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Percutaneous Interspinous Spacer vs Decompression in Patients with Neurogenic Claudication: An Alternative in Selected Patients?

BACKGROUND: Standalone interspinous process devices (IPDs) to treat degenerative lumbar spinal stenosis with neurogenic intermittent claudication (NIC) have shown ambiguous results in the literature.

OBJECTIVE: To show that a minimally invasive percutaneous IPD is safe and noninferior to standalone decompressive surgery (SDS) for patients with degenerative lumbar spinal stenosis with NIC.

METHODS: A multicenter, international, randomized, controlled trial (RCT) was conducted. One hundred sixty-three patients, enrolled at 19 sites, were randomized 1:1 to treatment with IPD or SDS and were followed for 24 mo.

RESULTS: There was significant improvement in Zurich Claudication Questionnaire physical function, as mean percentage change from baseline, for both the IPD and the SDS groups at 12 mo (primary endpoint) and 24 mo (-32.3 ± 32.1, -37.5 ± 22.8; and $-37.9 \pm 21.7\%$, -35.2 ± 22.8, both $P < .001$). IPD treatment was not significantly noninferior (margin: 10%) to SDS treatment at 12 mo ($P = .172$) but was significantly noninferior at 24 mo ($P = .005$). Symptom severity, patient satisfaction, visual analog scale leg pain, and SF-36 improved in both groups over time. IPD showed lower mean surgical time and mean blood loss (24 ± 11 min and 6 ± 11 mL) compared to SDS (70 ± 39 min and 189 ± 148 mL, both $P < .001$). Reoperations at index level occurred in 18.2% of the patients in the IPD group and in 9.3% in the SDS group.

CONCLUSION: Confirming 3 recent RCTs, we could show that IPD as well as open decompression achieve similar results in relieving symptoms of NIC in highly selected patients. However, despite some advantages in secondary outcomes, a higher reoperation rate for IPD is confirmed.

KEY WORDS: Interspinous device, Open decompression surgery, Lumbar spinal stenosis, Randomized controlled trial, Neurogenic intermittent claudication, Degenerative lumbar disease

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The use of interspinous process devices (IPDs) to treat degenerative lumbar spinal stenosis (DLSS) has gone through the usual cycle of most new medical products before solid evidence for their use became available: initial overusage being combined with broad indications for implantation. In addition, most surgeons have not taken into account that the basic design of IPDs differs with respect to their 2 main indications.[1] Some IPDs or interlaminar devices are designed as an adjunct to decompression for "soft" stabilization of minor degenerative instabilities with lumbar stenosis, ie, a replacement for pedicle screws.[2] Other IPDs, such as the one in this trial, are designed as standalone devices to replace open decompression surgery of the spinal canal. They act as a delordosing implant for indirect decompression, mimicking the way patients relieve symptoms by bending over. Level 1 evidence exists with regard to their superiority over conservative treatment.[3]

ABBREVIATIONS: DLSS, degenerative lumbar spinal stenosis; **IPD,** interspinous process device; **NIC,** neurogenic intermittent claudication; **SAE,** serious adverse event; **SDS,** standalone decompressive surgery; **SF-36 v2,** Short Form Generated Health Survey version 2; **VAS,** visual analog scale; **ZCQ,** Zurich Claudication Questionnaire

For the reasons above, the use of IPD has now reached the stage of overwhelming rejection among spine surgeons. This overlooks the possibility of a small window of indication for standalone devices. Recently, the results of 3 randomized clinical trials, overlapping with the recruitment period for the current study, have been published.[4-6] All studies have shown that IPDs are as effective as open decompression in treating neurogenic intermittent claudication (NIC), but with up to 3-fold higher reoperation rates in the IPD cohorts due mainly to "lack of success."

The objective of the current study was to show that a minimally invasive percutaneous IPD is safe and noninferior to standalone decompressive surgery (SDS) with regards to clinical outcomes in patients suffering from DLSS with NIC relieved by flexion.

METHODS

Study Design

The NICE study was a prospective 2-yr, multicenter, international, open label, randomized, controlled, comparative clinical trial designed and conducted in compliance with ISO 14155:2011 and the Declaration of Helsinki. All patients were suffering from DLSS with NIC relieved by flexion. Patients were randomized to treatment with either the minimally invasive percutaneous Aperius PercLID (Medtronic, Dublin, Ireland) system (IPD) or to SDS, the current standard of care. Patients were evaluated at baseline, 14 d, 6 wk, and 6, 12, and 24 mo.

Ethics Approval

The protocol was reviewed and approved by the medical ethics committees of all participating hospitals. Written informed consent was obtained from all participating patients. This study is registered at ClinicalTrials.gov (NCT00905359), and the authors confirm that all ongoing and related trials for this drug/intervention are registered.

Participants

Patients had to provide written informed consent and have at least 6 wk of intermittent NIC due to DLSS at 1 or 2 levels, with symptoms relieved by flexion. DLSS was confirmed by magnetic resonance imaging, and absence of instability by lumbar flexion/extension x-rays. In addition, the visual analog scale (VAS) leg pain score had to be greater or equal to back pain. The following exclusion criteria were applied: previous lumbar surgery, unremitting pain in any spinal position, candidates for instrumented decompressive surgery, back pain without leg pain, degenerative spondylolisthesis > grade 1, spondylolysis, spinous process fracture at any lumbar level, history of osteoporosis, fragility fracture(s), ankylosis at the affected level, fixed motor deficit, symptomatic spinal stenosis at L5-S1 level, symptomatic disc herniation causing radiculopathy at any level between T12-S1, BMI equal to or higher than 40, scoliosis with Cobb angle $\geq 25^{\circ}$, or other spinal deformities.

Eligible patients were randomized to treatment with either IPD (investigational group) or to SDS (control group). Randomization was implemented by the electronic data capture system, with patients allocated to either of the 2 treatment groups via blinded blocks in a 1:1 ratio. There were to be at least 51 analyzable patients per arm (102 in total).

The study was conducted in 19 centers across 10 countries (Australia, Belgium, France, Germany, Iceland, Italy, Poland, Singapore, Sweden, and the United Kingdom).

Interventions

Patients randomized to the IPD group were operated in prone position under general or local anesthesia; no bony decompression was performed in these patients. Under radiographic identification, an incision of approximately 1.5 cm was made, 6 to 10 cm lateral to the midline. Under fluoroscopy, the smallest (8 mm) sharp trocar is introduced and advanced toward the interspinous space, followed by percutaneous insertion of blunt trocars of increasing size. An inserter is then used to achieve correct placement of the implant and actuating deploys wings, which expand on each side of the spinous process, stabilizing the IPD on the midline and working with the intact supraspinous ligaments to keep the IPD in place.[7] Patients in the SDS group were also operated in prone position and decompressed with standard microsurgical procedures according to local practice, ie, laminectomies, bilateral laminotomies, and laminotomies with undercutting.

Outcomes and Assessments

The prespecified primary endpoint was the mean percentage change in physical function from baseline to 1-yr follow-up, obtained by the Zurich Claudication Questionnaire (ZCQ), a patient-reported outcome[8]. Secondary endpoints evaluated the mean percentage change from baseline in ZCQ for other assessed timepoints.

Additional secondary endpoints evaluated symptom severity and patient satisfaction using the ZCQ[8] leg pain using VAS scores and quality of life using the Short Form Generated Health Survey version 2 (SF-36 v2) questionnaire. The SF-36 v2 questionnaire profiles physical and mental health in 8 different dimensions, including physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional, and mental health, each of which is analyzed separately and combined as a physical component summary and mental component summary. Finally, the percentage of patients requiring additional surgical intervention at the index level in the follow-up period was determined, as well as the proportion of patients with serious adverse events (SAEs). Changes in physical examination data, walking condition and distance, use of pain medication, and adverse events were also assessed.

Sample Size Estimation

A sample size calculation was performed to determine the number of patients needed to detect a noninferior difference of 10% in the primary endpoint with 80% power, and a one-sided alpha of 5%, comparing SDS to the IPD. Initially, a standard deviation of 30% on the primary endpoint was assumed. After finding a pooled standard deviation of 17% when 71 patients had evaluable data, it was calculated, using a Student *t*-test with expected difference of 0.0 and common standard deviation of 20%, that at least 51 analyzable patients per arm (102 in total) were needed to show noninferiority with 80% power under the given assumptions.

Statistical Methods

The primary objective was to show noninferiority of treatment with IPD compared to SDS regarding physical function. The noninferiority margin was defined as 10%. A *t*-test was performed applying multiple imputations to replace missing values based on the following variables (applied in a proc MI model): previous measurements of the same variable, the baseline value, gender, age, completion status, center, and treatment group. This approach was used to analyze both primary and secondary endpoints. There was no correction for multiple testing. It was prespecified that the intention-to-treat population, consisting of all

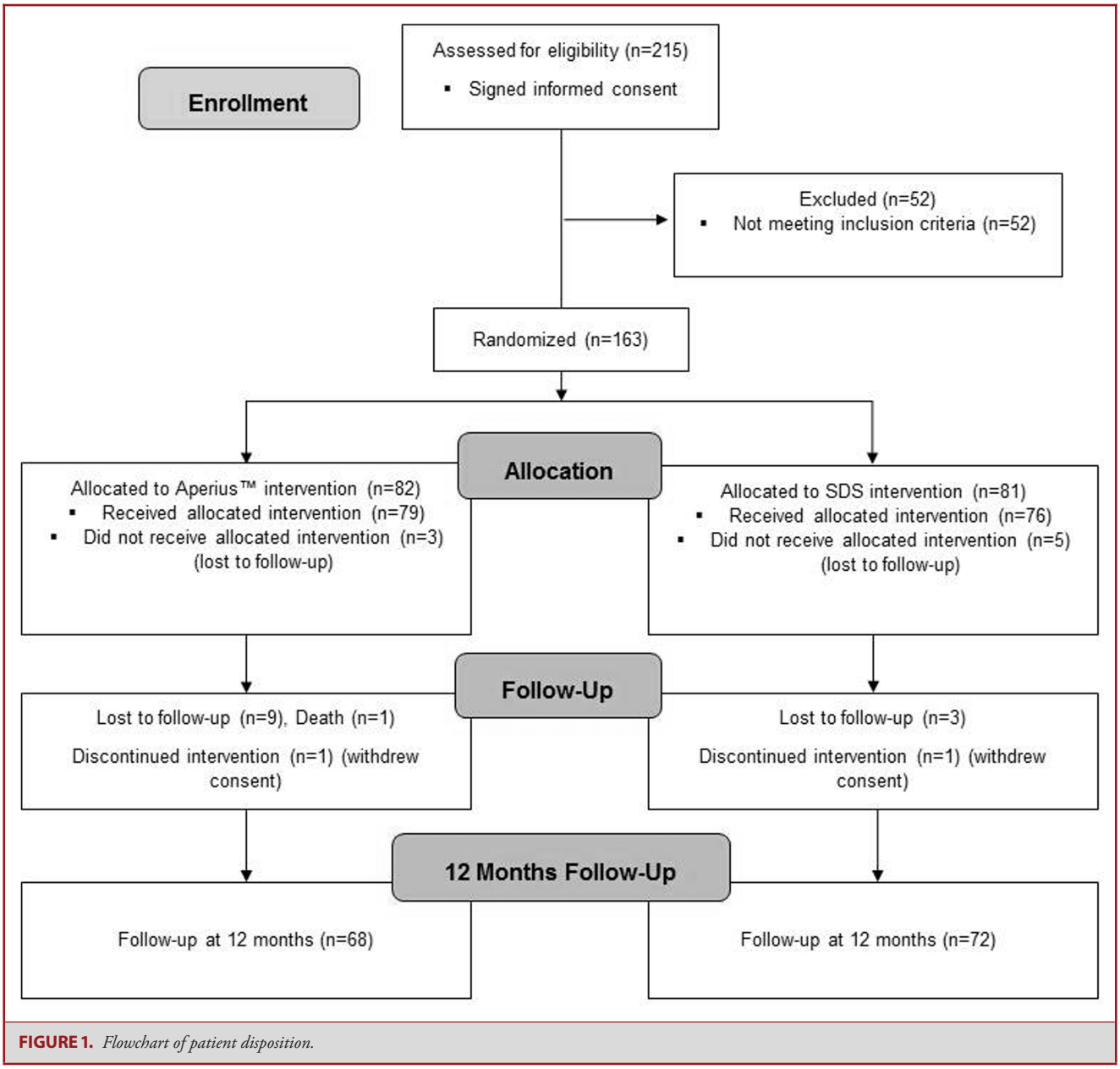

FIGURE 1. *Flowchart of patient disposition.*

randomized patients who were operated and had at least 1 postoperative assessment, would be used for efficacy analysis. However, the results reported here are for the per-protocol set. This is a subset of patients in the intention-to-treat population who were treated according to the protocol specifications. For this per-protocol subset, patients on whom surgical procedure as defined per randomization was not performed were removed.

Time to additional surgical intervention at index level was analyzed by a Kaplan–Meier analysis and a log-rank test to assess the difference between both treatment groups. Data were analyzed using SAS/STAT® software version 9.3 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Patient Disposition

A total of 215 patients from 19 sites were screened and consented to inclusion in the study. Of these, 163 patients were randomized, from January 2010 to April 2014, to the IPD (82) or SDS (81) group (Figure 1), with 79 patients implanted with the IPD and 76 patients receiving SDS. Twelve patients (9 IPD and 3 SDS) were lost to follow-up after 12 mo, 2 patients withdrew consent (1 patient in each group), and 1 IPD patient died, which

TABLE 1. Baseline Characteristics

	IPD	SDS	*P*-value
Age (years), mean (range)	65 (26-90)	65 (32-83)	.58
Gender (%)	53	49	.75
BMI, mean (range)	29 (22-35)	28 (20-35)	.91
Duration of leg symptoms (years), mean (range)	2.6 (0.2-31)	2.5 (0.2-31)	.61
ZCQ, physical function (SD)	2.6 (0.6)	2.7 (0.6)	.49
ZCQ, symptom severity (SD)	3.3 (0.5)	3.3 (0.5)	.48
SF36 v2, PCS, mean (SD)	30.7 (8.1)	30.8 (6.5)	.08
SF36 v2, MCS, mean (SD)	44.0 (14.2)	43.4 (15.6)	.45
Leg pain (VAS), mean (SD)	7.9 (1.3)	8.0 (1.3)	.99

Abbreviations: BMI, body mass index; MCS, mental component summary; PCS, physical component summary; SDS, standalone decompressive surgery; IPD, interspinous process device; VAS, visual analog scale; ZCQ, Zurich Claudication Questionnaire.

TABLE 2. Procedural Data

	IPD	SDS	*P*-value
Operating time (minutes), mean (SD)	23.5 (11.2)	69.9 (38.7)	<.001
1 level operating time, mean (SD)	19.8 (9.8)	62.0 (35.8)	<.001
2 level operating time, mean (SD)	27.9 (11.2)	80.4 (40.9)	<.001
Total blood loss (mL), mean (SD)	6.0 (10.8)	188.6 (147.9)	<.001
1 level blood loss, mean (SD)	4.4 (4.8)	133.5 (79.1)	<.001
2 level blood loss, mean (SD)	8.3 (15.7)	259.1 (183.6)	<.001

Abbreviations: SDS, standalone decompressive surgery; IPD, interspinous process device.

resulted in a follow-up rate of 83% and 89% per study group, respectively. Between 12 and 24 mo, 14 patients (7 IPD and 7 SDS) were lost to follow-up, 1 IPD patient withdrew consent, and 1 IPD patient died, which resulted in a follow-up rate of 71% and 81% at 24 mo, respectively. The per-protocol set, used for reporting efficacy results, was made up of 72 IPD patients and 73 SDS patients.

Baseline Characteristics

Baseline characteristics were similar in both treatment arms and showed no statistically significant difference (Table 1). Mean age of included patients was 65 ± 11 (range 26-90) yr. Fifty-one percent of patients were female. Mean leg pain was 7.9 ± 1.3 and 8.0 ± 1.3 in the IPD and SDS groups, respectively. Mean back pain was 4.0 ± 2.3 and 4.4 ± 2.0, respectively.

Surgical Treatment

Mean operation time and mean blood loss in the IPD group (24 ± 11 min and 6 ± 11 mL) were significantly lower compared to the SDS group (70 ± 39 min and 189 ± 148 mL, both $P <$ .001; Table 2).

Patient-Reported Outcomes

There was a significant improvement in the mean percentage change from baseline in ZCQ physical function for both the IPD and the SDS treatment groups at 12 mo (−32.3 ± 32.1, $P <$ .001 and −37.5 ± 22.8, $P <$ .001, respectively). Comparison of difference in physical function of the ZCQ between IPD and SDS groups at baseline and 12-mo follow-up showed a mean intergroup difference of 5% with a confidence interval of −4 to +15 ($P =$ .172, Figure 2). Therefore, noninferiority of IPD to SDS treatment, with a 10% acceptable difference margin, could not be established with statistical significance.

Improvement in ZCQ physical function, predefined as a decrease of ≥0.5 compared to baseline, was achieved by 62.5% of the patients of the IPD group and 65.8% of the patients in the SDS group at 12 mo.

Secondary Outcomes

The improvement in ZCQ physical function remained up to 24 mo for both the IPD and the SDS treatment groups (–37.9 ± 21.7%, $P <$ .001 and –35.2 ± 22.8, $P <$ 0.001). Comparison of difference in ZCQ physical function between IPD and SDS treatment groups at baseline and 24 mo showed noninferiority of IPD treatment compared with SDS treatment (mean intergroup

TABLE 3. ZCQ at Baseline and 12- and 24-mo Follow-up

	Baseline	12 mo	%CfB (SD)	24 mo	%CfB (SD)	*P*-value
Physical function						
IPD, mean (SD)	2.6 (0.6)	1.7 (0.7)	−32.3 (32.1)	1.5 (0.5)	−37.9 (21.7)	<.001
SDS, mean (SD)	2.7 (0.6)	1.6 (0.6)	−37.5 (22.8)	1.7 (0.6)	−35.2 (22.8)	<.001
Symptom severity						
IPD, mean (SD)	3.3 (0.5)	2.2 (0.8)	−31.2 (26.9)	1.9 (0.7)	−40.3(21.9)	<.001
SDS, mean (SD)	3.3 (0.5)	2.1 (0.8)	−36.4 (24.5)	2.1 (0.7)	−32.8 (23.9)	<.001

Abbreviations: CfB, change from baseline; SDS, standalone decompressive surgery; IPD, interspinous process device.

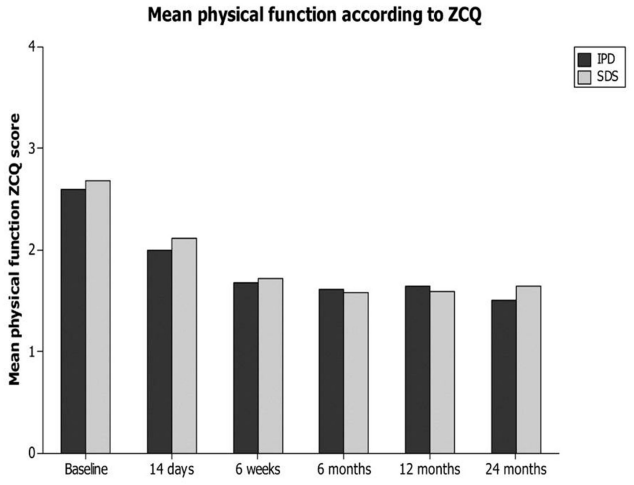

FIGURE 2. *Mean physical function score according to Zurich Claudication Questionnaire at all follow-up time points. Intergroup comparison showed a significant difference between the IPD and SDS groups (P = .005) at 24 mo. Intragroup comparison showed significant improvement from baseline to 12 and 24 mo for each treatment group (* P < .001).*

difference of –1% with a confidence interval of –10 to +7; $P = .005$).

Improvement in ZCQ physical function, defined as a decrease of ≥0.5 compared to baseline, was achieved by 54.2% of the patients of the IPD group and 60.3% of the patients in the SDS group at 24 mo.

ZCQ symptom severity improved significantly in both groups from baseline to 12 mo (IPD: –31.2 ± 26.9%, $P < .001$ and SDS –36.4 ± 24.5%, $P < 0.001$) and to 24 mo (IPD: –40.3 ± 21.9%, $P < .001$ and SDS –32.8 ± 23.9%, $P < .001$; Table 3).

In both treatment groups, VAS pain scores for leg, buttock/groin, and back pain showed that pain decreased from baseline to 24 mo. No significant differences were observed between the IPD and SDS groups for VAS leg, buttock/groin, or VAS back pain scores. SF-36 v2 physical and mental aggregated scores improved significantly for both treatment groups over

TABLE 4. VAS Leg and Back at Baseline and 12- and 24-mo Follow-up

	Baseline	12 mo Mean (SD)	24 mo
Leg pain			
IPD	7.93 (1.31)	3.11 (2.74)	2.17 (2.49)
SDS	8.04 (1.32)	2.68 (2.60)	2.66 (2.59)
Back pain			
IPD	4.00 (2.33)	3.15 (2.59)	2.17 (2.02)
SDS	4.38 (1.97)	2.89 (2.30)	3.05 (2.43)

Abbreviations: SDS, standalone decompressive surgery; IPD, interspinous process device.

time (significant: $P = .045$ back pain, $P = .01$ leg pain; not significant: buttock/groin pain, $P = .144$; Table 4).

Twenty-four months after the procedure, more than 59.7% of patients implanted with an IPD walked fluently vs 41.6% of the patients at baseline. In the SDS group, 61.3% of patients were judged by their investigator to walk fluently, vs 37.3% at baseline. Statistically significant improvement in walking distance was observed for both groups at 24 mo after procedure ($P < .001$; Table 5 and Figure 3).

Adverse Events and Additional Surgical Interventions

Seventy-four SAEs were recorded at up to 24 mo of follow-up, 39 SAE in the IPD group, and 35 SAE in the SDS group. The number of patients experiencing at least 1 SAE was 26 (33.8%) in the IPD group and 25 (33.3%) in the SDS group.

After 24 mo of follow-up, an additional surgical intervention at index level was performed 21 times: 14 times in the IPD group and 8 times in the SDS group (Table 6; Figure 4). Only in 2 patients was a complication (spinous process fracture) the reason for a revision in the IPD group. In 12 instances, however, "lack of success" of the initial procedure (IPD implantation), ie, early recurrence or unsatisfying relief of NIC symptoms, was responsible for additional surgery in the index segment. In the SDS group, 4 "typical" early complications (eg, hematoma or

TABLE 5. Walking Distance at Baseline and 12- and 24-mo Follow-up

	Baseline		12 mo		24 mo	
	0-100 m	>1000 m	0-100 m	>1000 m	0-100 m	>1000 m
IPD	29.9%	11.7%	5.2%	53.2%	3.9%	54.5%
SDS	37.3%	12.0%	4.0%	65.3%	6.7%	57.3%

Abbreviations: SDS, standalone decompressive surgery; IPD, interspinous process device.

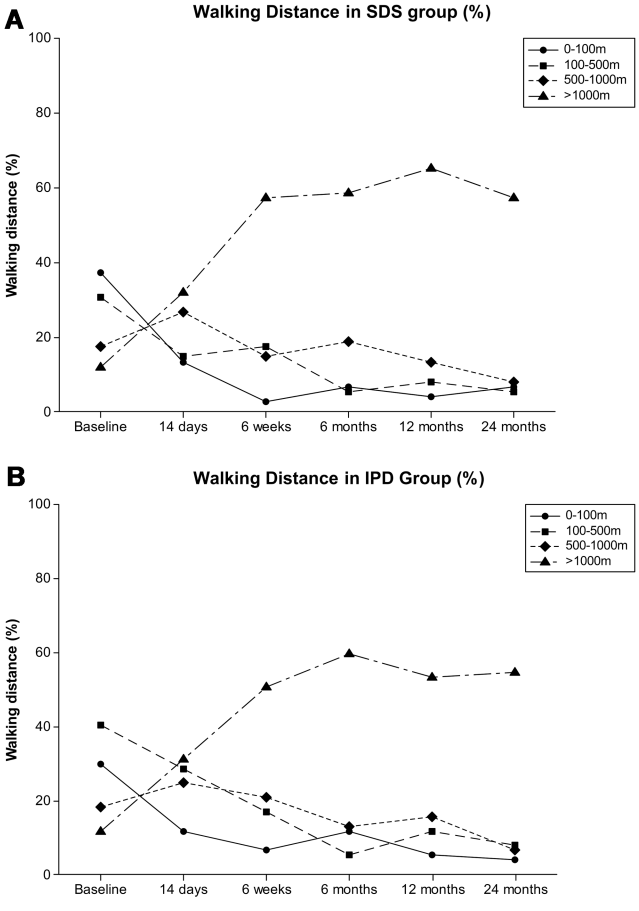

FIGURE 3. *Development of walking distances in* **A**, *the SDS group and* **B**, *the IPD group was very similar following the respective intervention. Shorter walking distances decreased, while walking distance >1000 m increased.*

infections) were the reason for revision, and in 4 patients, symptoms attributed to instability.

DISCUSSION

Our study results indicate that standalone IPDs are as effective as standard decompression in patients with neurogenic claudication due to lumbar stenosis that is relieved by flexion. Although treatment with an IPD was not noninferior to SDS treatment at 12 mo, the prespecified primary endpoint, it was noninferior at 24 mo. These results are in line with 3 recently published randomized clinical trials.[4-6]

Our primary outcome and most of the secondary outcomes are similar to the outcomes presented by Moojen,[4] Strömquist,[5] and Lønne,[6] despite the fact that different implants were used. Therefore, the sum of these findings represents level 1a evidence. Without doubt, the key to this lies in the very strict indication (classical NIC relieved by flexion in lumbar stenosis without instability), which was applied in all studies alike. This also demonstrates that correct and strict indication for a given spinal disorder prevails over technical or biomechanical nuances with regard to outcome. It also explains the contradicting results seen in the vast majority of over 200 publications on IPDs, reporting mostly uncontrolled data from heterogeneous indications.[9-11]

Thus, IPDs may be regarded as a less invasive alternative to open decompression in patients with NIC avoiding typical surgical complications such as leaks or epidural hematomas.[12] The results of all 4 studies point in this direction and do not raise safety concerns with respect to the implants used.

However, the very high reoperation rate for IPD cohorts remains the most problematic issue, with reoperation rates of 29% after 12 mo and 26% after 24 mo being reported, compared to 6% and 8% in the control groups, respectively.[4-6] A similarly high reoperation rate has also been reported in a terminated study.[12,13] The reoperations in the IPD cohorts in these studies were mostly due to "lack of success" and were not revisions for obvious complications, as mostly seen in the decompression groups. We made a similar observation in our investigational cohort (see Figure 4). In the current study, the reoperation rate after 24 mo was 18.2% in the IPD group, which is lower than in the other studies, while the revision rate in the control group compares well with other reliable data.[14]

This discrepancy constitutes a dilemma with regard to clinical consequences and conclusions. The results of Moojen,[4] Strömqvist,[5] and Lønne[6] lead us to conclude that the benefits of IPDs are outweighed by the high revision rate. Moojen[4] argues that patients needing revisions fare worse than those who do not. They deduce this from the results of Radcliff et al[14] in a 4-yr post hoc subgroup analysis of the original data of the SPORTS

TABLE 6. Revision Surgeries at the Index Segment After 24 mo in the IPD and SDS Group

IPD				SDS			
Patient no.	Time to revision (d)	Reason for revision	Type of revision	Patient no.	Time to revision (d)	Reason for revision	Type of revision
1IPD	54	Persistent NIC	Decompression and fusion	1SDS	1	Postop L5 palsy	Revision
2IPD	112	Persistent NIC	Decompression	2SDS	4	Epidural hematoma	Revision
3IPD	145	Recurrent NIC	Decompression	3SDS	8	Infection	Revision
4IPD	207	Recurrent NIC	Decompression	4SDS	50	Instability/ persistent NIC	Extended decompression and fusion
5IPD	254	Recurrent NIC	Decompression	5SDS	401	Recurrent NIC	Extended decompression
6IPD	348	Recurrent NIC	Decompression and fusion	6SDS	609	New sciatica/ herniated disc	Decompression
7IPD	363	Fracture L3	Decompression and kyphoplasty	7SDS	672	Instability/recurrent NIC	Extended Decompression and fusion
8IPD	408	Recurrent NIC	Decompression				
9IPD	427	Spinous Process Fracture	Decompression				
10IPD	473	Recurrent NIC	Decompression				
11IPD	490	Recurrent NIC	Decompression and fusion				
12IPD	519	Persistent NIC	Decompression				
13IPD	644	Recurrent NIC	Decompression				
14IPD	707	Recurrent NIC	Decompression				

Abbreviations: SDS, standalone decompressive surgery; IPD, interspinous process device; NIC, neurogenic intermittent claudication.

trial (Weinstein et al).[15] The outcome of the 13% of patients needing repeat surgery after standard decompression was inferior to the rest. This may also be the case after revision of an IPD, but this is a mere extrapolation. Furthermore, the results from Strömqvist are in contradiction to this, showing similar outcomes for reoperated patients in the IPD group and after primary decompression.[5]

Lønne et al[6] describe 2 serious complications in the cohort of patients receiving standard decompression, ie, 2 persisting cauda syndromes.

Our study shows a somewhat more acceptable rate of reoperation at the index segment of the IPD group compared to SDS. Moreover, the percutaneous implantation technique offers a clear advantage over open decompression (and the open implantation technique of the other 2 devices) with respect to surgical time and blood loss. The former would at least partially outweigh the direct costs for the implant by substantially saving operating room time. The IPD can also be implanted under local anesthesia as day care surgery, which reduces associated costs. On the other hand, this again might be foiled by the increase in costs due to the higher rate of revision surgeries. As neither direct nor indirect costs were measured in this study, that remains speculative.

The reasons for this discrepancy in revision rates might include the following. Although we believe that technique and/or implant is less important than indication, at least 1 worrisome aspect with the choice of IPD in the FELIX trial remains.[4] This implant (Coflex, Paradigm Spine LLC, New York, New York) was designed, marketed, and tested as a soft stabilization device to be used in addition to open decompression.[2] Its effectiveness as a standalone device for this indication must be questioned. This argument is certainly not true for the choice of implant in Strömqvist's[5] and Lønne's[6] studies (X-Stop, Medtronic, Dublin, Ireland).

However, a further confounder may have been introduced in both studies due to a center effect, and Strömqvist acknowledges this in his discussion.[5] The trial was conducted in only 3 centers in Sweden, and the high reoperation rate was mainly due to 1 center alone. Thus, Strömqvist's conclusion was more balanced than the Dutch group's, which completely rejected the use of IPDs on the basis of their results.[5]

We believe that this indicates the most important problem, which is a lack of equipoise. It is quite obvious that at the time the trials were conducted, most surgeons had a clear, predefined negative opinion on IPDs in general, due to officially and unofficially reported high reoperation rates (ie, Lønne, Verhoof).[6,9] It was, therefore, an already common view that IPDs are an unsuccessful device. This clearly introduces a bias when evaluating a success or the lack thereof. Even though the evaluations in the Dutch trial were done by a blinded research nurse, the indication for revision lies in the hands of the surgeons.

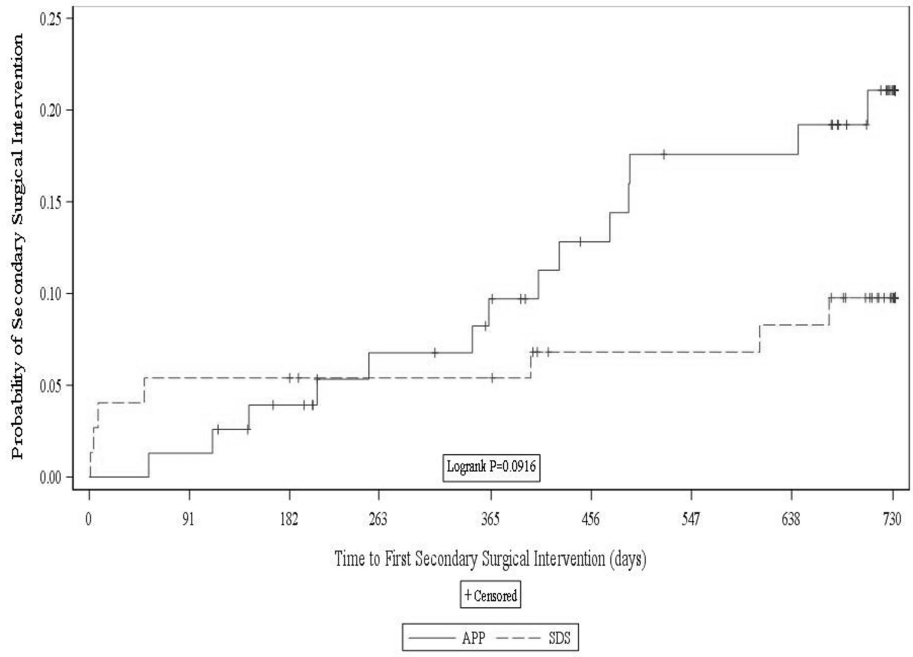

FIGURE 4. *Time to secondary surgical intervention at index level in both study groups after 24 mo. Fourteen patients in the IPD group (18%) and 8 in the SDS group (9%) needed revision surgery in the index segment, the former in a more delayed fashion and the latter rather early in the postoperative course. A lack of success, ie, persisting/recurring symptoms, was given as the reason for revision in 12 cases in the IPD group. Four out of 8 patients in the SDS group were revised early for typical operative complications. IPD = IPD group, SDS = SDS group.*

Apart from this bias, we acknowledge that there may also be a biomechanical reason for the earlier relapse of symptoms or "lack of success" following IPD implantation. Taking into account the radiological data, it becomes obvious that the gain in cross-sectional area of the spinal canal is less with IPD than with open decompression. This may be one of many factors for the shorter "half-life" of these devices. No correlation of radiological and clinical parameters could be shown in line with Moojen's recent publication.[4]

Due to the above arguments and in the light of our own results, we would carefully advocate a more balanced view on standalone IPD implantation for the treatment of DLSS with NIC. Progress in clinical science only occurs in small steps. A complete rejection of an innovation because of nonsuperiority would stall this process for almost all technological evolutions. We value and share a very critical attitude toward costly and/or ineffective innovations. However, weighing the evidence available, we see a possible indication in a small subset of patients, ie, those with comorbidities and/or anticoagulation.

CONCLUSION

This study confirms 3 recent prior randomized controlled trials in showing that IPDs are as effective as standard decompression in relieving symptoms of NIC due to lumbar stenosis in a highly selected subset of patients. It also confirms that this occurs at the price of a significantly higher reoperation rate. Percutaneous IPDs may still have a very narrow window of indication in patients with typical NIC due to lumbar stenosis and cardiac comorbidities and/or anticoagulation, because surgery is shorter, safer, and less invasive.

Disclosures

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REFERENCES

1. Wilke HJ, Drumm J, Häussler K, et al. Biomechanical effect of different lumbar interspinous implants on flexibility and intradiscal pressure. *Eur Spine J*. 2008;17(8):1049-1056.
2. Davis RJ, Errico TJ, Bae H, et al. Decompression and Coflex interlaminar stabilization compared to decompression and instrumented spinal fusion for spinal stenosis and low-grade degenerative spondylolisthesis: two-year results from the prospective, randomized, multicenter food and drug administration investigational device exemption trial. *Spine*. 2013;38(18):1529-1539.
3. Zucherman JF, Hsu KY, Hartjen CA, et al. A multicenter, prospective, randomized trial evaluating the X Stop interspinous process decompression system

for the treatment of neurogenic intermittent claudication: two-year follow-up results. *Spine.* 2005;30(12):1351-1358.
4. Moojen WA, Arts MP, Jacobs WC, et al. Interspinous process device versus standard conventional surgical decompression for lumbar spinal stenosis: randomized controlled trial. *BMJ.* 2013;347:f6415.
5. Strömqvist BH, Berg S, Gerdhem P, et al. X-Stop versus decompressive surgery for lumbar neurogenic intermittent claudication: A randomized controlled trial with 2 years follow-up. *Spine.* 2013;38(17):1436-1442.
6. Lønne G, Johnsen LG, Rossvoll I, et al. Minimally invasive decompression versus x-stop in lumbar spinal stenosis: a randomized controlled multicenter study. *Spine.* 2015;40(2):77-85.
7. Meirhaeghe JV, Fransen P, Morelli D, et al. Clinical evaluation of the preliminary safety and effectiveness of a minimally invasive interspinous process device Aperius in degenerative lumbar spinal stenosis with symptomatic neurogenic intermittent claudication (INCA). *Eur Spine J.* 2012;21(12):2565-2572.
8. Stucki G, Daltroy L, Liang MH, et al. Measurement properties of a self-administered outcome measure in lumbar spinal stenosis. *Spine.* 1996;21(7):796-803.
9. Verhoof OJ, Bron JL, Wapstra FH, et al. High failure rate of the interspinous distraction device (X-Stop) for the treatment of lumbar spinal stenosis caused by degenerative spondylolisthesis. *Eur Spine J.* 2008;17(2):188-192.
10. Kuchta J, Sobottke R, Eysel P, et al. Two year results of interspinous spacer (X-Stop) implantation in 175 patients with neurologic intermittent claudication due to lumbar spinal stenosis. *Eur Spine J.* 2009;18(6):823-829.
11. Kantelhardt SR, Török E, Gempt J, et al. Safety and efficacy of a new percutaneously implantable interspinous process device. *Acta Neurochir.* 2010;152(11):1961-1967.
12. Thomé C, Zevgaridis D, Leheta O, et al. Outcome after less-invasive decompression of lumbar spinal stenosis: a randomized comparison of unilateral laminotomy, bilateral laminotomy, and laminectomy. *J Neurosurg Spine.* 2005;3(2):129-141.
13. Lønne G. Treatment of lumbar spinal stenosis; comparison of two different surgical methods; mini-invasive decompression to X-stop (LSSS). Available at: https://clinicaltrials.gov/ct2/show/NCT00546949.
14. Radcliff K, Curry P, Hilibrand A, et al. Risk for adjacent segment and same segment reoperation after surgery for lumbar stenosis: a subgroup analysis of the spine patient outcomes research trial (SPORT). *Spine (Phila Pa 1976).* 2013;38(7):531-539.
15. Weinstein JN, Lurie JD, Tosteson TD, et al. Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *N Engl J Med.* 2007;356(22):2257-2270.

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COMMENT

This multi-center, randomized, prospective trial compared percutaneous interspinous process device (IPD) placement to standalone decompressive surgery (SDS) for degenerative lumbar stenosis. Designed as a non-inferiority trial, this investigation found that IPD was not less effective than SDS. Although this randomized study should be viewed as higher level evidence in regards to the effectiveness of IPD, there are a few points that should be highlighted. Based on the inclusion/exclusion criteria, only a subset of patients with lumbar stenosis would qualify. More problematic is that reoperation rates were much higher in this study, which has been observed in other studies of IPD. Increased reoperation rates are a burden to the patient and likely contribute to increased costs. This begs the question of why an IPD should be implanted instead of performing a traditional SDS.

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