To fuse or not to fuse: The elderly patient with lumbar stenosis and low-grade spondylolisthesis. Systematic review and meta-analysis of randomised controlled trials

Abdel-Rahman Abdel-Fattah [a,b], *Fraser Bell* [b], *Luke Boden* [b], *Jamie Ferry* [b], *Conall McCormick* [b], *Matthew Ross* [b], *Isobel Cameron* [b,c], *Toby Smith* [d], *Santosh Baliga* [e], *Phyo K. Myint* [a,*]

[a] *Ageing Clinical and Experimental Research (ACER) Team, Institute of Applied Health Sciences, School of Medicine, Medical Sciences & Nutrition, University of Aberdeen, Aberdeen, UK*
[b] *School of Medicine, Medical Sciences & Nutrition, University of Aberdeen, Aberdeen, UK*
[c] *Applied Health Sciences (Mental Health), University of Aberdeen, Royal Cornhill Hospital, Aberdeen, UK*
[d] *Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, UK*
[e] *Department of Trauma & Orthopaedics, Aberdeen Royal Infirmary, Aberdeen, UK*

ARTICLE INFO

Article history:
Received 30 November 2021
Received in revised form
10 February 2022
Accepted 17 February 2022
Available online 16 March 2022

Keywords:
Lumbar spinal stenosis
Degenerative spondylolisthesis
Decompression
Fusion
Back pain
Leg pain

ABSTRACT

Background: The optimum surgical intervention for elderly patients with lumbar spinal stenosis (LSS) and low-grade degenerative-spondylolisthesis (LGDS) has been extensively debated. We conducted a systematic review and meta-analysis of randomised-controlled-trials (RCTs) comparing the effectiveness of decompression-alone against the gold-standard approach of decompression-with-fusion (D + F) in elderly patients with LSS and LGDS.

Methods: A systematic literature search was performed on published databases from inception to October-2021. English-language RCTs of elderly patients (mean age over-65) with LSS and LGDS, who had undergone DA or D + F were included. The quality and weight of evidence was assessed, and a meta-analysis performed.

Results: Six RCTs (n = 531; mean age: 66.2 years; 57.8% female) were included. There was no difference in visual-analogue-scale (VAS) scores of back-pain (BP) or leg-pain (LP) at mean follow-up of 27.4 months between both DA and D + F groups (BP: mean-difference (MD) 0.24, 95%CI: −0.38–0.85; LP MD:0.39, 95%CI: −0.34–1.11). No difference in disability, measured by Oswestry-Disability-Index scores, was found between both groups (MD:0.50, 95%CI: −3.31–4.31). However, patients in DA group had less hospital complications and fewer adverse events (total-surgical-complications OR:0.57, 95%CI: 0.36–0.90), despite a higher rate of worsening DS (OR:3.49, 95%CI: 1.05–11.65). No difference in BP or LP was found in subgroup-analysis of open-laminectomy compared to posterolateral-fusion (PLF) (BP: MD: −0.24, 95%CI: −1.80–1.32; LP MD:0.80, 95%CI: −0.95–2.55).

Conclusions: DA is not inferior to D + F in elderly patients with LSS and LGDS. DA carries a lower risk of hospital complications and fewer adverse events, however, surgeons should weigh these findings with the increased risk of DS progressing post-operatively.

Abbreviations: DA, Decompression alone; D+F, Decompression with fusion; LSS, Lumbar spinal stenosis; LGDS, Low-grade degenerative spondylolisthesis; BP, Back pain; LP, Leg pain; VAS, Visual Analogue Scale; ODI, Oswestry Disability Index; JOA, Japanese Orthopaedic Association; PCS, Physical component summary; MCS, Mental component summary; SF-36, 36-item Short Form; QoL, Quality of Life.

* *Corresponding author*. Room 4:013, Polwarth Building, School of Medicine, Medical Sciences and Nutrition, Foresterhill, Aberdeen, AB25 2ZD, Scotland, UK. Fax: +44 0 1224 437911.
E-mail address: phyo.myint@abdn.ac.uk (P.K. Myint).

https://doi.org/10.1016/j.surge.2022.02.008

Introduction

Lumbar spinal stenosis (LSS) is the narrowing of the spinal and nerve root canals caused by hypertrophy of osseous and soft tissue structures within the lumbar vertebrae[1] which compresses the spinal nerves and blood vessels exiting the foramen. It clinically manifests with long-term radiculopathy; specifically, back pain (BP) and bilateral radicular leg pain (LP) and paraesthesia, with progression to lower limb weakness.[2,3] Symptoms are aggravated by walking upright, standing or hyperextension due to further narrowing of the vertebral canal.[2] It is one of the most prevalent pathologies in the elderly population affecting 200,000 adults in the United States. It is estimated by 2025 that 64 million elderly people will be affected by the condition.[4] In patients between the age of 40 to 49 years of age, the prevalence of LSS is estimated to be 3.8% in men and 1.4% in women increasing to 9.8% in men and 5.7% in women between ages 50 to 59 years.[5] LSS precipitates BP in both middle-aged and elderly patients resulting in loss of productivity and work hours in the working population and consequently significant economic burden.[6] Despite the dramatic decrease in quality of life (QoL) in those suffering and its overwhelming prevalence, an optimal treatment for elderly patients with both LSS and LGDS is yet to be definitively agreed. Surgical rates for LSS have grown significantly over the last decade, and currently, LSS is the most common reason for spinal surgery in patients 65 years and older.[7]

Recent studies have assessed the clinical effectiveness of DA and D + F in patients with LSS and LGDS. Two previous systematic reviews demonstrated that DA is not inferior to gold-standard D + F, irrespective of LGDS.[8,9] However, a number of recent studies have been published which may alter these conclusions. This study aims to determine whether DA is as effective as D + F in elderly patients, over the age of 65 years, with LSS and LGDS.

Methods and materials

A systematic review and meta-analysis of RCTs was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement guidance.[10]

Eligibility and study selection

The inclusion criteria for both comparisons included RCTs of elderly adult subjects (mean age over 65 years) with LSS and LGDS, comparing outcomes of interest between DA (by open laminectomy, bilateral laminotomy or micro-endoscopic decompression) and D + F (by posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF) or anterior lumbar interbody fusion (ALIF)). There were no limitations on geographical location. Exclusion criteria included: samples with mean age less than 65 years, patients with degenerative spondylolisthesis (DS) alone without LSS or with foraminal stenosis and studies with sample sizes of less than twenty subjects. Studies which did not compare both groups or assessed specific techniques of decompression or fusion (such as cage fusions only), studies with patient cohorts who did not undergo any instrumented fusions in their D + F group and fusions where no autogenous bone graft was used, were excluded.

Outcome measures

Primary outcomes were postoperative BP and LP measured using Visual Analogue scale (VAS) scores ranging from 0 to 10; higher scores indicating greater degree of pain. Secondary outcomes: (a) degree of disability by Oswestry Disability Index (ODI) ranging from 0 to 100; higher score indicating greater degree of disability[11] (b) QoL using 36-item short form (SF-36) survey: physical component summary (PCS) and mental component summary (MCS) scores[12]; (c) hospital complications: duration of operation, intra-operative blood loss and length of hospital stay and (d) adverse events: total number of surgical complications, incidence of dural tears, postoperative DS and reoperation rate.

Search strategy

Two authors [ANONYMOUS] independently performed a literature search using the databases: Ovid Medline, EMBASE, Cochrane Register of Systematic Reviews, Cochrane Register of Controlled Trials (CENTRAL), PubMed and Web of Science, from inception to June 2020. A manual search of reference lists of relevant reviews and their included studies was carried out.

Data extraction

Search strategies are shown in Supplementary File 1. Titles and abstracts were independently screened according to the PICOS criteria (Table 1) by two authors [ANONYMOUS] and full-text articles independently screened and assessed for eligibility. A third author [ANONYMOUS] resolved any discrepancies at title, abstract and full-text screening stages. The extracted data included basic study characteristics including participant age, gender, country of origin, surgical interventions and outcomes. Primary authors for all eligible trials were contacted to request missing data.

Quality assessment

Two authors independently performed data extraction [ANONYMOUS] of included RCTs and three authors assessed risk of bias [ANONYMOUS] in accordance with the Cochrane Handbook for Systematic Reviews of Intervention version 2.[13] The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) methodology was used by the aforementioned authors [ANONYMOUS] to assess the weight of evidence from the findings of the meta-analyses.[14]

Table 1 – PICOS diagram for inclusion and exclusion criteria.

	Inclusion	Exclusion
Patient	Elderly patients defined as mean age above aged 65 years or older. Lumbar Spinal Stenosis with Low-grade Degenerative Spondylolisthesis.	Studies with mean age <65 years old. <20 patients in the sample population. Patients with non-degenerative spondylolisthesis alone (no mention of lumbar spinal stenosis). Patients with foraminal stenosis (and not vertebral canal stenosis).
Intervention	Decompression alone (DA) by open laminectomy, bilateral laminotomy or micro-endoscopic decompression.	Any study not assessing the comparison of decompression versus decompression with fusion. Any study assessing techniques such as Coflex systems with no mention of DA and D + F.
Control	Decompression with fusion (D + F) by posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF) or anterior lumbar interbody fusion (ALIF).	No comparison to gold standard decompression with fusion. Papers that include only subgroups (e.g. cages only). Studies of purely non-instrumented or 'soft' fusion techniques used in all patients in the control arm. Fusions where no autogenous bone graft was used.
Outcomes	Postoperative back and leg pain (VAS score), degree of disability, QoL and hospital related outcomes: duration of operation, intraoperative blood loss, length of hospital stay, reoperation and surgical complications.	Any study that does not assess the outcomes of interest in this study.
Study	Randomised controlled trials (or equivalent e.g. prospective randomised study/randomised controlled study).	Any study methodology which does not adequately describe a randomised controlled trial methodology such as quasi-randomised trials, observational studies: retrospective analysis of RCT data, case reports, case–control, cross-sectional or cohort studies.

Data synthesis

Study heterogeneity was assessed for participant, intervention and study characteristics to determine if there was sufficient homogeneity of data pool. Where study homogeneity was assured by the review team, a meta-analysis was carried out. Meta-analysis results were expressed as weighted mean difference (MD) and 95% confidence intervals (CI), and dichotomous variables were reported as odd ratios (ORs) and 95% CI. Results were regarded as statistically significant if p-values were less than 0.05. Statistical heterogeneity was measured using the I^2 scores and a fixed-effects model was implemented. Subgroup analysis was performed for primary outcomes in patients undergoing open laminectomy (DA group) and PLF (D + F group) by excluding studies which used other techniques. Data were analysed using RevMan v.5.4 (Cochrane Collaboration, Oxford, UK).[15]

Results

Search results

The literature search (Fig. 1) generated 6690 records. Full-text articles were reviewed for 107 studies and six RCTs were eligible (N = 531).

Study characteristics

The characteristics of included studies are shown in Table 2. Mean follow-up was 27.4 months (range 24 months–37.2 months). There were 256 patients and 275 patients within the DA and D + F groups respectively (mean age = 66.2 years; 57.8% female). The surgical techniques used were defined as shown in Table 4. All study participants had a diagnosis of LSS and LGDS based on clinical and radiological criteria (Table 5). Clinical criteria in all studies included the presence of typical symptoms of: neurogenic claudication or radiculopathic leg pain with associated neurological symptoms. Three studies used slippage of >3 mm to define LGDS[16–18]. One study used vertebral slippage exceeding 5% to define LGDS[19] and two studies did not specify their criteria[20,21]. In the DA group, the surgical technique consisted of an open laminectomy in four studies[17,18,21] both open laminectomy (82%, n = 98) and bilateral laminotomy (18%, n = 22) in one study,[16] bilateral laminotomy only in one study[20] and micro-endoscopic decompression in one study.[19] In the D + F group, the surgical technique was PLF in all studies, however one study[16] also carried out PLIF in 5% of patients (n = 6) and non-instrumented fusion in 4% of patients (n = 5). One study[19] also carried out PLIF in 47% of patients (n = 8) and ALIF in 6% of patients (n = 1).

Quality appraisal

Three of the six studies did not perform or did not demonstrate good random sequence generation[17,20,21] (Fig. 2). Only two studies demonstrated adequate allocation concealment.[19,18] Nevertheless, all studies demonstrated very low rates of attrition bias.

Results of meta-analysis

Primary outcome measures: pain by visual analogue scale (VAS)

Three studies reported BP[19,16,18] and two studies reported LP[16,18] using VAS scores. The data showed no difference in BP or LP by VAS scores between patients who had undergone DA

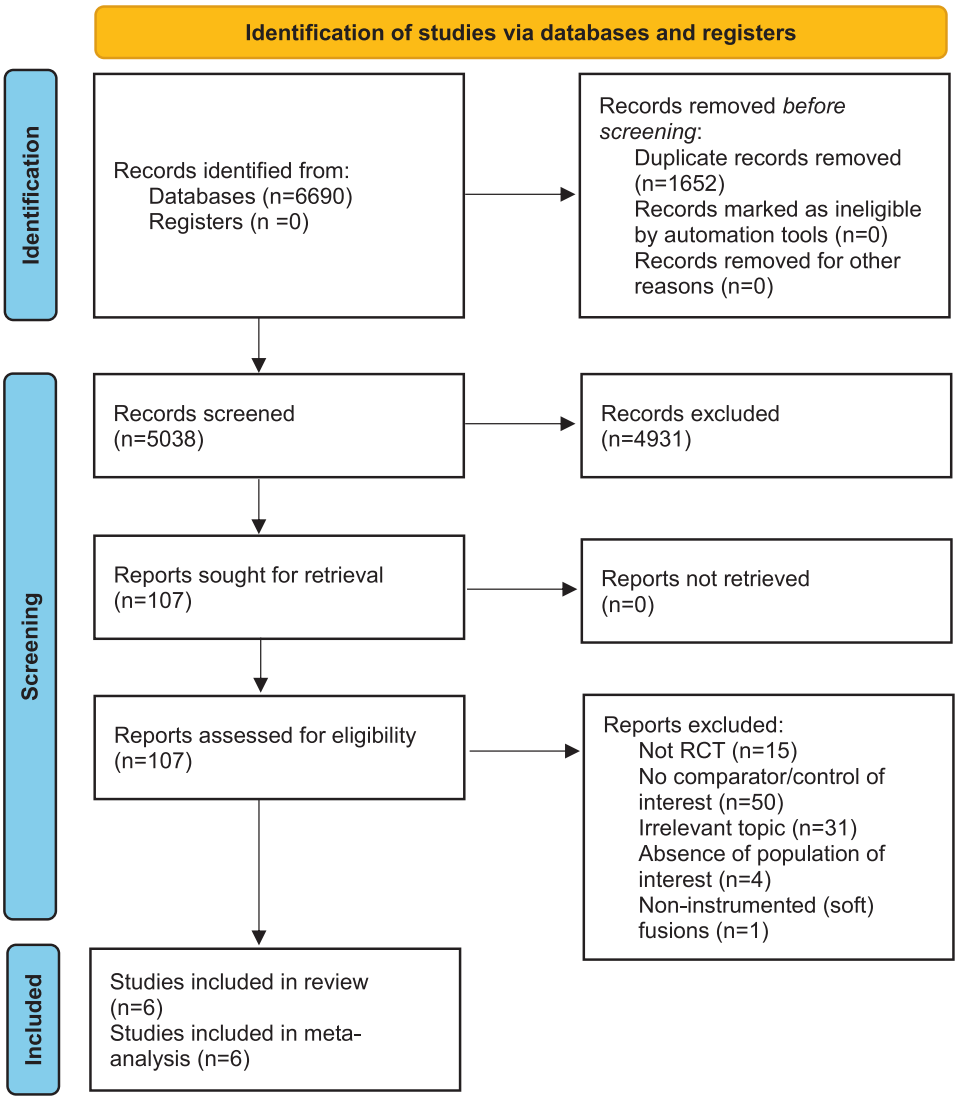

Fig. 1 – PRISMA Flow Diagram. *From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021; 372:n71. doi: 10.1136/bmj.n71.

versus D + F (BP: mean difference (MD) 0.24; 95% CI -0.38 to 0.85, p = 0.45, N = 329; LP: MD 0.39; 95% CI -0.34 to 1.11, p = 0.29, N = 279, GRADE: moderate) (Table 3). Similarly, a subgroup analysis comparing patients who underwent open laminectomy with those who underwent PLF showed no difference in post-operative BP and LP between the two groups at two years follow-up (BP: MD: −0.24, 95% CI: −1.80 to 1.32 p = 0.76, N = 51; LP MD: 0.80, 95% CI: −0.95 to 2.55, p = 0.37, N = 51, GRADE: moderate).

Secondary outcome measures

Degree of disability

Two studies reported data on degree of disability by ODI scores[16,17] (Table 3). The data showed no difference in degree of disability between patients who had undergone DA compared to D + F (MD 0.50 95% CI -3.31 to 4.31, p = 0.80, N = 294, GRADE: moderate)[18] reported no difference in post-operative disability scores, using Japanese Orthopaedic Association (JOA) scores, between patients who had undergone DA compared to D + F (MD -1.40; 95% CI -3.85 to 1.05; N = 58).

Quality of life

Only one study[17] reported data on QoL using SF-36 scores. This study showed that those who had undergone a DA had lower PCS score than those who had undergone D + F at two years (MD -5.70; 95% CI 2.24 to 9.16; N = 66, GRADE: moderate) and four years follow-up (MD -6.70; 95% CI -10.16 to −3.24; N = 66, GRADE: moderate).

Hospital complications

Five studies reported duration of operation and volume of blood lost intra-operatively[16–20] whilst four reported data on length of hospital stay[16–19] There was shorter duration of operation (MD -68.84; 95% CI -76.03 to-61.66; p < 0.00001, N = 449, GRADE: low), less volume of intra-operative blood loss (MD -389.29; 95% CI -411.30 to-367.29, p < 0.00001, N = 434,

Table 2 – Characteristics of included studies.

Study reference	Design	Participants (N = 531)	Age (SD)	% female	Intervention (N = 256)	Comparison (N = 275)	Outcomes	Mean follow-up time
[18]	Multi-centre RCT, Japan	80 D 40 D + F 40	D 63.4 (8.6) D + F 61.2 (6.7)	D 41% D + F 65%	Open laminectomy (n = 40)	PIF + autogenous iliac crest bone graft and pedicle screw fixation (n = 40)	VAS pain score, JOA pain score, surgical parameters and hospital-related outcomes and surgical complications	24 months
[17]	Multi-centre RCT, USA	66 D 35 D + F 31	D 66.5 (8.0) D + F 66.7 (7.2)	D 77% D + F 84%	Open laminectomy and medial facetectomy (n = 35)	PLF (pedicle screws and titanium alloy rods) + autogenous iliac crest bone graft (n = 31)	ODI score, SF-36 summary, and hospital-related outcomes	24 months
[22]	Multi-centre RCT, Sweden	247 D 124 D + F 123	D 67.0 (7.0) D + F 68.0 (7.0)	D 59% D + F 39%	Open laminectomy (n = 102) Bilateral laminotomy (n = 22) (Total n = 124)	PLF (n = 111) PLF (n = 7) Non-instrumented fusions (n = 5) +autogenous iliac crest bone graft (Total n = 23)	VAS pain score, ODI score, EQ-SD, ZCQ, complications and reoperations	24 months
[19]	Single-centre RCT, Japan	50 D 33 D + F 17	D 63.0 (10.2) D + F 65.0 (9.2)	D 33% D + F 45%	MED using tubular retractor with preservation of posterior structures (n = 33)	PLF with pedicle screws (n = 8) PLIF with inter body cages (n = 8) ALIF (n = 1) (Total n = 17)	JOA back pain score	27 months
[20]	Single-centre RCT, Switzerland	45 D 15 D + F 30	D 66.0 D + F 71.0	D 60% D + F 50%	Laminotomy and medial facetectomy (n = 15)	PLF with trans-laminar screws (n = 14) Cotrel-Dubosset instrumentation (trans-pedicle) (n = 16) + autogenous iliac crest bone graft (Total n = 30)	Subjective patient-reported pain (poor, fair, good, very good), VAS pain score, hospital-related outcomes	28 months
[21]	Single-centre RCT, USA	44 D 9 D + F 34	D 72.3 D + F 64.6	D 72% D + F 69%	Open laminectomy with preservation of facets bilaterally (n = 9)	PLF + autogenous iliac crest bone graft (n = 34)	Categorical functional assessment, hospital-related outcomes	37.2 months

*RCT = Randomised Controlled Trial, PLF= Posterolateral fusion, PLIF= Posterior Lumbar Interbody fusion, ALIF = Anterior Lumbar Interbody fusion, D = Decompression, D + F = Decompression with fusion, MED = Microendoscopic decompression, VAS= Visual analogue scale, ODI= Oswestry Disability Index, JOA = Japanese Orthopaedic Association, ZCQ = Zurich Claudication Questionnaire, EQ-5D = EuroQol-5D, SF-36 = 36-item short form survey, RMDQ = Rolland-Morris Disability Questionnaire.

GRADE: low) and shorter length of hospital stay (MD -43.04; 95% CI-52.82, −33.27, p < 0.00001, N = 404, GRADE: low) in patients who had undergone DA compared to D + F.

Adverse events

Six studies reported the total number of surgical complications[16–21] whilst three studies reported the number of dural tears,[16,18,20] post-operative DS,[18,21] and five studies reported data on reoperation rate[19,16,18,20,21]. The data showed that patients who had undergone DA had fewer total number of surgical complications than those who had undergone D + F (OR 0.57; 95% CI 1. 0.36 to 0.90, p = 0.02, N = 492, GRADE: moderate). However, those who had undergone DA had experienced more post-operative DS than patients who underwent D + F (OR 3.49; 95% CI 1.05 to 11.65, p = 0.04, N = 103, GRADE: moderate). There was no difference in incidence of dural tears or reoperation rate between the two groups (OR: 0.94; 95% CI

Table 3 – Summary of results from meta-analysis comparing outcomes in patients with lumbar spinal stenosis (LSS) with low-grade degenerative spondylolisthesis (LGDS) who had decompression alone (DA) versus patients who had decompression with fusion (D + F); mean difference (MD) for continuous variables, odds ratio (OR) for dichotomous variables and corresponding 95% confidence intervals (CI) reported.

Outcome	No. of participants (n)	Mean difference	95% CI	p-value
Back pain (VAS)	329	0.24	−0.38, 0.85	0.45
Leg pain (VAS)	279	0.39	−0.34, 1.11	0.29
Disability (ODI)	294	0.50	−3.31, 4.31	0.80
Hospital complications				
		Mean difference	95% CI	p-value
Duration of operation	449	−68.84	−76.03, −61.66	<0.00001
Intra-operative blood loss	434	−389.29	−411.30, −367.29	<0.00001
Length of hospital stay	404	−43.04	−52.82, −33.27	<0.00001
Adverse events				
		OR	95%CI	p-value
Total surgical complications	492	0.57	0.36, 0.90	0.02
Dural tears	334	0.94	0.44, 1.99	0.86
Post-op DS	103	3.49	1.05, 11.65	0.04
Reoperation	426	1.00	0.52, 1.94	1.00
Subgroup analysis of PLF[a]				
Outcome		Mean difference	95% CI	p-value
Back pain (VAS)	51	−0.24	−1.80, 1.32	0.76
Leg pain (VAS)	51	0.80	−0.95, 2.55	0.37

*PLF= Posterolateral fusion; VAS= Visual analogue scale; ODI= Oswestry Disability Index; DS = Degenerative Spondylolisthesis.
[a] Subgroup analysis reflects results from only one study.[18]

0.44 to 1.99, p = 0.86, N = 334, GRADE: moderate; OR 1.00; 95% CI 0.52 to 1.94, p = 1.00, N = 426, GRADE: low), respectively.

Discussion

The results of this systematic review indicate that there is no difference in BP or LP postoperatively between elderly patients with LSS and LGDS, who had undergone DA compared to those who had D + F. Data for degree of disability showed no

Table 4 – Surgical technique for Decompression alone (DA) group (N = 256) and Decompression with fusion (D + F) group (N = 275).

Paper	DA Technique	D + F Technique
[18]	Open **laminectomy** (n = 40)	Decompression and posterolateral fusion (**PLF**) + autogenous iliac bone graft and pedicle screw fixation (n = 40)
[16]	Open **laminectomy** by central decompression (82%, n = 98) Bilateral laminotomies with preservation of midline structures (18%, n = 22) (Total n = 124)	Decompression and **PLF** (90% n = 102), **PLIF** (5% n = 6) and non-instrumented (**soft**) fusions (4% n = 5) + autologous bone transplant from lamina or iliac crest for all fusions (Total n = 123)
[17]	Open **laminectomy** with complete laminectomy and partial medial (n = 35)	Decompression and **PLF** (pedicle screws and titanium alloy rods across level of spondylolisthesis) + bone graft harvested from iliac crest (n = 31)
[19]	**Micro-endoscopic decompression** using tubular retractor while preserving the posterior structures (n = 33)	Decompression and **PLF** with pedicle screws (n = 8), **PLIF** with inter body cages (n = 8) and **ALIF** (n = 1) + autologous bone graft from iliac crest (Total n = 17)
[20]	**Laminotomy** with widening of lateral recess and medial facetectomy (n = 15)	Decompression and **PLF** with trans-laminar screws (n = 14) or Cotrel-Dubosset instrumentation (trans-pedicle) (n = 16) + autologous bone graft from iliac crest (n = 30)
[21]	Open **laminectomy** with preservation of facets bilaterally (n = 9)	Decompression and **PLF** (transverse process) with instrumentation with one-level or two-level pedicle fixation + autogenous iliac crest bone graft (n = 34)
Total N = 531	**Open Laminectomy n = 184/256**	**Posterolateral Fusion n = 260/275**

Table 5 – Diagnostic criteria for case definition of Lumbar Spinal Stenosis (LSS) and Low-Grade Degenerative Spondylolisthesis (LGDS).

Paper	Clinical Criteria	Radiological Criteria
[18]	Presence of typical symptoms (neurogenic claudication or radicular leg pain with associated neurological signs) and findings from MRI and/or CT myelograms at L4/5 level.	LGDS defined as the presence of >3 mm of spondylolisthesis of the L4 vertebra on a plain lateral radiograph.
[16]	Presence of typical symptoms and findings on MRI.	MRI finding of LSS at one or two adjacent lumbar vertebral levels with cross-sectional area of dural sac measuring $\leq$75 mm^2. LGDS defined as the presence of a vertebra that had slipped forward $\geq$ 3 mm in relation to the vertebra below it.
[17]	Four standardised radiographic and MRI images for each patient to assess suitability by two neuroradiologists and one neurosurgeon to verify degenerative LSS with LGDS.	Grade I lumbar spondylolisthesis (defined as 3 to 14 mm) with LSS and neurogenic claudication with or without lumbar radiculopathy.
[19]	Presence of typical symptoms (unilateral or bilateral neurological symptoms) and radiological findings.	Plain radiographs and imaging studies consisting of a myelogram and contrast-enhanced CT and MRI with LSS at the level of spondylolisthesis. Vertebral slippage exceeding 5% was considered to indicate LGDS.
[20]	Based on history, clinical examination and CT myelography or MRI scan.	Mid-saggital diameter of spinal canal of <11 mm was considered stenotic. Instability of <5 mm with rotational instability of <5 mm.
[21]	Spinal claudication symptoms in all patients.	Coronal and lateral radiography, CT or CT myelography or MRI were used (criteria not specified).

difference whether patients had undergone either type of operation. Patients who had DA experienced less hospital complications and lower total number of surgical complications despite higher rates of post-operative DS.

Recent evidence points towards the non-inferiority of DA for treatment of LSS and LGDS compared to D + F. This hypothesis is supported by findings of a recent Cochrane systematic review of 24 studies with 2352 participants with LSS and LGDS concluding that D + F is not superior to DA.[23] Similarly, two previous systematic reviews demonstrated no difference in VAS pain or ODI scores between DA and D + F.[8,9] Similarly, a large observational study[22] of 4259 patients included in the National Swedish Register for Spine Surgery (Swespine), concluded that there was no significant difference in mean VAS LP scores ($p = 0.57$), ODI scores ($p = 0.33$) or EQ-5D scores ($p = 0.69$) between both treatment groups at two-years follow-up; regardless of the presence of pre-operative DS. A recent multicentre study of 306 patients enrolled in the Canadian Spine Outcomes and Research Network (CSORN) database showed clinically significant increased operative time, blood loss, length of hospital-stay and perioperative complications in the D + F group.[24] Nevertheless, both surgical interventions are not without their risks. DA was reported to be associated with post-operative vertebral instability.[25] On the contrary, albeit the lower rates of worsening of DS post-operatively, several studies have shown that D + F is associated with adjacent segment degeneration[26,27]. Another contentious issue is the economic burden of a fusion operation, having greater peri-operative cost implications as well as the economic consequences of higher complication rates ($p < 0.001$).[28]

This comprehensive systematic review and meta-analysis has a number of strengths. It presents the most up-to-date evidence from RCTs comparing the effectiveness of DA to D + F for elderly patients over 65 years with LSS and LGDS. We considered only experimental studies hence providing a higher level of evidence than if we had also included observational studies. The participants of studies represent a large demographic spread from various different healthcare systems which increases the generalisability and global applicability of our findings. All literature searches, data extraction, meta-analyses and quality appraisals were put through a rigorous cross-check by at least two independent researchers at every stage. This study also used the GRADE approach to evaluate the strength of the evidence allowing readers to appreciate the paucity of high-quality evidence on this subject area in the current literature. There are also some limitations worth highlighting. There was a high degree of heterogeneity in defining LGDS between included studies since different clinical and radiological criteria were used. Furthermore, surgical technique varied between studies, and within the patient cohorts of two studies.[19,16] We minimised this heterogeneity by clearly defining the acceptable surgical techniques in the inclusion criteria. Due to heterogeneity in follow-up time, there was an inadequate number of studies available to meta-analyse results at individual post-operative follow-up time points. In addition, there was a substantial lack of data with regards to walking ability and patient satisfaction in both comparisons.

Surgeons who operate on elderly patients with LSS and LGDS should be cognisant of the little benefit fusion provides for patients over a DA, as well as the increased risk of

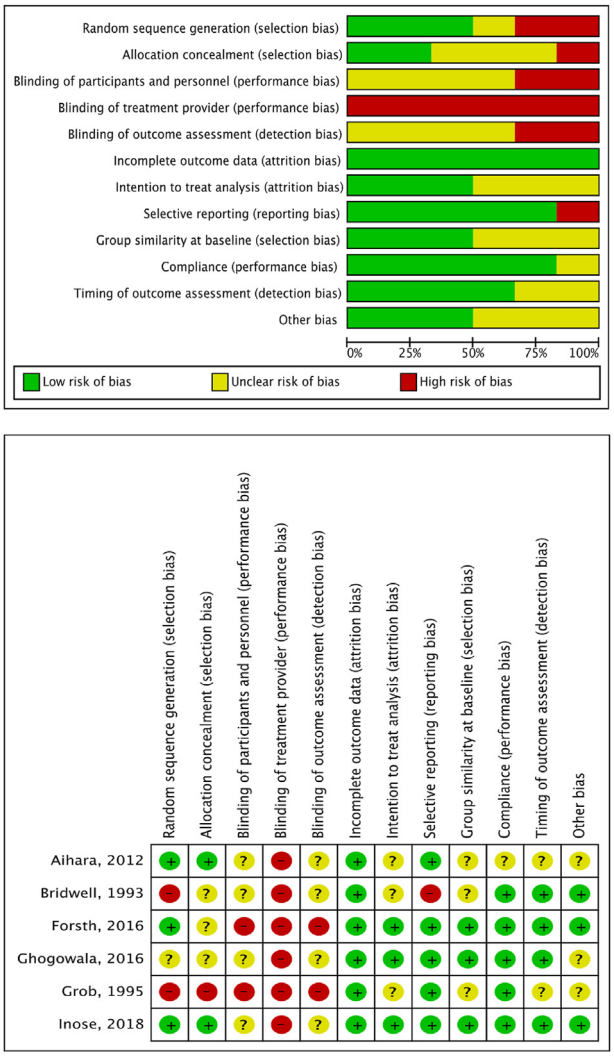

Fig. 2 – Risk of bias graph and risk of bias summary. *The authors judgement of each risk of bias item for each included study was categorised by 'low risk' (+), 'unclear' (?) and 'high risk' (–).

hospital complications and adverse events associated with fusion in this in age group. A thorough assessment of elderly patients with respect to their individual functional requirements as well as their comorbid conditions should be taken into account when justifying the addition of fusion in this age group. The clinical implication of the available evidence is substantially limited by low to moderate quality literature, therefore, further research is necessary to provide high quality evidence-based recommendations. This can be improved by standardising outcome measures and increasing follow-up length in the literature to allow both comparability of studies and address paucity of long-term follow-up data.

Conclusion

D + F is not a superior intervention to DA for elderly patients with LSS and LGDS. Although DA was found to be associated with lower hospital complications and adverse events, surgeons should balance this with the increased risk of progression of DS post-operatively. Given the low to moderate quality of RCTs comparisons, higher quality RCTs are warranted to ascertain the most appropriate surgical approach in managing LSS with LGDS in elderly patients.

Disclosures

None.

Funding

No funding received.

Declaration of competing interest

None declared.

Acknowledgements

AA: primary reviewer, literature review, data-analysis and drafting manuscript.

FB: literature review, data-analysis and drafting manuscript.

LB: critical appraisal, drafting manuscript.

JF: critical appraisal, drafting manuscript.

CM: critical appraisal, drafting manuscript.

MR: literature review, data-analysis and drafting manuscript.

IC: second reviewer, drafting manuscript.

TS: supervision, critical revision.

SB: supervision, senior reviewer for systematic review, critical revision.

PKM: supervision, senior reviewer for systematic review, critical revision.

PKM is the guarantor.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.surge.2022.02.008.

REFERENCES

[1]. Wu L, Cruz R. Lumbar spinal stenosis. Internet *StatPearls* 2020. PMID: 30285388, https://www;ncbi.nlm.nih.gov/books/NBK531493.

[2]. Siebert E, Prüss H, Klingebiel R, Failli V, Einhäupl K, Schwab J. Lumbar spinal stenosis: syndrome, diagnostics and treatment. *Nat Rev Neurol* 2009;**5**(7):392–403. https://doi.org/10.1038/nrneurol.2009.90.

[3]. Storm P, Chou D, Tamargo R. Lumbar spinal stenosis, cauda equina syndrome, and multiple lumbosacral radiculopathies. *Phys Med Rehabil Clin* 2002;**13**(3):713–33. https://doi.org/10.1016/S1047-9651(02)00013-X.

[4]. Wu A, Tong T, Wang X. A rethink of fusion surgery for lumbar spinal stenosis. *Evid Base Med* 2016;**9**(4):166–9. https://doi.org/10.1111/jebm.12215.

[5]. Ishimoto Y, Yoshimura N, Muraki S, Yamada H, Nagata K, Hashizume H, et al. Prevalence of symptomatic lumbar spinal stenosis and its association with physical performance in a population-based cohort in Japan: the Wakayama Spine Study. *Osteoarthritis Cartilage* 2012;**20**(10):1103–8. https://doi.org/10.1016/j.joca.2012.06.018.

[6]. Alvarez JA, Hardy RH. Lumbar spine stenosis: a common cause of back and leg pain. *Am Fam Physician* 1998;**57**(8):1825–34.

[7]. Lurie J, Tomkins-Lane C. Management of lumbar spinal stenosis. *BMJ* 2016;**4**(352):h6234. https://doi.org/10.1136/bmj.h6234.

[8]. Chang W, Yuwen P, Zhu Y, Wei N, Feng C, Zhang. Y, et al. Effectiveness of decompression alone versus decompression plus fusion for lumbar spinal stenosis: a systematic review and meta-analysis. *Arch Orthop Trauma Surg* 2017;**137**(5):637–50. https://doi.org/10.1007/s00402-017-2685-z.

[9]. Xu S, Wang J, Liang Y, Zhu Z, Wang K, Qian Y, et al. Decompression with fusion is not in superiority to decompression alone in lumbar stenosis based on randomized controlled trials: a PRISMA-compliant meta-analysis. *Medicine (Baltim)* 2019;**98**(46):e17849. https://doi.org/10.1097/MD.0000000000017849.

[10]. Page M, Moher D, Bossuyt P, et al. *PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews*. https://osf.io/preprints/metaarxiv/gwdhk/. [Accessed 10 October 2020].

[11]. Fairbank J, Couper J, Davies J. The Oswestry low back pain Questionnaire. *Physiotherapy* 1980;**66**:271–3.

[12]. Saris-Baglama RN, Dewey CJ, Chisholm GB, et al. *QualityMetric health outcomes™ scoring software* 4.0. Updated July, 2010, https://www.lynchburg.edu/wp-content/uploads/citation-style/Guide/to-AMA-Mnual-of-style.pdf?fbclid=IwAR3N-noEWvkESeHYq_3soAvYZW3egbTmeE37D5isf9oed6u4OVSgC_9OOXA. [Accessed 10 August 2020].

[13]. Higgins JPT, Thomas J, Chandler J. *Cochrane handbook for systematic reviews of interventions 2nd edition*. Updated March, 2011, https://training.cochrane.org/cochrane-handbook-systematic-reviews-interventions. [Accessed 12 August 2020].

[14]. Schünemann HJ, Oxman AD, Vist GE. *Cochrane handbook for systematic reviews of interventions version* 5.1.0. Updated March, 2011, https://training.cochrane.org/cohcrane-handbook-systematic-reviews-interventions. [Accessed 12 August 2020].

[15]. Review manager (RevMan) [Computer program]. *Version* 5.3. *Copenhagen: the nordic cochrane centre, the cochrane collaboration*. https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman, 2014. [Accessed 12 August 2020].

[16]. Försth P, Ólafsson G, Carlsson T, Frost A, Borgström F, Fritzell P, et al. A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med* 2016;**374**(15):1413–23. https://doi.org/10.1056/NEJMoa1513721.

[17]. Ghogawala Z, Dziura J, Butler W, Dai F, Terrin N, Magge S, et al. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. *N Engl J Med* 2016;**374**(15):1424–34. https://doi.org/10.1056/NEJMoa1508788.

[18]. Inose H, Kato T, Yuasa M, Yamada T, Maehara H, Hirai T, et al. Comparison of decompression, decompression plus fusion, and decompression plus stabilization for degenerative spondylolisthesis: a prospective, randomized study. *Clin Spine Surg* 2018;**31**(7):E347–52. https://doi.org/10.1097/BSD.0000000000000659.

[19]. Aihara T, Toyone T, Murata Y, Inage K, Urushibara M, Ouchi J. Degenerative lumbar spondylolisthesis with spinal stenosis: a comparative study of 5-year outcomes following decompression with fusion and microendoscopic decompression. *Asian Spine J* 2012;**12**(1):132–9. https://doi.org/10.4184/asj.2018.12.1.132.

[20]. Grob D, Humke T, Dvorak J. Degenerative lumbar spinal stenosis. Decompression with and without arthrodesis. *J Bone Joint Surg Am* 1995;**77**(7):1036–41. https://doi.org/10.2106/00004623-199507000-00009.

[21]. Bridwell KH, Sedgewick TA, O'Brien MF, Lenke LG, Baldus C. The role of fusion and instrumentation in the treatment of degenerative spondylolisthesis with spinal stenosis. *J Spinal Disord* 1993;**6**(6):461–72. https://doi.org/10.1097/00002517-199306060-00001.

[22]. Försth P, Michaëlsson K, Sandén B. Does fusion improve the outcome after decompressive surgery for lumbar spinal stenosis?: a two-year follow-up study involving 5390 patients. *Bone Joint Lett J* 2013;**95-B**(7):960–5. https://doi.org/10.1302/0301-620X.95B7.30776.

[23]. Machado G, Ferreira P, Yoo R, Harris I, Pinheiro M, Koes B, et al. Surgical options for lumbar spinal stenosis. *Cochrane Database Syst Rev* 2016;**11**(11):CD012421. https://doi.org/10.1002/14651858.CD012421.

[24]. Thomas K, Faris P, McIntosh G, Manners S, Abraham E, Bailey C, et al. Decompression alone vs. decompression plus fusion for claudication secondary to lumbar spinal stenosis. *Spine J* 2019;**19**(10):1633–9. https://doi.org/10.1016/j.spinee.2019.06.003.

[25]. Burgstaller J, Porchet F, Steurer J, Wertli M. Arguments for the choice of surgical treatments in patients with lumbar spinal stenosis – a systematic appraisal of randomized controlled trials. *BMC Muscoskel Disord* 2015;**16**:96. https://doi.org/10.1186/s12891-015-0548-8.

[26]. Levin D, Hale J, Bendo J. Adjacent segment degeneration following spinal fusion for degenerative disc disease. *Bull Hosp Joint Dis* 2007;**65**(1):29–36.

[27]. Park P, Garton H, Gala V, Hoff J, McGillicuddy J. Adjacent segment disease after lumbar or lumbosacral fusion: review of the literature. Phila Pa 1976 *Spine* 2004;**29**(17):1938–44. https://doi.org/10.1097/01.brs.0000137069.88904.03.

[28]. Ziino C, Mertz K, Hu S, Kamal R. Decompression with or without fusion for lumbar stenosis: a cost minimization analysis. Phila Pa 1976 *Spine* 2020;**45**(5):325–32. https://doi.org/10.1097/BRS.0000000000003250.