European Spine Journal
https://doi.org/10.1007/s00586-025-09271-4

RESEARCH

Midline-preserving vs. midline-removing surgery for lumbar spinal stenosis: national registry study based on the Finnish spine registry (FinSpine)

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Received: 7 June 2025 / Revised: 25 July 2025 / Accepted: 10 August 2025

Abstract

Purpose Lumbar spinal stenosis (LSS) can be treated surgically by decompressing the affected nervous structures, either by removing or preserving the midline structures. There is no conclusive evidence demonstrating the superiority of either surgical technique in the treatment of LSS. Our purpose was to compare the posterior midline-preserving techniques with midline-removing techniques separately for central stenosis and lateral recess stenosis to evaluate whether either technique leads to superior postoperative results in terms of functional outcome or pain reduction, by using data from the Finnish Spine Registry (FinSpine).

Methods A total of 7577 patients underwent decompression surgery for central (n=5670) or lateral recess (n=1907) stenosis in the lumbar spine between 2015 and 2022. In the central stenosis group 3025 patients were operated using midline-preserving techniques and 2645 using midline-removing techniques. In the lateral recess stenosis group, the corresponding numbers were 1536 and 371, respectively. Patients with less than 3mm degenerative spondylolisthesis were included. We recorded the baseline information, and the primary outcomes were the between-group differences in improvement in functional outcome and back and leg pain at one, two and five years postoperatively. Oswestry disability index (ODI) and visual analogue scale (VAS) for back and leg pain were used to assess clinical outcomes. We compared midline-preserving and midline-removing techniques separately in central and lateral recess stenosis groups.

Results Regardless of the surgical technique, patients improved in terms of functional outcome and pain during the 5-year follow-up. In the central stenosis group, there were no statistically significant differences between groups in primary outcomes. However, in the midline-preserving group, there were more new operations during the follow-up period as a secondary outcome. In the lateral recess stenosis group, there was a statistically significant improvement in the midline-preserving group in the change of ODI; 7.9 (95% C.I. [1.7, 14.1], p=0.01), and in the change in VAS leg; 12.8 (95% C.I. [0.5, 25.0], p=0.04) at the 5-year follow-up, compared to the midline-removing group.

Conclusions Based on a nationwide registry, the majority of patients improved in the primary outcomes and were satisfied with the operative treatment. Our study suggests that concerning central stenosis both techniques lead to good results, but midline-preserving techniques may lead to new operations more often than after midline-removing decompression in 5 years. Alternatively, in case of lateral recess stenosis, a question is raised whether surgery by midline-preserving decompression might benefit patients in terms of disability and leg pain.

Keywords Lumbar spinal stenosis · Registry based study · Midline-removing surgery · Midline-preserving surgery · Finnish Spine Registry · FinSpine

Extended author information available on the last page of the article

Published online: 18 August 2025

Introduction

Lumbar spinal stenosis (LSS) is a condition narrowing the spinal canal, compressing nervous structures and causing leg and lower back pain, numbness and fatigue, especially during walking or standing. Overall, the natural history of LSS seems to be rather stable [1]. Conservative treatment is usually the primary course of treatment in most patients, but surgical treatment by decompression seems to be beneficial in selected patients [2–4].

The main aim in surgical treatment for LSS is to decompress the affected nervous structures to relieve symptoms. Stenosis can occur mainly in the central region of the spinal canal, in the lateral recess, or in both. Decompression techniques can be divided into techniques which remove the midline structures, and midline-preserving techniques.

Several studies have compared midline-removing and midline-preserving techniques without results of definitive superiority of either group [5–7]. National registry-based studies have been published from Norway and Sweden comparing laminectomy with midline-preserving techniques [8, 9].

The Finnish Spine Registry (FinSpine) was established 2015 and includes most clinics performing spine surgeries in Finland [10]. No studies comparing results between surgical techniques have yet been published based on data from FinSpine.

Our aim was to compare posterior midline-preserving techniques with midline-removing techniques, to evaluate whether either technique leads to superior postoperative results in terms of functional outcome and postoperative pain by using the FinSpine registry.

Methods

FinSpine registry

FinSpine is a nationwide computer-based spine registry designed to collect data of surgical activity, quality, effectiveness, and long-term patient outcomes. Registry data is collected from electronic hospital records, surgeon-reported surgical details and patient follow-up questionnaires [10]. The registry covers 90% of spine surgeries performed annually in Finland [11]. The Finnish health care is publicly financed and nonprofit system that covers all citizens regardless of insurance or work status.

Data setting and participants

Using the FinSpine registry, we obtained prospectively collected data of patients undergone decompressive surgery for LSS from the beginning of FinSpine in 2015 until the end of the year 2022. Patients were divided into two groups based on the type of stenosis recorded in FinSpine: either central or lateral recess. The groups were further divided into two groups based on the type of decompressive surgery: either midline-preserving or midline-removing. Decompression types considered as midline-preserving were unilateral and bilateral microdecompressions or laminotomies, crossover laminotomies, and spinous process-splitting decompressions whereas midline-removing operation types were classic laminectomies and all other techniques where the interspinous ligament was interrupted. We included all patients aged 18 or older with less than 3 mm degenerative spondylolisthesis. Only operations recorded as primary operations were included.

Baseline characteristics, perioperative data, and outcome measures

Of the patient groups, we recorded baseline information regarding several potentially relevant covariates such as age, sex, body mass index (BMI), smoking, duration of pain, preoperative Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) for back and leg pain. Patient-reported outcome measures (PROMs) and "satisfaction with surgery" are recorded in the registry via follow-up questionnaires. Perioperative complications, levels of decompression and number of decompressed levels were recorded. The primary outcomes were the between-group differences in improvement of ODI and VAS back and leg pain at one, two and five years postoperatively.

Secondary outcome measures were satisfaction with surgery, and any subsequent spinal surgeries divided into reoperations and new lumbar spinal surgeries until the end of follow-up on December 31, 2022. Reoperations included additional operations at the index level. New surgeries included operations on other than the index level or on the contralateral side of the index level.

Statistical methods

Minimal clinically important difference (MCID) for ODI and VAS (leg and lower back) was estimated as half of the standard deviation of preoperative scores [12]. Differences between midline-preserving and midline-removing in ODI, VAS (leg), and VAS (lower back) were tested using a linear

mixed-effects models with one of these outcome variables as the dependent variable at a time. The analyses were done separately for central LSS and lateral recess patients. As fixed variables, we controlled for age and sex with the measurement timepoint (3 months, 1 year, 2 year, and 5 year) and surgery type (midline-preserving as reference level) and the interaction of timepoint and surgery type being the variables of interest. We included a patient-level random effect for the intercept. The 3-month timepoint was not of clinical interest, but was kept in the model as this provided an extra time point to better estimate the patient-specific random effects. All missing data were in dependent variables, and all data points with non-missing measurements were utilized. Models were fitted using restricted maximum likelihood (REML). The model assumptions about residual normality were graphically checked, and no large deviations from normality were detected. Differences in treatment satisfaction were tested with chi-squared test.

The unadjusted rate of revision with 95% confidence intervals, with re-operation or new surgery as an end point, was estimated using a Kaplan-Meier estimator. As a sensitivity test, we also estimated the survival time with any lumbar-spine surgery as the endpoint regardless of the diagnosis (see Supplementary Table 1, Supplementary Fig. 1). The statistical significance of the difference in survival times between midline-preserving and midline-removing surgeries was tested using Cox's proportional hazard model. The fitting was done first without controlling for any covariates and secondly controlling for sex, age, and number of decompressions. The proportional hazard assumption was tested using a statistical test based on Schoenfeld residuals [13, 14], and the assumption was not rejected for any of the four tested cases. However, based on graphical investigations, while the assumption is valid for central LSS, it may be problematic for lateral recess stenosis, and thus a non-parametric log-rank test was used in addition for lateral recess stenosis patients. All statistical analyses were carried out using the statistical software R (R Core Team, 2024) [15].

This study was reported according to the STROBE guidelines [16].

Results

A total of 7577 patients who underwent decompression surgery for central ($n=5670$) or lateral recess ($n=1907$) stenosis in the lumbar spine were included. In the central stenosis group 3025 patients had midline-preserving and 2645 midline-removing surgery. In the lateral recess stenosis group, the corresponding numbers were 1536 and 371, respectively. Patient demographics are shown in Table 1. Preoperative ODI was 42 (SD 16), VAS for leg pain 65 (SD 27), and VAS for back pain 60 (SD 27) (Table 2)

Of all the patients 77% had answered the PROMs at one year, 59% at two years, and 13% at five years (Fig. 1). Follow-up ended due to new surgery in 7.8% and mortality in 5.3% of the patients.

Until the 5-year follow-up point no significant difference between the operative methods in the central stenosis group was found in the change of ODI. In the lateral recess stenosis group, there was a statistically significant difference between the operative methods in change of ODI; 7.9 (95% C.I. [1.7, 14.1.], $p=0.01$) at 5-years follow-up point in favour of the midline-preserving group. No difference in the change was found at 1-year or at 2-years follow-up points (Fig. 2, Supp. Tables 2–3)

In VAS for leg pain, no statistically significant difference was found between the operative method groups in central stenosis group at any of the measured time points. In lateral recess stenosis group, no difference between operative method groups in VAS leg was found at 1- or 2- year follow-ups, but a significant difference was found at 5-years in favor of the midline-preserving group, the difference in change between groups being 12.8 (95% C.I. [0.5, 25.0], $p=0.04$). No significant difference was found in the change between the operative methods for VAS for back pain in

Table 1 Demographics of the sample. BMI, duration of pain, and smoking were available for 46% of the sample. There were no missing data regarding age and sex

		Central stenosis		Lateral recess stenosis		All
		Midline-preserving	Midline-removing	Midline-preserving	Midline-removing	
N		3025	2645	1536	371	7577
Age, mean (SD)		69 (10)	71 (10)	61 (13)	66 (12)	68 (11)
BMI, mean (SD)		29 (5)	29 (5)	28 (5)	29 (5)	29 (5)
Female, n (%)		1367 (45%)	1219 (46%)	841 (55%)	171 (46%)	3598 (47%)
Smoking, n (%)		167 (12%)	130 (11%)	132 (16%)	35 (17%)	464 (13%)
Pain duration	*< 6 weeks*	21	47	21	4	93
	6–12 weeks	52	45	46	8	161
	3–12 months	387	284	287	60	1018
	> 1 year	867	759	446	132	2204

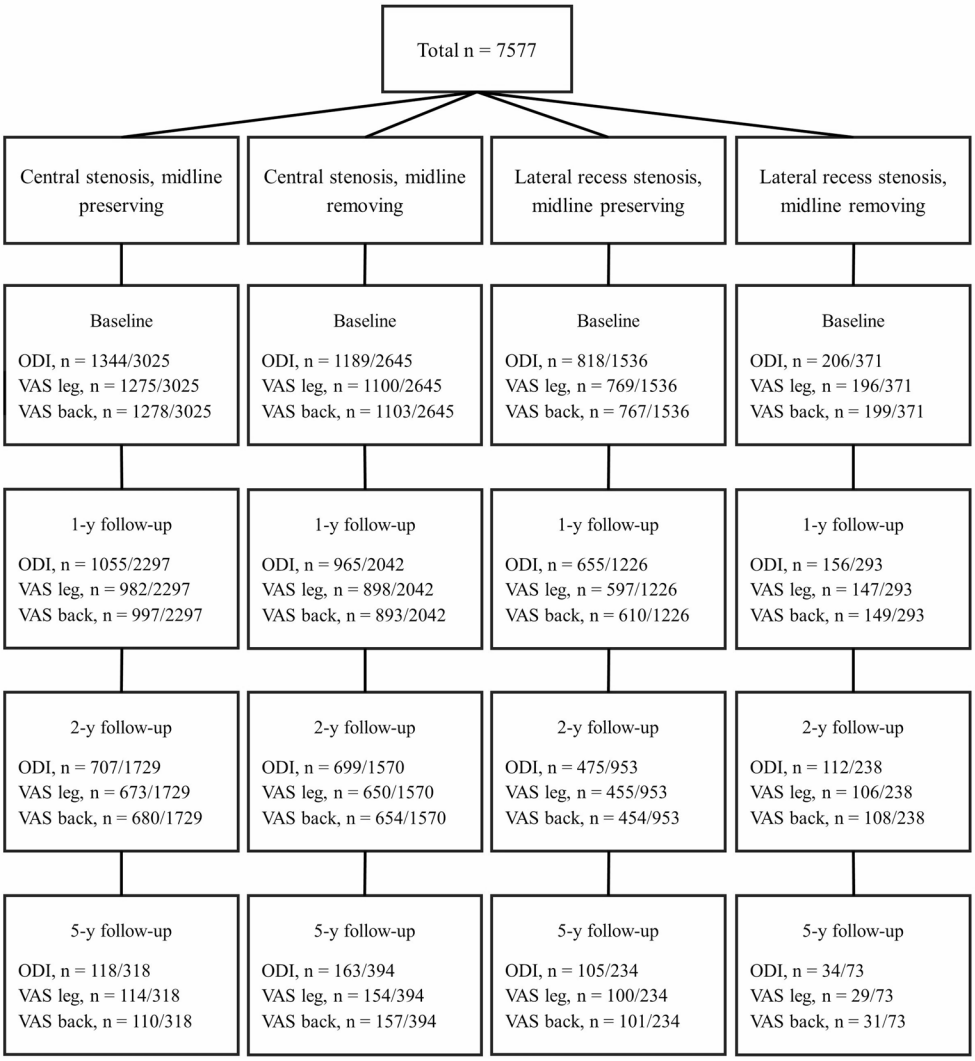

Fig. 1 Number of patients who responded at each timepoint for the three PROMs used in the study and the at risk numbers at each timepoint

Table 2 Preoperative ODI and VAS scores and decompression details of the operated patients. ODI was available For 47% of the sample, VAS For 44%, perioperative complications For 97%, and decompression details For 85%. See Fig. 1. For exact sample size details

		Central stenosis		Lateral recess stenosis		All
		Midline-preserving	Midline-removing	Midline-preserving	Midline-removing	
Preop. ODI, mean (SD)		42 (16)	43 (16)	41 (17)	41 (16)	42 (16)
Preop. VAS (leg), mean (SD)		64 (26)	65 (26)	66 (27)	64 (28)	65 (27)
Preop. VAS (lower back), mean (SD)		60 (26)	61 (26)	59 (27)	59 (28)	60 (27)
Perioperative complications	*No*	2699	2292	1449	337	6777
	Dural tear	223	267	36	27	553
	Nerve damage	4	1	1	0	6
	Other	5	8	3	0	16
Decompression level	*L1/2*	14	7	1	0	22
	L2/3	114	67	18	7	206
	L3/4	512	288	117	42	959
	L4/5	1050	642	914	176	2782
	L5/S1	20	16	201	6	243
No. of decompressed levels	*1*	1713	1022	1252	231	4218
	2	866	674	149	93	1782
	3	170	235	10	11	426
	4 or more	17	32	1	2	52

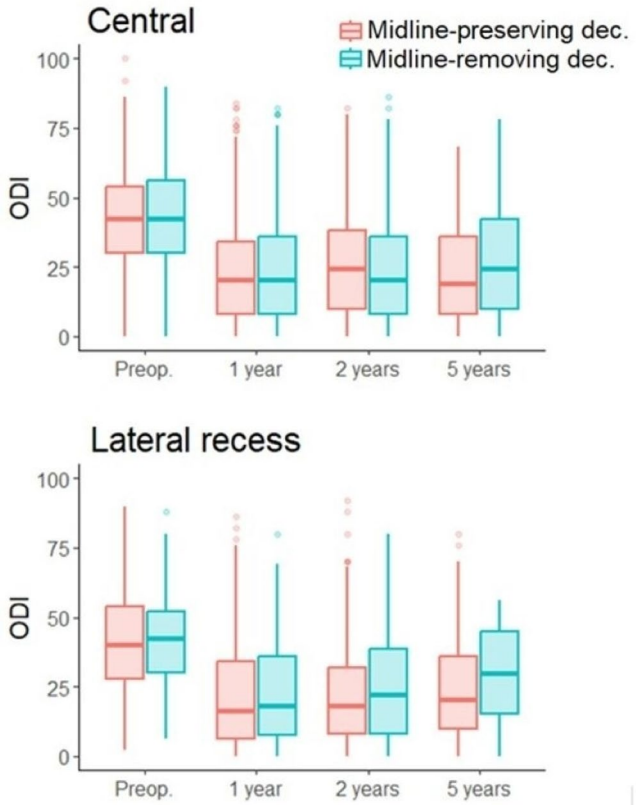

Fig. 2 ODI scores for central and lateral recess lumbar spinal stenosis patients treated using midline-preserving or midline-removing decompression. ODI response rates were 48%, 44%, and 41% of the patients at 12, 24, and 60 months, respectively. Note that the sample size is lower for longer observation periods, since some patients had been operated close to the cutoff date for this study, and thus did not have a chance to answer all follow-up questionnaires. See Fig. 1. for exact sample size details

either of the stenosis groups at any time point (Figs. 3 and 4, Supp. Tables 4–7).

The survival curves for reoperations and new operations are given in Fig. 5. There was no statistically significant difference in the hazards for reoperations. The hazard-ratios (HR) when controlling for covariates were 0.77 (95% C.I. [0.53, 1.11], $p=0.16$) for central stenosis and 1.19 (95% C.I. [0.66, 2.15], $p=0.56$) for lateral recess stenosis. Without controlling for covariates, the corresponding numbers were 0.77 (95% C.I. [0.56, 1.06], $p=0.11$) and 1.03 (95% C.I. [0.59, 1.78], $p=0.92$, log-rank $p=0.99$). Survival probabilities for both techniques in central and lateral recess stenosis are shown in Supplementary Table 8. In total, 167 reoperations were reported not to be due to complications, 33 were due to complications, and the data was missing in 34 cases.

For new operations, there was a difference for central stenosis patients in favor of midline-removing technique. The HRs when controlling for covariates were 0.62 (95% C.I. [0.44, 0.87], $p=0.006$) for central stenosis and 0.66 (95% C.I. [0.30, 1.73], $p=0.29$) for lateral recess stenosis.

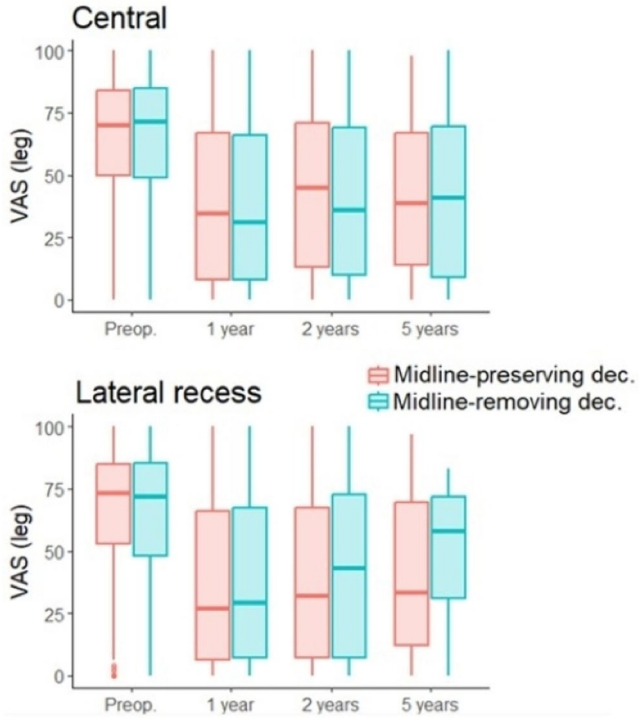

Fig. 3 Same as Fig. 2. but for VAS (leg) scores. The answer rates for VAS were nearly identical to those of ODI with deviations of 1–2%. See Fig. 1. for exact sample size details

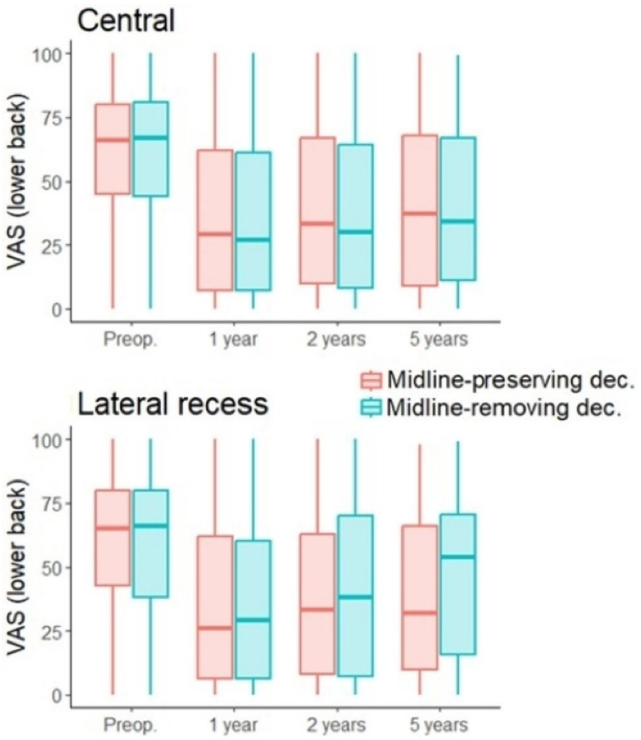

Fig. 4 Same as Fig. 2. but for VAS (lower back) scores. The answer rates for VAS were nearly identical to those of ODI with deviations of 1–2%. See Fig. 1. for exact sample size details

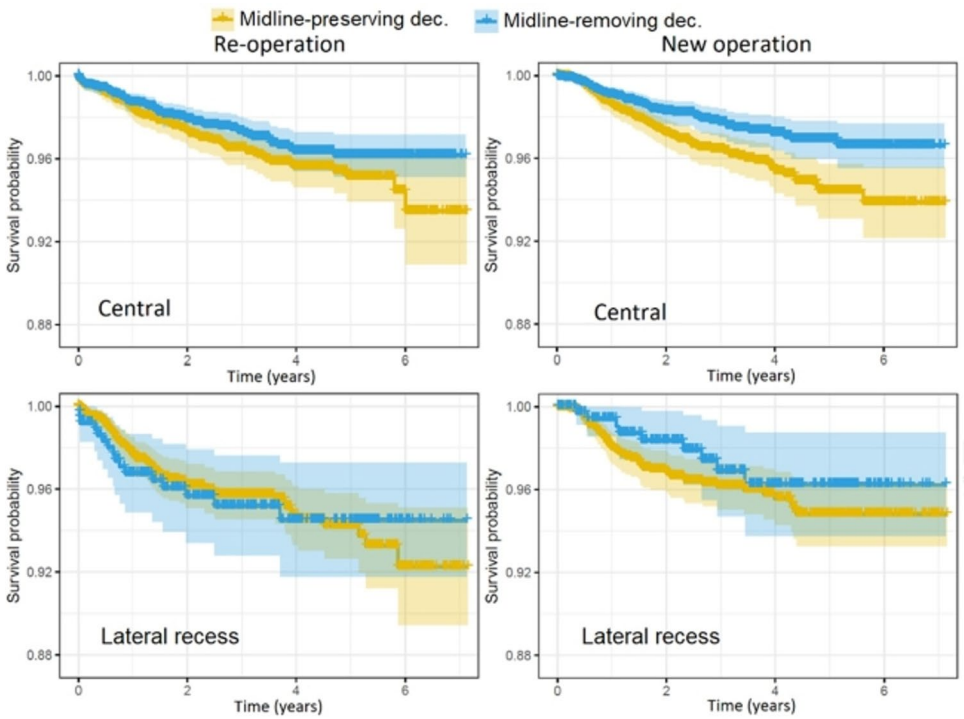

Fig. 5 The Kaplan–Meier estimates for survival probabilities with re-operation or new operation as the endpoint for central and lateral recess LSS patients. The exact survival probabilities at key time points are provided in supplementary Tables 8–9

Without controlling for covariates, the corresponding numbers were 0.61 (95% C.I. [0.43, 0.86], $p=0.004$) and 0.70 (95% C.I. [0.35, 1.42], $p=0.32$, log-rank $p=0.30$). Survival probabilities for both techniques in central and lateral recess stenosis are shown in Supplementary Table 9.

Majority of the patients were satisfied with the operative treatment and its effect on relieving the symptoms. For central stenosis there was a small statistically significant difference in favor of midline-preserving group in "I am satisfied with the treatment" at 5 years ($p=0.03$). (Supp. Table 10)

The MCID values estimated from the data were 8.2 points for ODI, 13.0 points for VAS leg pain, and 13.3 points for VAS back pain.

Discussion

This national registry study, based on FinSpine, compared midline-preserving and midline-removing techniques separately in central and lateral recess stenosis groups. Regardless of the surgical technique, functional outcomes and pain scores improved. Patients with central stenosis, who underwent surgery using the midline-preserving technique were more likely to undergo a new surgery than those who had the midline structures removed. However, patients with lateral recess stenosis who underwent midline-removing surgeries experienced more leg pain and rated their functional outcomes lower compared to those who underwent midline-preserving surgery.

In our study, postoperative ODI improvement reached the estimated MCID in both central and lateral recess stenosis groups during follow-up. At 5 years, the ODI improvements in central stenosis was 17.8 points with midline-preserving, and 15.6 points with midline-removing technique. In the lateral recess stenosis group, the corresponding values were 18.7 and 10.8, respectively. The estimated MCID for ODI improvement was 8.2 points, which is consistent with values often used in the literature [17]. The difference in the change in ODI between the operative technique groups in the central stenosis group did not reach the MCID. However, in the lateral recess stenosis group, the difference in the change in ODI reached statistical significance between the surgical techniques, in favor of the midline-preserving group but the confidence interval does not allow for an interpretation of whether the difference is clinically significant. Cochrane reviews by Overdevest et al. in 2015 and by Machado et al. in 2016 could not establish superiority between midline-preserving and midline-removing techniques in terms of disability [5, 6]. Elmqvist et al. also found no significant differences in ODI between the techniques during 2-year follow-up [8]. However, Zhang et al. reported that midline-preserving techniques resulted in better outcomes for functional recovery and patient satisfaction compared to traditional laminectomy [7]. Also, Nerland et al. identified a statistically significant difference in ODI changes favoring the midline-preserving over laminectomy, but this difference was not considered clinically significant, leading to the conclusion that the techniques were equivalent [9].

Improvement in VAS for leg and back pain reached the MCID in both stenosis groups, regardless of the surgical technique, during the first 2 years. However, at 5 years, the change in VAS for leg or back pain in the lateral recess stenosis group after midline-removing surgery did not reach the MCID. The difference in the change in VAS for leg or back pain between the operative technique groups in the entire patient population did not reach the MCID. However, in the lateral recess stenosis group, the difference in the change in VAS for leg pain was statistically significant in favor of the midline-preserving techniques but the confidence interval does not allow for an interpretation of whether the difference is clinically significant. We hypothesize that laterally compressed nerve root may not be as easily and adequately decompressed through a midline-removing technique. Therefore, a unilateral or bilateral approach might provide better outcomes in terms of alleviating radiating leg pain. However, fewer lateral recess stenosis patients underwent midline-removing surgery in our data leaving this subgroup quite small and poor answering percentage in the follow up time points might compromise the reliability of the results. In previous studies, neither technique has been shown to be superior in terms of postoperative leg pain [5–8].

Biomechanical models suggest that removing posterior structures may compromise spinal stability and potentially lead to adjacent segment disease [18, 19]. However, clinical evidence remains inconclusive [20]. In our study, the midline-removing technique did not result in a higher probability of new operations during the follow-up period. On the contrary, the midline-preserving technique led to higher probability of new operations in the central stenosis group. We hypothesize that this is due the fact that "new surgeries" include new operations at the contralateral side of the index level. We hypothesize that possibly better access to the spinal canal and thus better conditions to perform an adequate decompression of the neural structures with plausible lower risk of restenosis compared to minimally invasive techniques might explain the difference in favor of midline-removing techniques. In addition, a better prerequisite to preserve a larger part of the facet joints might be beneficial for stability.

Our data is derived from a national registry that covers most spinal surgeries performed in Finland, allowing the opportunity to use comprehensive data from different clinics and surgeons, which enables authentic clinical setting on patient selection and large patient population [10, 11]. 5-year follow-up time enables evaluation of long-term benefits and reoperations which are relevant to patients and surgeons treating LSS. Although, since patients operated until the end of the year 2022 were included, a considerable number of patients have not yet reached the 5-year follow-up time-point, which naturally limits the interpretation of the 5-year results. Unlike earlier registry studies, FinSpine offers the advantage of assessing outcomes between the surgical techniques according to stenosis anatomical location.

We acknowledge our study has several limitations. First, registry data introduces selection bias. The reason to choose particular surgical technique may differ due to patient- or clinician-related factors and preferences. We have tried to minimize this by adjusting our analysis. Second, even though we had information on whether the midline structures were removed or spared during surgery, we could not identify the specific technique used. Further studies are needed to compare differences in outcomes between different decompression techniques within the two groups. Third, the PROM response rate was 41–48% depending on the time point, which is lower than optimal for extrapolating the results. However, FinSpine is a relatively new registry, and its use has expanded gradually [10]. According to Solberg et al., loss to follow-up does not indicate worse outcomes in non-responders [21]. Hatakka et al. also studied this particular patient population using the FinSpine dataset and conducted a subgroup analysis of the non-responders, finding that they did not have significantly different baseline PROMs [22]. Additionally, we could not differentiate whether the new surgery was performed at the contralateral side of the index level or at other levels, nor the surgical techniques used for new operations or reoperations. Furthermore, we do not know whether the patients with lateral recess stenosis had unilateral or bilateral symptoms or decompressions.

Conclusion

In our study, patients improved in terms of functional outcomes and pain regardless of the surgical technique. Our study suggests that, in case of central stenosis, midline-preserving decompression might lead to new operations more often than midline-removing decompression. For lateral recess stenosis, a question is raised whether surgery by midline-preserving decompression might benefit patients more.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00586-025-09271-4.

Acknowledgements The authors thank the FinSpine committee who have worked on developing this registry.

Author contributions CRediT authorship contribution statement: NP: Writing – original draft, Writing – review & editing, Visualization. IR: Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. KP: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Conceptualization. JK: Writing – review & editing, Visualization, Formal analysis, Data curation. HS: Writing – review & editing, Resources. IL: Writing – review & editing, Supervision, Project administration,

Methodology, Conceptualization.

Funding Open Access funding provided by University of Turku (including Turku University Central Hospital).

Data availability The data supporting the findings of this study are available from the Finnish Institute for Health and Welfare. Restrictions apply to the availability of these data, as they were used under license for this study. Access is available with permission from the Finnish Institute for Health and Welfare.

Declarations

Competing interests The authors declare that they have no known potential conflicts of interest influencing the work with this paper. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Other financial disclosures outside the submitted work: I. Laaksonen: yearly institutional research support funding from Southwestern Finland, institutional travel fund from Arthrex and Styker.

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