Clinical Study

Radiographic fusion rate after implantation of facet bone dowels

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Received 20 August 2013; revised 5 November 2013; accepted 30 December 2013

Abstract

BACKGROUND CONTEXT: Achieving a posterolateral fusion in conjunction with performing decompressive laminectomies can prevent recurrence of stenosis or worsening of spondylolisthesis. Facet bone dowels have been introduced and marketed as a less invasive alternative to pedicle screws. Surgeons have been placing them during lumbar laminectomy surgery and coding for intervertebral biomechanical device and posterolateral fusion. These bone dowels have also been placed percutaneously in outpatient surgery centers and pain clinics for facet-mediated back pain.

PURPOSE: To describe fusion outcomes in patients who underwent facet bone dowel placement.

STUDY DESIGN/SETTING: Retrospective analysis of a single center’s experience.

PATIENT SAMPLE: Ninety-six patients comprise the entire cohort of patients who underwent facet bone dowel implantation at our institution with adequate postoperative imaging to determine fusion status.

OUTCOME MEASURES: Fusion rates as determined on postoperative computed tomography (CT) scans and dynamic lumbar X-rays if CT is not available.

METHODS: Threaded facet bone dowels in this study were placed according to the manufacturer’s recommended methods. The bone dowels were placed after open exploration of the facet complex or percutaneously through a tubular retractor on the contralateral side from a microdiscectomy or synovial cyst resection. The most recent available postoperative imaging was reviewed to determine fusion status.

RESULTS: Of 96 patients in our series, 6 (6.3\%) had a fusion seen on CT and 4 did not exhibit any movement on dynamic lumbar X-rays for a total fusion rate of 10.4\% (10/96). Eighty-six (89.6\%) patients were shown on imaging to not have a solid fusion either by visualizing a patent facet joint on CT or measurable movement between the flexion and the extension lumbar X-rays.

CONCLUSIONS: This article is mainly intended to question whether the implantation of facet bone dowels can produce a solid fusion radiographically. In our experience, the placement of facet bone dowels does not equal the time, skill, or attention to detail that is necessary for a posterolateral lumbar arthrodesis, and our follow-up radiographic studies clearly demonstrate an inadequate fusion rate. © 2014 Elsevier Inc. All rights reserved.

Keywords: Spinal fusion; Facet fusion; Threaded bone dowel; Posterolateral fusion; Facet bone dowel; Bone dowel

FDA device/drug status: Approved (NuFix facet bone dowels [NuTech Spine, Inc.]).

Author disclosures: SMP: Nothing to disclose. EWN: Royalties: Globus Spine (C), Globus Spine (C, Paid directly to institution); Consulting: Depuy/Synthes (B); Speaking/Teaching Arrangements: Depuy/Synthes (B), BrainLAB (B), Medtronic Navigation (B); Scientific Advisory Board/Other Office: K2M Spine (B), Medtronic Navigation (B). GR: Nothing to disclose. HGD: Nothing to disclose. RR: Nothing to disclose. REW: Nothing to disclose.

1529-9430/$ - see front matter © 2014 Elsevier Inc. All rights reserved. http://dx.doi.org/10.1016/j.spinee.2013.12.027

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com. The authors did not receive any funding in the preparation of the manuscript and do not report any conflicts of interest.

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Introduction

The surgical care of the degenerated lumbar spine is becoming increasingly less invasive. Payers and hospitals desire shorter length of stay for their patients, and likewise, patients appreciate procedures that allow for a quicker return to activities with less blood loss. One technology that offers a less invasive method to obtain spinal fixation in hopes of achieving a fusion is the implantation of small, machined bone dowels into the lumbar facet joints. These bone dowels can either be placed percutaneously through a tiny stab incision or as an adjunct to open surgery with a decompressive laminectomy. In either case, the actual time and additional blood loss required to properly place the bone dowels are minimal.

Companies have noted this technology and have touted its benefits for the patients and the facilities implanting them because of shorter operative times with less blood loss [1,2].

In 2008, reports made the following claims: “The US facet fixation market, comprising facet screws, bolts, and allograft dowels generated revenues of $34.9 million in 2007. The US facet fixation market is projected to experience rapid growth, with market expansion largely concentrated in 2008 through 2012 and projected to be a stand-alone market segment worth $385 million by 2012. Collectively, new facet fixation technologies will successfully cannibalize cases that would have been previously treated with pedicle screws, such as grade 1 and 2 spondylolisthesis” [3].

The implantation of facet bone dowels has been coded as a posterior spinal fusion procedure. However, the fusion rates achieved by the procedure may not appropriately justify the credit given to the surgeons and facilities as an arthrodesis. High-quality data regarding the actual fusion rates are lacking.

Materials and methods

One hundred and forty-nine patients underwent implantation of NuFix cylindrical threaded facet bone dowels (Nu-Tech, Birmingham, AL, USA) by five neurosurgeons at our institution (information blinded) from April 2008 to May 2011. A representative of the company was present during most (~90%) of the surgical procedures to ensure that the implantation was compliant with the company’s instructions. The implantation of the bone dowels was carried out by using a custom set of insertion tools supplied by the company. Steps included using a “facet finder” oriented in the craniocaudal plane and mallet to enter the facet joint, passing a cannula over the facet finder, and then using a guarded hand-held drill to create the space followed by tamping of the machined, cylindrical threaded bone dowel into position. For open cases, the surgeon was able to immediately gain visual feedback in seeing the facet joint splayed open by the facet finder and then tactile feedback by noting the joint being stabilized after the bone dowel was implanted snugly into position. For percutaneous cases, these steps were performed with assistance by anteroposterior, oblique, and lateral fluoroscopy and a K wire to hold the intended position in the joint. The decision to place...
the dowels before or after lumbar decompression was variable between surgeons according to the patient condition. Institutional review board approval was obtained for this retrospective study (Institutional Review Board ID: 12-007425). This study is intended to report on fusion status through the operated facet joints and not on other patient outcomes. A retrospective review of the Neurosurgery Department database identified all patients who underwent implantation of facet bone dowels. These patients’ charts were reviewed to determine whether they had postoperative computed tomography (CT) scans present on the institution’s digital radiology archive (information blinded). Imaging can be viewed on the archive whether the images were acquired in an internal institutional (information blinded) facility or digitally loaded into the archive from an external facility via CD, DVD, or flash drive. Obtaining postoperative CT scans to assess fusion status is not routine for all the surgeons.

This study reports the fusion status as judged by bridging the trabecular bone through the facet joints on the most recent CT. Patients who have had dynamic lumbar X-rays only were also reviewed. The flexion versus extension X-rays were evaluated for the distance between the anterosuperior corner of the lower vertebral body and the corresponding posteroinferior corner of the upper vertebral body and the posterosuperior corner of the vertebral body of the lower vertebral body and the corresponding posteroinferior corner of the upper vertebral body. The angle between the end plates of the operative level was also measured. Fusion criteria, based on dynamic films, included the demonstration of less than 1 mm of translation, less than 2° of angulation, and no further subluxation compared with the preoperative X-rays. Fusion criteria for CT-based studies included a lack of bony lucency, the presence of bony trabeculation and/or continuity of bone between the transverse processes, and/or facet fusion [4]. Fifty-three patients who had no postoperative imaging or only X-ray imaging within 6 months of bone dowel implantation were removed from the study, leaving a sample size of 96 patients for all further calculations.

Patient demographics are displayed in Table 1, including age, gender, number of implanted levels per patient, and radiographic indications for surgery as listed in the operative report.

Results

The imaging follow-up data are provided in Table 2 and also displayed as a flowchart in Fig. 1. Fifty-three patients either did not have any follow-up CT or only had dynamic X-ray imaging less than 6 months postoperatively. These patients were removed from the study because of inadequate imaging. Twenty-eight patients had lumbar flexion, extension, and oblique X-rays only. Sixty-eight patients had postoperative CT scans. The average postoperative time for CT follow-up is 12.6 months.

The fusion status data are provided in Table 3, which is graphically displayed in Fig. 2. Ninety-six (96/149 = 64.4%) patients with adequate follow-up imaging serve as the basis for our patient population. There were six (6/96 = 6.3%) patients with definite fusions with bridging bone through the facet joints noted on CT. Included in these six patients counted as a fusion are three patients whose fusions were

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**Table 2**

<table>
<thead>
<tr>
<th>Type of imaging</th>
<th>Number (% of total)</th>
</tr>
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<tbody>
<tr>
<td>X-rays with flexion and extension (mean 13.9 mo)</td>
<td>28 (29.2)</td>
</tr>
<tr>
<td>Less than 12 mo</td>
<td>10</td>
</tr>
<tr>
<td>13–24 mo</td>
<td>11</td>
</tr>
<tr>
<td>Greater than 24 mo</td>
<td>7</td>
</tr>
<tr>
<td>CT (mean 12.6 mo)</td>
<td>68 (70.8)</td>
</tr>
<tr>
<td>Less than 6 mo</td>
<td>30</td>
</tr>
<tr>
<td>7–12 mo</td>
<td>12</td>
</tr>
<tr>
<td>13–24 mo</td>
<td>13</td>
</tr>
<tr>
<td>Greater than 24 mo</td>
<td>13</td>
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</tbody>
</table>

CT, computed tomography.

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**Fig. 1.** Flowchart showing the follow-up imaging studies that were used to obtain the fusion status data.
noted on CT abdomen and pelvis (Fig. 3). These images did not include three-dimensional reconstructions or zooming into the spine. Two of the patients included in the fusion group healed a solid fusion at only a single level and could be classified as “incomplete fusion” by more discriminating reviewers (Fig. 4). Another patient in the fusion group showed a unilateral arthrodesis but not through the contralateral facet joint and could also be considered an incomplete fusion. Four (4/96 = 4.2%) other patients are considered “likely fusion” because no angular or translational movement was noted on dynamic lumbar X-rays at 12 and 24 months, respectively (Fig. 5). This leaves a total of 86 (86/96 = 89.6%) patients who definitely did not have a fusion identified at any level (Figs. 6 and 7).

The fusion rate per levels implanted was calculated for the patients who had CT imaging. These data are displayed in Table 4 and Fig. 8. In these 68 patients, a total of 103 levels of bone dowel implants were placed. In the 6 patients with “definite fusion,” 9 of 13 implanted levels in these patients were visibly fused on scans. That gives an overall fusion rate per level of (9/103) 8.7%. For the 38 patients with CT imaging greater than 6 months postoperatively, the fusion rate per level is (9/59) 15.3%. For the 26 patients with CT imaging greater than 12 months postoperatively, the fusion rate per level is (9/41) 22.0%. For the 13 patients with CT imaging greater than 25 months postoperatively, the fusion rate per level is (9/20) 45.0%. The assumption is that all of the nine fused levels healed before

<table>
<thead>
<tr>
<th>Fusion status</th>
<th>Number (%)</th>
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<tbody>
<tr>
<td>&quot;Definite fusion&quot; seen on CT</td>
<td>6 (6.3)</td>
</tr>
<tr>
<td>&quot;Likely fusion&quot; based on dynamic X-ray</td>
<td>4 (4.1)</td>
</tr>
<tr>
<td>&quot;Nonfusion&quot;</td>
<td>86 (89.6)</td>
</tr>
<tr>
<td>&quot;Indeterminant&quot; (removed from fusion calculations)</td>
<td>53 (35.6 of total 149)</td>
</tr>
<tr>
<td>No imaging</td>
<td>48</td>
</tr>
<tr>
<td>Flexion/extension X-ray &lt; 6 mo postoperatively</td>
<td>5</td>
</tr>
</tbody>
</table>

CT, computed tomography.
6 months and remained solid throughout the duration of the study. As mentioned in the “Materials and methods” section, we only evaluated the patients’ most recent imaging studies.

Of these six CT-proven fusion patients, three had usage of INFUSE rhBMP-2 (Medtronic, Memphis, TN, USA) in a Federal Drug Administration off-label fashion to help heal the arthrodesis. Their results are summarized subsequently. Four patients overall had INFUSE placed during surgery, three fused, and one had no follow-up imaging. Dosing of INFUSE bone morphogenic protein (BMP) included one patient with a small kit (4.2 mg), one patient with a medium kit (8.4 mg), and two patients with large kits (12 mg). One of the patients who had a large kit implanted developed a large postoperative seroma that required operative debridement followed by sepsis because of methicillin-resistant Staphylococcus aureus. This patient did not have follow-up imaging beyond 3 months and therefore was not included in the analysis. The other patient who received a large kit of INFUSE had a fusion noted on CT at one of the three implanted levels and also fused at the level below the surgical implants. This patient did not have satisfactory pain relief, had progression of scoliosis, and chose to participate in a multidisciplinary pain rehabilitation program with cognitive teaching and biofeedback rather than undergo further surgery that was offered. This patient was included in the definite fusion group. The other two patients who fused had their arthrodesis documented by CT. The patient who received the medium kit did have hypertrophic bone formation ventrally through the facet joint causing recurrent foraminal stenosis.

Several patients required further spinal procedures because of continued or recurrent pain at the level of implanted facet bone dowels. Thirty-four (34/96 = 35.4%) of the patients had documented further procedures performed at the level(s) of the implanted bone dowels. Thirteen (13/96 = 13.5%) had another surgery, including instrumented fusions to correct a structural anatomic issue. Twenty-six (21/96 = 21.9%) underwent further procedures in the pain clinic, including facet injections, rhizotomies, spinal cord stimulators, and intrathecal narcotic medication pumps.

Fig. 5. Preoperative (Left) lateral X-ray along with 24-month postoperative flexion (Middle) and extension (Right) X-rays. The patient has developed a Grade 1 anterolisthesis at the operative level (L4–L5), but the measured difference in angulation is only 1°, and the translation is less than 1 mm. Therefore, this was counted in the “likely fusion” group.

Fig. 6. Dynamic X-rays showing some angular and translational movements between the flexion (Left) and extension (Right) views. The official radiology report stated “no dynamic instability,” but a solid fusion is not present because of measured movement (6° on flexion, 16° on extension, and 2 mm translation).

Fig. 7. Axial lumbar computed tomography showing splayed facet joints and bilateral bone dowel extrusion noted at 1 month postoperatively.
Table 4
Fusion rate per level of implant (based on CT imaging), nine levels have fused

<table>
<thead>
<tr>
<th>Timing of postoperative imaging</th>
<th>Fusion rate per implanted level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>9/103 = 8.7%</td>
</tr>
<tr>
<td>&gt;6 mo</td>
<td>9/59 = 15.3%</td>
</tr>
<tr>
<td>&gt;12 mo</td>
<td>9/44 = 22%</td>
</tr>
<tr>
<td>&gt;24 mo</td>
<td>9/20 = 45%</td>
</tr>
</tbody>
</table>

CT, computed tomography.

The characteristics of the patients who fused are documented in the Appendix 1 and summarized in Table 5. The six definite fusion patients and four “likely fusion” patients are listed with their demographic information and findings on preoperative and postoperative imaging studies. We did not note a significant difference in the height of the intervertebral discs compared with the adjacent levels. Eight of the 10 overall patients were women, which differs from the overall population of patients in our series. Three of the patients who had been given INFUSE BMP are described previously.

Three authors reviewed all of the imaging studies. One of the reviewers was an independent neurosurgeon who was not previously involved with the study. One reported 7 fusions, 1 reported 10 fusions, and 1 reported 13 fusions. After further discussion, all 3 agreed on the 10 patients who are most likely to have fused at least 1 level of implanted bone dowels. These patients are described in Appendix 1.

Discussion

One relatively recent addition to the spine surgeon’s and interventional pain physician’s armamentarium is the placement of facet bone dowels to stabilize and potentially allow fusion across the arthritic joints. These bone dowels can be placed for a variety of indications, including isolated facet-based symptomatic back pain that is refractory to conservative measures, stabilization of the lumbar spine after decompressive procedures or where minor instability exists or presents postoperatively, minor instability (1–2 mm listhesis), posterior supplemental fixation to interbody fusion, or adjunct to motion-limiting devices.

There has been some confusion regarding the correct coding for these procedures. The American Association of Neurological Surgeons has recommended that the proper coding for the placement of facet bone dowels is an “unlisted spinal procedure” code or a structural allograft code [5]. Several companies continue to market the procedure as a minimally invasive method to achieve fusion across painful facet joints [6–9]. When performing a simple Internet search on Google for “facet bone dowel coding,” there are Web sites and blogs that continue to recommend coding fusions for facet bone dowel implantation [10]. This contrasts with the 2011 current procedural terminology updates that do not recommend 22851 coding for threaded facet bone dowels but rather suggest they would be more appropriately coded as a structural bone allograft [11]. This also contrasts with the 2012 CPT updates which state that procedures that code for 22612 should include the lateral transverse technique [12], which is not a part of a purely percutaneous facet bone dowel implantation.

Facet bone dowels are cortical allograft tissues and are regulated only under code of federal regulations 1,271, a Class 1 substance. There is no additional Federal Drug Administration clearance necessary [1]. They are being marketed as a minimally invasive lumbar fusion procedure or as a quick addition to a lumbar laminectomy procedure [1,13,14]. The radiographic results in this case series would argue against coding these procedures as fusions.

The fusion rates after placement of these facet bone dowels in our experience is quite low. Applying liberal fusion success by including the patients who have fused one level but not the others into the “fusion” group still does not provide an adequate definite fusion rate (6/96 = 6.3%). Including the likely fusions that do not have CT evidence of fusion into the fusion group only raises the rate to (10/96) 10.4%. If we eliminate all patients with less than 12 months of imaging follow-up, the likely fusion rate is (10/51)

![Image](Fig. 8. Chart showing the fusion rate per level of implanted bone dowels in the patients who had postoperative computed tomography (CT) imaging.)
19.6%. If we eliminate all patients with less than 24 months of imaging follow-up and assume the fusions remain solid, the likely fusion rate is (10/20) 50%. If fusion evaluation only used CTs, the fusion rates are (6/26) 23.1% for studies 13 months or greater postoperatively or (6/13) 46.2% for studies 25 months or greater postoperatively.

When calculating the fusion rate per level based on CT imaging, the rate is (9/103) 8.7%, which improves to (9/20) 45% when only counting patients with CTs greater than 24 months postoperatively.

A poster presentation at the 2012 Congress of Neurological Surgeons meeting reported on 41 patients who were compared with those found in a literature-based pedicle screw fusion cohort. The bone dowel fusion patients had a 95% dynamic stability rate, and 100% of them had signs of early fusion. This study showed that TruFuse bone dowel implantation compared favorably with pedicle screw placement in terms of decreased blood loss, operative time, and length of stay. The reported subjective patient outcomes were 80% "excellent" or "somewhat improved," 10% "unchanged," and 10% "worse" [15]. These radiographic results differ from our results. Our series used CTs as the best judge of a radiographic arthrodesis. The statement "no dynamic instability" does not equal fusion, as the vast majority of patients in our study had a similar statement in the radiology report; yet, calculations did not reveal a solid fusion (Fig. 6).


The authors acknowledge several weaknesses of this study in addition to its retrospective design. At the outset of using this technology in our practice, we did not plan to formally study or attempt to publish our results. The decision to review all of our data occurred after realizing that the technique may not have been accomplishing our goals. There was not uniformity in the operative techniques because the bone dowels were placed by different surgeons, and there was also single-surgeon variability. Much of this variability was caused by noting the lack of arthrodesis in previous patients, and attempts were made to improve the fusion rate. Also, our center only implanted the NuFix bone dowels. The authors understand that these bone dowels are made by different companies and each have special patents related to their size, shape, coating, and method of implantation, including the NuFixII updated facet bone dowels made by NuFix. Another weakness is the incomplete radiographic follow-up. Obtaining postoperative CTs is not routine for all partners in our practice, and there is variability in the reported imaging. Computed tomography, rather than flexion-extension X-ray, is used as our standard for determining arthrodesis; however, this point has been debated in the literature [16–21]. We understand that there may be a bias toward patients with continued pain getting CTs during workup for the postoperative pain generator and finding a lack of fusion. Meanwhile, the patients who are doing well may not have had any indication for further imaging except for routine surveillance. The determination of fusion based on dynamic X-rays is not consistent in the literature with some studies still counting fusions despite some movement on the X-rays (up to 15% translation) and others only counting fusion if there is no movement [4,22]. The fusion status was graded by surgeons rather than independent radiologists, and the stricter dynamic X-ray criteria of no movement and less than 2° of angulation allowed were applied for those patients who did not have CTs. As per our institutional review board approval process, we did not make an attempt to contact the patients in hopes of obtaining CTs for those who have not had one. Many patients in the series did not have adequate long-term radiologic follow-up and were removed from the calculations. However, if all 53 patients who were excluded from the final analysis actually fused, then the overall fusion rate would only be (63/149) 42.3% (Fig. 9).

This article is not intended to discuss the clinical efficacy of facet bone dowels, indications for their placement, or their biomechanics. Most patients initially improved postoperatively, but objective standardized outcome data

Table 5

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noted on CT abdomen/pelvis</td>
<td>3 out of 6</td>
</tr>
<tr>
<td>BMP applied (not an FDA-approved indication)</td>
<td>3 out of 6</td>
</tr>
<tr>
<td>Incomplete (not all levels or only unilateral facet fusion)</td>
<td>3 out of 6</td>
</tr>
<tr>
<td>Number of levels fused in the definitely fused patients</td>
<td>9 out of 13</td>
</tr>
<tr>
<td>Number of definitely fused levels that are unilaterally fused</td>
<td>5 out of 9</td>
</tr>
<tr>
<td>Number of definitely fused levels that are bilaterally fused</td>
<td>4 out of 9</td>
</tr>
</tbody>
</table>

BMP, bone morphogenetic protein; CT, computed tomography; FDA, Federal Drug Administration.
were not collected. There was not a plan to study outcomes prospectively at the outset of our implantations. This article is meant to add some data for evaluation of fusion efficacy after facet bone dowel placement and may be included in a meta-analysis with a higher volume center.

Conclusions

This article is mainly intended to question whether the implantation of facet bone dowels can produce a solid fusion radiographically and to report our outcomes. In our experience, the placement of facet bone dowels does not equal the time, skill, or attention to detail that is necessary for a posterolateral lumbar arthrodesis, and our follow-up radiographic studies clearly demonstrate an inadequate fusion rate. Secondary points to be considered from this article include the appropriateness of coding for an arthrodesis with simple facet bone dowel placement.

Acknowledgments

The authors would like to thank Victoria L. Jackson, MLIS (Academic and Research Support, Mayo Clinic, Jacksonville, FL, USA) for her editorial support in the preparation of the manuscript.

References


Appendix

Characteristics of the patients who fused (based on CT)

65-Year-old woman

BMP (large kit) used.

Three levels of laminectomies and bone dowels L2–L5.

No preoperative flexion-extension: six lumbar type vertebra—operative note terminology states lumbosacral junction at L5–S1; so, this is the nomenclature we proceeded with.

Flexion-extension at 25 months: no subluxation, no angular changes at L2–L3 and L5–S1, 4° at L3–L4, and 8° at L4–L5.

Computed tomography at 25 months: L2–L3 fused on right joint but not on left and had progression of lateral lysis, disc height further collapsed from 4.2 to 2.7 mm as measured on CT, L3–L4 incompletely fused and developed
a 12.5° curve (was straight preoperatively), and L4–L5 incompletely fused.

L5–S1 (no bone dowels) solid facet fusion.

Scoliosis progressed, and patient was referred to a comprehensive, multidisciplinary pain rehabilitation program.

**77-Year-old woman**

BMP (medium kit) used.

Two levels of laminectomies and bone dowels were placed from L3 to L5.

Preoperative magnetic resonance imaging (MRI) revealed mildly decreased disc height at the operative levels with 8.2 and 5.6 mm heights measured on sagittal MRI at the operative levels and 11.3 mm height at the adjacent L2–L3 level.

Preoperative flexion-extension did not show any measurable angular changes or subluxation.

Grade 1 spondylolisthesis at L4–L5 unchanged after surgery.

Computed tomography and flexion-extension at 14 months show fusion with bridging bone through the facet joints and no movement on dynamic imaging. Computed tomography also shows hypertrophic bone formation ventral to the facet joint.

**84-Year-old man**

No BMP.

Single-level laminectomy and bone dowels placed at L4–L5.

Relatively preserved disc height at 12.0 mm that mildly decreased to 10.5 mm as measured on coronal CT.

Preoperative flexion-extension did not show subluxation and had angular movement from 11.2° to 13.2° at L4–L5. Postoperative flexion-extension obtained at 3 months had no subluxation and angular movement from 13.5° to 16.3°. Computed tomography obtained at postoperative 5 months did not show any lucency surrounding the bone dowel in the left L4–L5 facet joint, but the right joint remained patent and unfused.

The patient passed away because of multiple medical comorbidities 7 months postoperatively.

**66-Year-old woman**

BMP (small kit) used.

Three levels of laminectomies and bone dowels were placed from L2 to L5 and L2 to L3 synovial cyst at level of previous laminectomy.

Preoperative flexion-extension showed Grade 1 spondylolisthesis at L4–L5 with slight movement from 7.3 to 11.1 mm of subluxation. No angular movement at the other operative levels.

Preoperative disc heights were 7.0 mm at L2–L3, 6.3 mm at L3–L4, and 2.8 mm at L4–L5. The adjacent disc height at L1–L2 was 11.9 mm.

Fusion was noted on CT abdomen and pelvis 11 months postoperatively. Solid fusion with posterolateral bone mass and facet fusion was noted at L3–L4 and L4–L5. No solid fusion was noted at L2–L3.

Flexion-extension at 17 months postoperatively revealed no angular motion at L4–L5, 3° (1.5°–4.5°) of motion at L3–L4, and 4° (4°–8°) of motion at L2–L3. No subluxation at L2–L3 or L4–L5, and stable Grade 1 anterolisthesis (9 mm) at L3–L4 comparing the flexion and extension views.

The fusion was called because of the bridging bone noted on CT.

**86-Year-old woman**

No BMP.

Two-level laminectomies and bone dowels were placed at L3–L5 (no other decortication or arthrodesis techniques). Preoperative disc heights were 6.7 mm at L3–L4 and 8.6 mm at L4–L5 as measured on sagittal MRI. The adjacent level disc heights were 14 mm at L5–S1 and 5.3 mm at L2–L3.

Preoperative flexion-extension showed angular change from 4.1° to 5.4° at L4–L5 and 2.5° to 2.9° at L3–L4.

Fusion noted on CT abdomen/pelvis at 21 months postoperatively—possibly bilaterally L3–L4 and definitely left L4–L5, but right L4–L5 is clearly not fused (spontaneous L5–S1 facet fusion noted).

No postoperative flexion-extension X-rays.

**77-Year-old man**

No BMP.

Two levels of bone dowels were placed at L3–L5 and L3–L4 laminectomies (previous L4–L5 laminectomy). Preoperative disc heights were 9.5 mm at L3–L4 and 6.9 mm at L4–L5 with the adjacent levels measured at 7.1 mm at both L2–L3 and L5–S1.

Preoperative flexion-extension showed Grade 1 L4–L5 anterolisthesis that increased to 9.8 mm on flexion and decreased to 4.9 mm on extension. Angulation minimally changed at L3–L4 from 5.1° to 5.7° and at L4–L5 from 1.8° to 2.0°.

No postoperative flexion-extension X-rays.

Fusion was called on CT abdomen/pelvis at L4–L5 but no clearly bridging bone. However, no clearly patent facet joints bilaterally. Left L3–L4 facet joint is definitely not fused, and the right is possibly fused.

**Characteristics of the patients who likely fused (no CTs)**

**51-Year-old woman**

No BMP.

One level of bone dowels—right L5–S1 hemilaminectomy and discectomy (dural tear).
Preoperative disc heights were 7.7 mm at L5–S1 and 9.0 mm at L4–L5 as measured on sagittal MRI.
Preoperative flexion-extension X-ray had a 5.3° to 8.9° change in lordotic angulation and no translation.
Postoperative flexion-extension X-ray at 39 months has 6.0° to 7.2° change in lordotic angulation and no translation.

65-Year-old woman
No BMP.
Two levels of bone dowels: L3–L5 laminectomies and L3–L4 discectomy.
Preoperative disc heights were 5.2 mm at L3–L4, 5.1 mm at L4–L5, and the adjacent L2–L3 was 7.8 mm and L5–S1 was 3.1 mm as measured on sagittal MRI.
Preoperative flexion-extension X-rays had change in lordotic angulation from 0.1° to 0.7° at L4–L5 and 4.1° to 7.3° at L3–L4. There was a slight change of 10.7 to 12.4 mm anterolisthesis at L3–L4 and no translation at L4–L5.
Postoperative flexion-extension X-ray at 24 months revealed no change in translation at 13.8 mm on both views and stable lordotic angulation (4.3°–5.1°).

72-Year-old woman
No BMP.
One level of bone dowels (L4–L5) during L3–L5 laminectomies (L4–L5 was found to be unstable intraoperatively when manipulating the spinous processes) (patient has transitional lumbosacral anatomy).
Preoperative disc heights were 7.5 mm at L3–L4 and 8.6 mm at L4–L5, and the heights at the adjacent levels were 9 mm at L5–S1 and 4.8 mm at L2–L3.
Preoperative flexion-extension X-ray showed no translation and stable lordotic angulation (4.3°–5.1°).
Postoperative flexion-extension X-ray at 12 months showed stable lordotic angulation (3.7°–4.6°) at L4–L5 and no translation.

78-Year-old woman
No BMP.
Two levels of bone dowels during L3–L5 laminectomies.
Preoperative disc heights were 3.8 mm at L4–L5 and 6.3 mm at L3–L4, and the heights at adjacent levels were 8.0 mm at L5–S1 and 5.7 mm at L2–L3.
Preoperative flexion-extension X-ray did not reveal significant translation, and the lordotic angulation slightly changed from 2.1° to 2.3° at L4–L5 and 0.2° to 2.8° at L3–L4.
Postoperative flexion-extension X-ray at 33 months revealed increased lordotic angulation at L3–L4 from 2.4° to 6.4° but stable at L4–L5 (1.5°–2.2°). There was no significant translation. The possible fusion was called at L4–L5 but not likely at L3–L4.
Patient has undergone further treatments in the pain clinic for persistent back pain, including facet injections L3–S1.
The only postoperative CT that has been obtained was at 3 months and did not show a fusion.