Superion Interspinous Spacer Treatment of Moderate Spinal Stenosis: 4-Year Results

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OBJECTIVE: To determine 4-year clinical outcomes in patients with moderate lumbar spinal stenosis treated with minimally invasive stand-alone interspinous process decompression using the Superion device.

METHODS: The 4-year Superion data were extracted from a randomized, controlled Food and Drug Administration investigational device exemption trial. Patients with intermittent neurogenic claudication relieved with back flexion who failed at least 6 months of nonsurgical management were enrolled. Outcomes included Zurich Claudication Questionnaire (ZCQ) symptom severity (ss), physical function (pf) and patient satisfaction (ps) subdomains, leg and back pain visual analog scale (VAS), and Oswestry Disability Index (ODI). At 4-year follow-up, 89 of the 122 patients (73%) provided complete clinical outcome evaluations.

RESULTS: At 4 years after index procedure, 75 of 89 patients with Superion (84.3%) demonstrated clinical success on at least 2 of 3 ZCQ domains. Individual component responder rates were 83% (74/89), 79% (70/89), and 87% (77/89) for ZCQss, ZCQpf, and ZCQps; 78% (67/86) and 66% (57/86) for leg and back pain VAS; and 62% (55/89) for ODI. Patients with Superion also demonstrated percentage improvements over baseline of 41%, 40%, 73%, 69%, and 61% for ZCQss, ZCQpf, leg pain VAS, back pain VAS, and ODI. Within-group effect sizes all were classified as very large (>1.0): 1.49, 1.65, 1.42, 1.12, and 1.46 for ZCQss, ZCQpf, leg pain VAS, back pain VAS, and ODI.

CONCLUSIONS: Minimally invasive implantation of the Superion device provides long-term, durable relief of symptoms of intermittent neurogenic claudication for patients with moderate lumbar spinal stenosis.

INTRODUCTION

Lumbar spinal stenosis is an increasingly common disorder affecting the aging population with patients experiencing reduced mobility and chronic leg and back pain.¹ Decompressive laminectomy is considered the gold standard surgical treatment when conservative options are exhausted.² Direct surgical decompression of the neural structures with laminectomy has been shown to offer superior clinical benefit compared with continued nonoperative care; however, the procedure is not without risks. For example, laminectomy is routinely performed under general anesthesia. Although anesthesia-related morbidity and mortality are rare, the incidence of adverse events is markedly higher among the oldest age groups.³ In studies that directly compared general anesthesia with monitored anesthesia care for the same surgical procedure, mortality was greater and perioperative complications were consistently worse with general anesthesia.⁴,⁵

As an alternative, interspinous process decompression is a minimally invasive procedure that builds on the concept that back extension is a seminal factor in the causative chain that instigates neurogenic claudication, the cardinal symptom of lumbar spinal stenosis. This procedure involves the implantation of a stand-alone interspinous spacer that functions by serving as a lumbar...
vertebral joint extension blocker to prevent compression of neural elements in extension. The spacer blocks the extension motion without exposure or removal of tissue adjacent to the dura mater or exiting nerves. The implantation procedure does not cause substantial alterations or disruptions to the spinal anatomy adjacent to neural structures. Specifically, the epidural space is not surgically exposed during spacer insertion, whereas laminectomy decompression directly opens the epidural space. The surgical exposure of the epidural space puts the dura mater at risk of injury, and it is known to routinely produce epidural scar, adhesions, and tethering around the dural sac and exiting nerve roots, which can cause symptomatic problems.\(^5\)\(^6\)

The Superion is the second “stand-alone” interspinous spacer approved by the U.S. Food and Drug Administration (FDA) and the only device currently available on the U.S. market. The Superion is the only spacer to receive approval from the Centers for Medicare and Medicaid Services for use in surgical procedures in ambulatory surgery centers under monitored care anesthesia. This article reports the 4-year clinical outcomes from the Superion arm of a multicenter, randomized controlled FDA investigational device exemption noninferiority trial of interspinous spacer treatment for moderate lumbar spinal stenosis.

**MATERIALS AND METHODS**

This study was approved by the institutional review board at each participating site, and patients provided written informed consent before any study-related procedures were performed. The trial was prospectively registered at ClinicalTrials.gov (ClinicalTrials.gov Identifier NCT00692276). The 4-year Superion clinical outcomes were extracted from an FDA investigational device exemption trial comparing 2 interspinous spacers: Superion (VertiFlex, Inc., Carlsbad, California, USA) and X-STOP (Medtronic, Minneapolis, Minnesota, USA). The study methodology, including eligibility criteria, randomization methods, sample size estimates, outcome measures, and statistical analyses, has been detailed previously.\(^10\)\(^11\)

Briefly, this investigational device exemption trial evaluated the use of interspinous process decompression in the treatment of subjects ≥45 years old with moderate symptoms of intermittent neurogenic claudication secondary to a confirmed diagnosis of moderate degenerative lumbar spinal stenosis at 1 or 2 contiguous levels from L1 to L5. Patients were treated between June 2008 and December 2011 at 31 investigational sites. The randomized study group comprised 391 subjects, including 190 Superion subjects and 201 X-STOP control subjects.

The comparative postoperative findings of the Superion and X-STOP spacers have been reported previously at 6 months,\(^12\) 2 years,\(^13\) and 3 years.\(^14\) The 2-year clinical outcomes establishing noninferiority provided the basis for FDA regulatory approval for the Superion on May 20, 2015.\(^10\) Concurrently in 2015, the X-STOP was withdrawn from commercial distribution in the United States. Owing to this lack of physician and patient availability, we restricted our current analysis to report only the Superion arm of the trial at the 4-year follow-up interval.

The Superion is indicated to treat skeletally mature patients experiencing pain, numbness, or cramping in the legs (intermittent neurogenic claudication) secondary to a diagnosis of moderate degenerative lumbar spinal stenosis, with or without grade 1 spondylolisthesis, confirmed by x-ray, magnetic resonance imaging, or computed tomography evidence of thickened ligamentum flavum, narrowed lateral recess, or central canal or foraminal narrowing. The Superion is indicated for patients with impaired physical function who experience relief in flexion from symptoms of leg, buttock, or groin pain, numbness, or cramping, with or without back pain, and who have undergone at least 6 months of nonoperative treatment.\(^11\) The Superion may be implanted at 1 or 2 adjacent lumbar levels in patients in whom treatment is indicated at no more than 2 levels, from L1 to L5.

For this intended use, moderate degenerative lumbar spinal stenosis is defined as follows:

- 25%–50% reduction in the central canal and/or nerve root canal (subarticular, neuroforaminal) compared with the adjacent levels on radiographic studies, with radiographic confirmation of any one of the following:
  - Evidence of thecal sac and/or cauda equina compression
  - Evidence of nerve root impingement (displacement or compression) by either osseous or nonosseous elements
  - Evidence of hypertrophic facets with canal encroachment

And associated with the following clinical signs:

- Moderately impaired physical function (pf) defined as a score of ≥2.0 on the Zurich Claudication Questionnaire (ZCQ)
- Ability to sit for 50 minutes without pain and to walk ≥50 feet

Of the 190 subjects randomly assigned to receive treatment with Superion, 144 (75.8%) were free from reoperation, revision, or supplemental fixation at their index level at 4 years. Within the group of 46 patients requiring reoperation, 41 patients (89%) had the Superion device explanted. The remaining 159 patients (87.7%) were free from epidural steroid injections or nerve block procedures at 4 years. Of 190 patients, 128 (67.4%) were free from reoperation or steroid injection at 4-year follow-up. There were 6 patient deaths, leaving 122 patients with the Superion intact, with no intervening procedures, and actively participating in the postmarket period of this study. At the 4-year follow-up, 89 of the 122 patients (73%) provided complete clinical outcome evaluations, including the ZCQ, leg and back pain severity by visual analog scale (VAS), and the Oswestry Disability Index (ODI). These patients provide the basis for this report.

Responder rates for each outcome were calculated based on a priori definitions of the minimal clinically important difference: ≥0.5 point change for ZCQ symptom severity (ss) and pf, ≤2.5 points for ZCQ patient satisfaction (ps), ≥20 mm for pain VAS, and ≥15 percentage points for ODI. Additionally, improvement in each outcome measure at 4 years compared with preoperative values was assessed graphically and by computing the percentage improvement.

To gauge the practical clinical significance, we also computed the within-group (i.e., Superion arm only) effect size at the 4-year postoperative interval compared with baseline for each clinical outcome separately using the Cohen formula and thresholds.\(^15\)\(^16\) The effect size is computed as the standardized
difference between 2 means or, simply put, the mean score (preoperative) – mean score (follow-up)/SD of the change. Effect sizes are typically reported in the range from 0.0 (no effect) to >1.0 (very large effects) with the following thresholds: 0.2 (small effect), 0.5 (medium effect), 0.8 (large effect), >1.0 (very large effect). The effect size calculation provides some normalization for baseline and distribution imbalances.

RESULTS

At 4 years after the index procedure, 75 of 89 patients (84.3%) demonstrated clinical success on at least 2 of 3 ZCQ domains. The corresponding individual component responder rates were 83% (74 of 89), 79% (70 of 89), and 87% (77 of 89) for ZCQss, ZCQpf, and ZCQps; 78% (67 of 86) and 66% (57 of 86) for leg and back pain VAS; and 62% (55 of 89) for ODI. Consistently large improvements were also realized at each annual follow-up interval compared with baseline for the ZCQ (Figure 1), leg and back pain VAS (Figure 2), and ODI (Figure 3). Patients with Superion demonstrated percentage improvements over baseline of 41%, 40%, 73%, 69%, and 61% for ZCQss, ZCQpf, leg pain VAS, back pain VAS, and ODI (all \( P < 0.001 \)) (Figure 4). Within-group effect sizes all were classified as very large (i.e., >1.0): 1.49, 1.65, 1.42, 1.12, and 1.46 for ZCQss, ZCQpf, leg pain VAS, back pain VAS, and ODI (all \( P < 0.0001 \)) (Figure 5).

Long-term clinical follow-up information was also provided by 11 additional patients with Superion who had an intervening epidural steroid injection. Including the results of these patients did not measurably affect the overall clinical findings. For example, the responder rates were 82% (82 of 100), 77% (77 of 100), and 85% (85 of 100) for ZCQss, ZCQpf, and ZCQps. Similarly, responder rates were 77% (75 of 97) for leg pain VAS, 67% (65 of 97) for back pain VAS, and 61% (61 of 100) for ODI.

DISCUSSION

The clinical improvements achieved with Superion treatment reported here corroborate published results after 3 years of follow-up and extend the durability to 4 years postoperatively.
For every outcome, within-group effect sizes at 4 years were $>1.0$, representing very large effect sizes that were all highly statistically significant.

Approximately one quarter of patients randomly assigned to Superion treatment underwent a reoperation within the 4-year duration of this study. This reoperation rate is intermediate between recently published results from 2 randomized controlled trials of decompressive laminectomy.\textsuperscript{17,18} Over a follow-up interval similar to the present study, Forsth et al.\textsuperscript{17} reported that 21% of patients underwent revision surgery after decompressive laminectomy in a Swedish trial, whereas Ghogawala et al.\textsuperscript{18} observed a reoperation rate of 34% in a U.S. trial.

Although a freedom from reoperation rate of approximately 76% with Superion compares favorably with direct surgical decompression, the revision procedure itself is notably different between these treatments, with laminectomy requiring wide surgical exposure, dissection of extensive scar tissue with significant blood loss and operative risks, and conversion to fusion necessitating bone grafting and insertion of instrumentation. Alternatively, removal of the Superion can be accomplished with minimal tissue disruption and low surgical risk before conversion to a laminectomy. Thus, the Superion device, with its avoidance of epidural exposure, allows the patient to consider a wider choice of potential reoperations and their timing.

At 4-year follow-up, the patients with Superion are now several years subsequent to achieving the primary FDA trial endpoint at 2 years. Consequently, maintaining compulsory patient adherence to annual outcome reporting becomes increasingly challenging, particularly among individuals who continue to do well clinically. That said, including data from 11 patients who had an intervening epidural steroid injection, we captured complete 4-year clinical outcomes in 100 of 190 Superion-treated patients. In contrast, in the X-STOP pivotal FDA trial, Zucherman et al.\textsuperscript{19} reported a 93% (93 of 100) follow-up rate at the 2-year primary trial endpoint. However, by 4 years postoperatively, patient-reported outcomes were published for only 18 patients (18%).\textsuperscript{20}

CONCLUSIONS

Interspinous spacers fill a distinct gap in the continuum of care for patients with moderate degenerative lumbar spinal stenosis. These patients have exhausted conservative care but may be inappropriate candidates for or unwilling to undergo surgical decompressive laminectomy. Because spacers such as the Superion are implanted in a minimally invasive fashion with relatively minor anatomic disruption, they can be easily removed and converted to a laminectomy if symptoms reemerge. Systematic reviews have found similar clinical benefit provided by both spacers and laminectomy,\textsuperscript{21-23} giving patients a minimally invasive option without compromising symptom relief.

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REFERENCES