the 1st postoperative day.

Statistical analysis

Statistical analysis was performed with the Wilcoxon Signed Rank Test. Statistical significance required a *P* value of 0.05 or less. This is a nonrandomized prospective cohort study.

Outcome measures

We report on back and leg pain visual analogue scale (VAS), patient reported % (percent) resolution of LBP, patient reported % (percent) resolution of leg pain, perioperative complications, operative blood loss, number of spinal disc levels treated, reoperation rate for adjacent segment disease and hospital length of stay (LOS). A sub-analysis was performed to compare Medicare versus non-Medicare patient outcomes for overall pain relief.

RESULTS

Two-hundred and five consecutive patients underwent lumbar reconstruction and instrumented fusion with an average

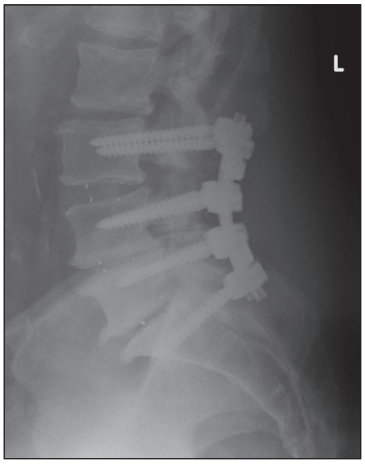

Figure 1: Lateral postoperative X-ray demonstrates typical surgical construct and alignment

postoperative follow-up of 528 days (1.5 years). Of the 205 patients with chronic back pain, 107 (52%) were male. The age range was between 20 and 85 years , and 81 patients (40%) had Medicare as their primary insurance. Ninety-three percent of the cohort (n = 190) had preoperative leg pain. The total number of spinal discs fused was 478 [Table 1] or an average of 2.3 lumbar spinal levels treated per patient. Mean hospital LOS was 1.2 days per patient. Operative blood loss averaged 252 ml per surgical case or 108 ml perfused level. Typical radiation from intraoperative fluoroscopy was 30 s per case. These results are summarized in Table 2.

Pain relief

VAS scores significantly improved with fusion. Average VAS for combined back and leg pain significantly improved from a preoperative value of 9.0 to a postoperative value of 1.1 ($P \leq 0.0001$), a change of 7.9 points for the cohort [Figure 2]. The average resolution of preoperative back pain was 84% (n = 205) with fusion [Figure 3], while the average resolution of preoperative leg pain was 90% (n = 190) [Figure 4] as reported by the patients. There was no significant difference in resolution of pain between Medicare (n = 81) versus non-Medicare (n = 124) patients undergoing fusion (P = 0.222).

Complications

Complications are occurred in 5% of patients (n = 11) undergoing fusion [Table 3]. The rate of reoperation for symptomatic adjacent segment disease was 2% (n = 4).

DISCUSSION

In this study, over 200 consecutive patients that underwent lumbar instrumented fusion for a primary preoperative diagnosis of DDD achieved a significant improvement in their daily chronic LBP as a result of their surgery. LBP in the setting of DDD is common and in many cases does not respond to conservative treatment. The results of this study demonstrates that patients who fail to achieve significant relief of their chronic LBP with therapy and injections may be treated successfully with spinal fusion surgery with excellent results. To understand, why we must look at the source of discogenic pain, the posterior annular tear within the intervertebral disc.

The intervertebral disc is the larger of two types of weight bearing joints that make up the repeating vertebral motion segments in the spine. The lumbar spine contains five distinct intervertebral discs, each paired with two facet joints. The posterior annulus of the intervertebral disc is innervated with pain sensory fibers (somatic afferent) from the sinuvertebral nerve embedded

Table 1: Incidence of fused levels

Level fused	Incidence
L1-2	5
L2-3	31
L3-4	105
L4-5	182
L5-S1	155

Note: Total levels fused = 478 (average 2.3 per patient)

Table 2: Summary of results

Outcome	Result
Resolution LBP	84%
Resolution leg pain	90%
Hospital LOS	1.2 days
Blood loss*	108 ml
Radiation	30 s
Complications	5%
Reoperation ASD	2%

*Per level fused. LBP = Lower back pain, LOS = Length of stay ASD = Adjacent segment disease

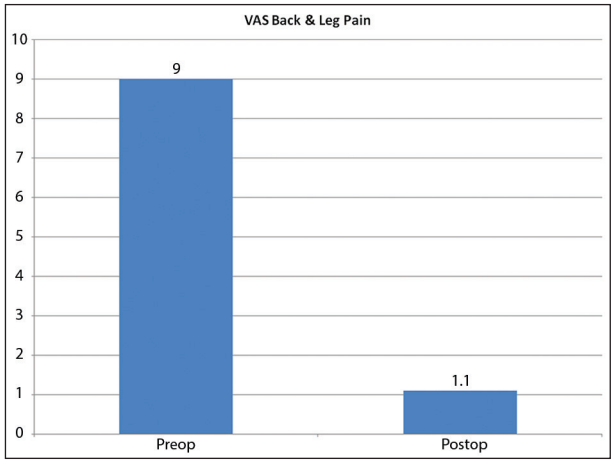

Figure 2: Significant improvement in visual analogue scale (P < 0.0001)

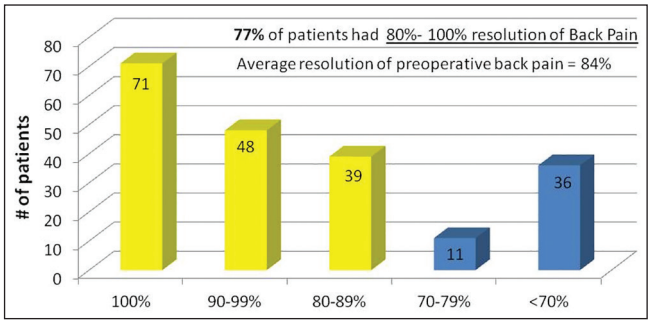

Figure 3: Resolution of preoperative back pain with fusion

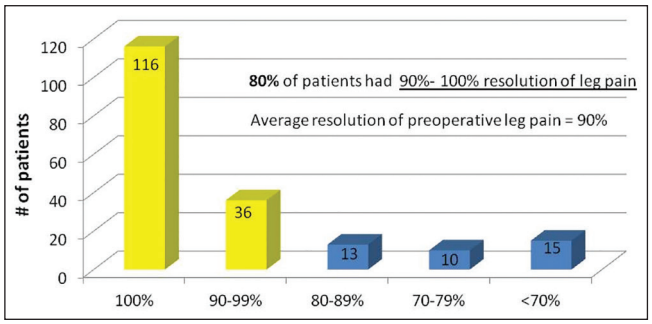

Figure 4: Resolution of preoperative leg pain with fusion

in the posterior annulus fibrosus and posterior longitudinal ligament.[1,2,3,4,5,6,7,8,9,10,11,12,13] Like any other weight bearing joint in the body, the intervertebral disc can become injured and painful. Axial pain originating from the spinal intervertebral disc(s) is called "discogenic pain"[4,9,11,13-17] and it must be distinguished from other common sources of back pain such as the facet joints, sacroiliac joints, and piriformis muscles. This can be accomplished through the use of fluoroscopically guided diagnostic blocks including: Facet medial branch block, sacroiliac joint injection, and piriformis muscle injection.[2,18,20-26] If the diagnostic block confirms the facet joints, sacroiliac joints or piriformis muscle to be the primary source of the patient's LBP then nonoperative treatment should be directed to those structures. In the absence of facet or sacroiliac joint pain, the degenerated disc(s) seen on MRI or CT scan become the most likely cause of the patient's chronic LBP and treatment of discogenic pain should be initiated. In select cases, evocative discography can be used to confirm the source(s) of discogenic pain.[9,15,27-30] Discogenic pain does not respond well to nonoperative treatments.[21,31] Therapy and needle based treatments including injection and rhizotomy are highly effective in alleviating back pain from arthritic facet and sacroiliac joints; however, they are useless for eliminating discogenic pain.[9,26,30,32-36] In the setting of DDD, discogenic pain can be successfully treated with spinal surgery including fusion, arthroplasty and Deuk Laser Disc Repair directed at the symptomatic intervertebral disc(s).[37-51]

The 205 patients in this study originally presented for treatment with the chief complaint of mechanical LBP related to DDD. The primary goal of surgical treatment in this cohort was elimination of back pain and leg pain if present; therefore, the primary outcome measure used was the "percent resolution of preoperative back and leg pain" as reported by the patient after surgery. All patients were encouraged to resume normal daily activities, hobbies, sports and work as soon as possible after their surgery. Back braces were discontinued at 6 weeks postoperative, lifting and bending restrictions were removed at 3 months postoperatively. Because all activity restrictions were removed by 3 months postoperative in this study, the patient reported pain relief was a "true" measure of pain with normal daily activities. One-way to reduce activity related pain is to require patients to reduce their activities and lead a sedentary lifestyle. The patients in this study were required to do the "opposite" through rigorous postoperative exercise programs. Patients were strongly encouraged to resume the activities they enjoyed doing as soon as 2-6 weeks postoperative. Many nonoperative studies for the treatment of back pain report improved outcomes that are largely a result of the severe activity restrictions they place on patients called "behavioral modifications." These nonoperative strategies are doing nothing more than "robbing" patients of the quality of life they deserve to have by imposing severely restrictions on their activities. It is no surprise that these patients become at risk for depression, obesity, and osteoporosis due to inactivity from restrictions placed on them by their physicians or their health insurance company. The primary goal of back surgery for pain should be to allow the patient to resume normal activity levels without pain or long-term restrictions.

We believe the extreme variability observed in outcomes published for lumbar fusion studies in patients with DDD are most likely the result of differences in patient selection and operative technique. A meta-analysis of peer-reviewed studies on lumbar fusion report wide variation in postoperative improvement in functional outcomes that clearly reflect differences in operative techniques [Table 4]. The surgical technique used in this study was selected for its safety and ability to achieve specific surgical goals including: Minimal blood loss (100 ml per level fused), minimal collateral damage to paraspinal structures, excellent restoration of lumbar alignment, maximize fusion surface area, optimize decompression of the bilateral neuroforamen and lateral recesses, minimize radiation exposure (typically 30 s per case), reduce risk of instrumentation and implant related complications while achieving excellent segmental fixation. Blood loss was minimized by using the following strategies: Keeping the patient's systemic blood pressure at the low end of the safe range throughout the case, reducing intra-abdominal pressure and venous bleeding through the use of the "Jackson" spinal table, subperiosteal (muscle sparing) paraspinal muscle dissection off of the bony spine with Bovie monopolar, aggressive use of chemical muscle relaxation to reduce bleeding and muscle metabolic rate until placement of pedicle screws and discontinue use of blood thinners and antiplatelet therapy 7–10 days prior to surgery.

Table 3: Complications

Complication	Incidence (%)
Hardware failure	0.5 (*n*=1)
Symptomatic nonunion	0 (*n*=0)
Surgical site infection	3.5 (*n*=7)
CSF leak	0.5 (*n*=1)
Vascular complication	0 (*n*=0)
Neurological deficit	0 (*n*=0)

CSF = Cerebrospinal fluid

Table 4: Variation in outcome based on surgical technique

Procedure	Efficacy* (%)	Complications (%)
PLF (ICBG), NI	44	15-25
ALIF, NI	77.8	30
PLF + PSF	68	32
ALIF + I	83	20-26
PLIF + PSF	—	—
PLIF + PLF + PSF	23-27	23-28
ALIF + PLF + PSF	28-47	51
TLIF + PLF + PSF	45-50	23
XLIF	61	25

*Efficacy is percent improvement in ODI. PLF = Posterolateral fusion, NI = Noninstrumented, ALIF = Anterior lumbar interbody fusion, PSF = Pedicle screw fixation, I = Instrumented, PLIF = Posterior lumbar interbody fusion, TLIF = Transforamenal lumbar interbody fusion, XLIF = Extreme lateral interbody fusion, ICBG = Iliac crest bone graft, ODI = Oswestry disability index

Posterior osteotomies to remove abnormal facet complexes were performed bilaterally at each vertebral segment fused to allow decompression of the neuroforamen and restoration of coronal and saggital alignment. In our experience, we found that abnormal facet joints contributed significantly to symptomatic lateral stenosis and made correction of any observed deformity difficult unless they were removed. Nerve roots within the neuroforamen were frequently found to be compressed by the hypertrophied facet complex including the facet capsule, tip of the superior facet and subluxed inferior facet. Congenitally short pedicles were also frequently found associated with severe lateral recess stenosis in most of the cases of leg pain. Decompression with fusion provided excellent symptomatic relief of radicular pain in this study (90% resolution of leg pain).

The overall complication rate for fusions in this study was 5% which included one patient with two postoperative complications. In our analysis of the peer-reviewed literature, published complication rates for the spinal surgery range from 0% up to 60% with most studies reporting between 15% and 20% complication rate. We believe that the 5% complication rate found in this study for spinal fusion is acceptable. Seven of the complications in this fusion study (58%) were surgical site infections (SSI). Since July 2011, we began using 1-2 g of vancomycin powder topically in the surgical wound after lumbar fusion. From July 2011 to June 2013, 173 additional lumbar fusions have been performed using topical vancomycin with zero infections (unpublished results). Taking this new strategy into account the authors could extrapolate that by eliminating surgical site infections (SSIs) the projected complication rate could be as low as 2% for lumbar fusion. The future looks bright for patients considering the risk to benefit analysis of fusion for symptomatic DDD.

We believe that MRI or CT alone in the setting of DDD should never be used to determine a surgical candidate. Our treatment algorithm requires that all patients with chronic back or leg pain fail a reasonable course of therapy (6-12 weeks), medical management (anti-inflammatory, muscle relaxers, and low dose narcotics as appropriate) and a trial of interventional pain management. The interventionalist's goal will be to either "rule out" or "rule in" common sources of LBP other than the degenerative disc(s) present on imaging. Specifically, before fusion surgery will be considered for a painful degenerated intervertebral disc, the facet joints, sacroiliac joints, and piriformis muscles must be clinically evaluated and "ruled out" as the source of the patient's back pain. This is accomplished through the physical exam and injection "blocks" by the interventional pain management specialist using lidocaine or marcaine to eliminate temporarily pain from specific joints or muscles in the region of the patient's pain.

The patient's selected for fusion surgery all failed to achieve pain relief with blocks to known common pain generators (facet joints, sacroiliac joint, and piriformis muscles), had no other structural abnormality seen on MRI or CT scan to explain their pain other than DDD (discogenic pain source), had failed all reasonable nonoperative treatment as described above and their pain localized topographically on physical exam to the region of DDD. If there was still any uncertainty after the above criteria had been met, an evocative discogram was used to confirm the pain generator(s) to be one or more of the degenerated discs seen on MRI or CT scan. The key point is that fusion was only performed for debilitating, chronic painful lumbar discs that failed to improve with conservative management after other nonsurgical sources of pain (inflamed facet joints, inflamed sacroiliac joints, injured piriformis muscles, vertebral body fractures, kidney stones, tumor, and infections other nonspinal causes of back pain) had been ruled out first. Psychological testing or psychoanalysis should be considered in selected patients based on a history of significant stressors such as abuse or malingering or secondary gain.

Bilateral facetectomy was performed for the following reasons: To allow complete decompression of the foramen and lateral recess at each stenotic segment; to allow correction of any deformity present at the segment including kyphosis, scoliosis, and listhesis if they were present; allow unobstructed view of the pedicle and exiting nerve root for optimal segmental pedicle screw placement and to remove abnormal hypertrophied facet and capsule contributing to deformity and stenosis. The segments treated were unstable to begin with which is why they were painful under normal physiological loads. The most universally accepted definition of spinal instability is by White and Panjabi who defined instability of the spine as "the loss of the spine's ability to maintain its patterns of displacement under the physiologic loads so there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain." (A.A. White, M.M. Panjabi [Eds.], Clinical biomechanics of the spine, 2nd ed., JB Lippincott, Philadelphia, PA, 1990.) All of the patients in this fusion study met White and Panjabi's criteria for segmental instability resulting in incapacitating pain. The incapacitating pain is the symptom of instability targeted and successfully treated (84% resolved) in this study cohort with fusion.

The authors acknowledge the ideal study to compare the effect of different treatment strategies in a specific population is a randomized double-blinded prospective cohort study; however, this type of study is nearly impossible to perform when comparing spinal surgical outcomes as evidenced by the extreme paucity of such studies available to the massive body of peer-reviewed literature. The most common studies published are retrospective to evaluate the effectiveness of a given intervention. The authors felt it would be unethical to perform "sham" surgeries on the "control" group.

We believe our excellent results were due to a combination of a highly selective patient and operative level selection algorithm combined with optimal surgical technique. All of the patients treated surgically had debilitating chronic spinal pain originating from one or more degenerated lumbar intervertebral discs. All study patients first failed high quality interventional and rehabilitative care before they were selected for fusion. We treated all symptomatic degenerated discs in the region of

the patient's back pain (topography); hence, we did not limit our treatment to only a single degenerated disc when it was surrounded by other painful degenerated discs. If 3 discs are painful and only one is fused poor results are expected. The surgeon must fuse all painful discs to eliminate pain. In this study we fused an average of 2.4 symptomatic (painful) degenerated discs per patient. Surgical success is predicated on ensuring proper treatment of all diseased levels. Finally, we believe the transforaminal lumbar interbody fusion procedure with removal of abnormal facet joints, using the largest interbody cage that can be fit into the disc space, using the largest diameter pedicle screws, always performing a wide foraminal and lateral recess decompression when stenosis is present and always using a Jackson spinal table are essential elements of success. We believe most failures are due to nonadherence to these key strategies we have presented here.

All of the patients fused in this study had discogenic back pain. Discogenic back pain is pain originating specifically within the spinal disc itself. The intervertebral disc is known to have somatic afferent (conscious pain) fibers innervating the posterior annulus fibrosus. It is our view these pain fibers are the source of discogenic back and neck pain. Recent studies confirm these facts. The authors believe chronic inflammation within the posterolateral annular tears of symptomatic degenerated discs is the source of discogenic back and neck pain. Fusing the painful segment(s) allows the tears to heal and inflammation within the outer annular tears to subside. Fusing only one painful disc and leaving the adjacent painful disc(s) untreated will result in ongoing back pain from the untreated painful disc(s). In our opinion, this is likely the cause of poor results seen in other fusion series for painful disc disease. All painful disc levels must be treated with the initial surgery, or the patients will continue to have pain.

In summary, we are not proposing a "new" disease category for treatment. We are recommending surgically treating medically refractory discogenic pain. Discogenic pain originates from degenerated spinal discs and was first described by Cloward in the 1960's. There are 845 peer reviewed publications in PubMed found with the search term "discogenic pain" and most of them confirm the presence of the spinal disc as being the source of chronic back pain. We are not advocating surgical treatment of nonspecific back pain. We are advocating treatment of pain that has an anatomical source. The source of pain we are advocating treatment for is the painful spinal discs which do not heal on their own. The concept of treating painful lesions in the human body is by no means "new." Painful joints have been treated for "pain" and loss of movement for over 100 years and continue to be problematic throughout the world. As our population ages we will see more and more painful joint diseases that needs treatment to improve the quality of life and maintain the independence for our patients. It is our sole responsibility as physicians to care for the medical and surgical needs of our patients especially under the circumstances where progress is called for. The successful treatment of debilitating back pain is within our grasp but we must act if we are to help our patients.

All too often we have encountered patients in our clinics with debilitating pain who have been told by others that their pain exists only in their head and they needs psychiatric help. We proposed that in the vast majority of these patients there is an organic basis of their symptoms and it can be found in physiologically abnormal joints and muscles. The best treatment will be a comprehensive approach to their pain that includes a psychiatric component that addresses their concomitant mood disorder but does not ignore the anatomical basis of their pain.

CONCLUSION

Lumbar fusion for symptomatic DDD can be a safe and effective treatment for medically refractory LBP with or without leg pain. In this study, patients undergoing lumbar fusion for LBP from DDD had 84% and 90% resolution of their preoperative back and leg pain respectively with an average follow-up of 1.5 years and only a 5% complication rate.

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Conflicts of interest
There are no conflicts of interest.

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