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-Fattaha,b, Fraser Bellb, Luke Bodenb, Jamie Ferryb, Conall McCormickb, Matthew Rossb, Isobel Cameronb,c, Toby Smithd, Santosh Baliga e, Phy o K. Myinta,*

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

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 to 0.85; LP MD:0.39, 95%CI: 0.34 to 1.11). No difference in disability, measured by Oswestry-Disability-Index scores, was found between both groups (MD:0.50, 95%CI: −3.31 to 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 to 0.90), despite a higher rate of worsening DS (OR:3.49, 95%CI: 1.05 to 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 to 1.32; LP MD:0.80, 95%CI: −0.95 to 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.

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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: phy o.myint@abdn.ac.uk (P.K. Myint).
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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.\(^5\) 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 report 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, post-operative 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.\(^14\)
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 I² 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 LGDS16–18. One study used vertebral slippage exceeding 5% to define LGDS and two studies did not specify their criteria. In the DA group, the surgical technique consisted of an open laminectomy in four studies17,18,21 both open laminectomy (82%, n = 98) and bilateral laminotomy (18%, n = 22) in one study,16 bilateral laminotomy only in one study20 and micro-endoscopic decompression in one study. In the D + F group, the surgical technique was PLF in all studies, however one study also carried out PLIF in 5% of patients (n = 6) and non-instrumented fusion in 4% of patients (n = 5). One study20 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 generation17,20,21 (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 BP19,16,18 and two studies reported LP6,15 using VAS scores. The data showed no difference in BP or LP by VAS scores between patients who had undergone DA

### Table 1 — PICOS diagram for inclusion and exclusion criteria.

<table>
<thead>
<tr>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient</strong></td>
<td>Elderly patients defined as mean age above aged 65 years or older.</td>
</tr>
<tr>
<td></td>
<td>Lumbar Spinal Stenosis with Low-grade Degenerative Spondylolisthesis.</td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
<td>Decompression alone (DA) by open laminectomy, bilateral laminotomy or micro-endoscopic decompression.</td>
</tr>
<tr>
<td></td>
<td>Decompression with fusion (D + F) by posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF) or anterior lumbar interbody fusion (ALIF).</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Decompression alone (DA).</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Study</strong></td>
<td>Randomised controlled trials (or equivalent e.g. prospective randomised study/randomised controlled study).</td>
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</tbody>
</table>
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 sub-group 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 -0.24, 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)\(^{18}\) 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 -1.40; 95% CI: 2.24 to 9.16; N = 58, 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.

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

*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, whilst three studies reported the number of dural tears, post-operative DS, and five studies reported data on reoperation rate. 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 1.05 to 1.10, 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
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 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.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>No. of participants (n)</th>
<th>Mean difference</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back pain (VAS)</td>
<td>329</td>
<td>0.24</td>
<td>−0.38, 0.85</td>
<td>0.45</td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>279</td>
<td>0.39</td>
<td>−0.34, 1.11</td>
<td>0.29</td>
</tr>
<tr>
<td>Disability (ODI)</td>
<td>294</td>
<td>0.50</td>
<td>−3.31, 4.31</td>
<td>0.80</td>
</tr>
</tbody>
</table>

### Hospital complications

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Mean difference</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of operation</td>
<td>−68.84</td>
<td>−76.03, −61.66</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Intra-operative blood loss</td>
<td>−389.29</td>
<td>−411.30, −367.29</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Length of hospital stay</td>
<td>−43.04</td>
<td>−52.82, −33.27</td>
<td>&lt;0.00001</td>
</tr>
</tbody>
</table>

### Adverse events

<table>
<thead>
<tr>
<th>Outcome</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surgical complications</td>
<td>0.57</td>
<td>0.36, 0.90</td>
<td>0.02</td>
</tr>
<tr>
<td>Dural tears</td>
<td>0.94</td>
<td>0.44, 1.99</td>
<td>0.86</td>
</tr>
<tr>
<td>Post-op DS</td>
<td>3.49</td>
<td>1.05, 11.65</td>
<td>0.04</td>
</tr>
<tr>
<td>Reoperation</td>
<td>1.00</td>
<td>0.52, 1.94</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Subgroup analysis of PLF

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Mean difference</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back pain (VAS)</td>
<td>−0.24</td>
<td>−1.80, 1.32</td>
<td>0.76</td>
</tr>
<tr>
<td>Leg pain (VAS)</td>
<td>0.80</td>
<td>−0.95, 2.55</td>
<td>0.37</td>
</tr>
</tbody>
</table>

*PLF= Posterolateral fusion; VAS= Visual analogue scale; ODI= Oswestry Disability Index; DS = Degenerative Spondylolisthesis.

### 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).

<table>
<thead>
<tr>
<th>Paper</th>
<th>DA Technique</th>
<th>D + F Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Open laminectomy (n = 40)</td>
<td>Decompression and posterolateral fusion (PLF) + autogenous iliac bone graft and pedicle screw fixation (n = 40)</td>
</tr>
<tr>
<td>16</td>
<td>Open laminectomy by central decompression (82%, n = 98)</td>
<td>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)</td>
</tr>
<tr>
<td>17</td>
<td>Bilateral laminotomies with preservation of midline structures (18%, n = 22) (Total n = 124)</td>
<td>Decompression and PLF (pedicle screws and titanium alloy rods across level of spondylolisthesis) + bone graft harvested from iliac crest (n = 31)</td>
</tr>
<tr>
<td>19</td>
<td>Open laminectomy with complete laminectomy and partial medial (n = 35)</td>
<td>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 = 31)</td>
</tr>
<tr>
<td>20</td>
<td>Micro-endoscopic decompression using tubular retractor while preserving the posterior structures (n = 33)</td>
<td>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)</td>
</tr>
<tr>
<td>21</td>
<td>Laminotomy with widening of lateral recess and medial facetectomy (n = 15)</td>
<td>Decompression and PLF (transverse process) with instrumentation with one-level or two-level pedicle fixation + autogenous iliac crest bone graft (n = 34)</td>
</tr>
<tr>
<td>Total N = 531</td>
<td>Open Laminectomy n = 184/256</td>
<td>Posteriorlateral Fusion n = 260/275</td>
</tr>
</tbody>
</table>
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. 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...
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.

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**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


