Effective of Fusion in the Treatment of Lumbar Spinal Stenosis: A Systematic Review And Meta-Analysis

Yang Yang (✉ 1278590247@qq.com)
Mianyang Central Hospital  https://orcid.org/0000-0003-2343-0591

Shi-tian Tang
Mianyang Central Hospital

Qian Chen
Mianyang Central Hospital

fang chen
Mianyang Central Hospital

Research

Keywords: Lumbar spinal stenosis, Degenerative Spondylolisthesis, Decompression, Fusion, Meta-analysis

Posted Date: November 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-868342/v1

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.  Read Full License
Abstract

Objective: The debate on efficacy of fusion added to decompression for lumbar spinal stenosis (LSS) is ongoing. The primary objective of this systematic review is to compare the outcome after decompression with and without fusion in patients with lumbar spinal stenosis.

Methods: A literature search was performed in the Web of Science, EMBASE, PubMed, and Cochrane Library from January 1990 to May 2021. The information of screened studies included clinical outcomes, and secondary measures, then data synthesis and meta-analysis were progressed. Data analysis was conducted using the Review Manager 5.0 software.

Results: 17 studies were included in the analysis involving 2947 patients in total. In the majority of studies, including seven RCTs and ten observational studies, the pooled data revealed that fusion was associated with significantly higher rates of back pain scores when compared with decompression alone in RCT subgroup (SMD = -0.42, 95% CI (-0.60, -0.23), Z = 4.31, P = 0.0001). However, fusion significantly increased the intraoperative blood loss, operative time and hospital stay. Both techniques had similar leg pain scores, EQ-5D, walking ability/ability to major complication, clinical satisfaction, and reoperation rate.

Conclusions: Our studies showed that the additional fusion in the management of LSS yielded no clinical improvements over decompression alone within a 1-year follow-up period. We suggested that the least invasive and least costly procedure, being decompression alone, is preferred in patients with degenerative lumbar spinal stenosis. The appropriate surgical protocol for LSS should be discussed further.

Introduction

Lumbar Spinal Stenosis (LSS) is one of the most common conditions in the elderly. It is defined as a gradual narrowing of the spinal canal, which usually results in neural compression. Patients with lumbar spinal stenosis typically present with neurogenic claudication, radicular pain, low back pain, which occur especially when they are walking[1]. Patients with significant symptoms that do not respond to conservative treatment often elect surgical treatment[2]. In fact, in adults older than age 65, spinal stenosis is the most common reason to undergo lumbar spine surgery[3]. Decompression alone has been proved to be beneficial for patients in the absence of instability. However, as spinal instability is a frequent consequence following laminectomy, and fusion surgery in addition to decompression surgery for the treatment of some patients with spinal stenosis[4]. Over the past decade, the incidence of lumbar fusion for degenerative indications has more than doubled from 7.5 per 100 000 in 2000 to 17.8 per 100 000 in 2009[5]. However, a recently published RCT article believes that additional fusion surgery in patients with LSS cannot bring better clinical results than simple decompression surgery[6]. Shen[7] published a meta-analysis that provides evidence of better clinical outcome but a higher reoperation rate for spinal fusion, compared with decompression alone. A large sample Meta-analysis concluded that complications and higher reoperation rate limit the benefits of fusion in lumbar spinal stenosis[8]. Although both surgical techniques are effective in treating LSS, lack of evidence supporting this rapid evolution of surgical techniques usually render the clinicians to rely on their personal experiences. Therefore, we conducted a meta-analysis to compare the surgical and prognostic outcomes of LSS quantitatively between decompression and decompression plus fusion and to provide further evidence to guide and standardize practice.

Methods

Literature search and evaluation

We performed this systematic review and meta-analysis following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement[10]. An online search was performed in the Web of Science, EMBASE, PubMed, and Cochrane Library from January 1990 to May 2021. Relevant references were selected and the included studies were manually reviewed. We present the search strategy as follows: (laminotomy OR laminectomy OR fenestration OR hemilaminectomy OR decompression) AND (lumbar spondylolisthesis OR lumbar spinal stenosis OR lumbar canal stenosis OR degenerative lumbar spondylolisthesis) AND (fusion OR arthrodesis). The search strategy is detailed in Fig. 1.

Eligibility criteria

Included studies fulfilled the following criteria:

1. They were randomized controlled trials (RCTs) or clinical comparative observation studies written in English;
2. The studies assessed the comparison between decompression alone versus decompression plus fusion surgery for LSS;
3. LSS was with or without Lumbar spondylolisthesis;
4. The comparative data of clinical outcomes, major complications, reoperations, and other perioperative desirable outcomes could be acquired, and;
5. The sample size was bigger than 10 per group and a minimum follow-up time of 1 year.

Exclusion criteria

1. Non-English-language articles;
2. No randomized controlled trials (RCTs) or clinical comparative observation studies, biomechanical study, cadaveric study, editorials, conference presentations, case report, reviews, expert opinions, and comment;
(3) Without a controlled group or with a small sample size (<10 patients per group);
(4) Participants mixed tumors, fractures, osteoporosis, or other irrelevant diseases;
(5) Studies with incomplete or unacceptable clinical information for a comparison.

Data extraction
Two authors independently sorted and reviewed all abstracts or full texts of the retrieved articles based on eligibility and exclusion criteria. Whenever disagreement arose about inclusion, a third reviewer (CVL) was consulted. Data from the included studies regarding the following items were extracted: (1) the basic characteristics of each study: the first author's last name, publication year, country, age, sex ratio, research period, comorbidities, surgery type, and follow-ups (more than 1-year period) were reported. (2) Primary measures included functional outcomes and results of pain evaluation such as back pain and leg pain, walking ability, quality-of-life EuroQol-5 Dimensions (EQ-5D), Oswestry Disability Index (ODI) scores, Numerical Rating Scale (NRS), and Japanese Orthopaedic Association (JOA) scores. (3) Secondary measures included incidence of complications and reoperations, operation time, blood loss, Clinically satisfaction, and length of hospitalization.

Risk of bias assessment
Two investigators independently graded each eligible study because both RCTs and comparative observational studies were included in current study, we applied two assessing tools to appraise the methodological quality. For RCTs, we used the Cochrane Handbook for Systematic Reviews of Interventions, version 5.0[9] for RCTs. The domains included sequence generation, allocation sequence concealment, blinding, incomplete outcome data, selective reporting, and other bias. Each domain of quality assessment was classified as adequate (A), unclear (B), or inadequate (C). If all domains were A, the study was A-level; if at least 1 domain was B, the study was B-level; if at least 1 domain was C, the study was C-level. For comparative observational studies, the Newcastle–Ottawa Scale (NOS) was assessed for quality evaluation[10]. As recommended by the Cochrane Non-Randomized Studies Methods Working Group, that based on assessing three dimensions: selection quality, comparability, and exposure. Scale scores range from zero to nine points, with higher scores indicating better quality.

Statistical analysis
Statistical analyses were performed using the Cochrane Collaboration's Review Manager 5.0 software. Subgroup analysis of RCTs versus observational studies was conducted to explore potential heterogeneity. A Z test was performed to determine the overall effects. If the heterogeneity between studies was statistically significant ($I^2 \geq 50\%$), a random effects model was used for further sensitivity analysis. Otherwise, a fixed effects model was selected ($I^2 < 50\%$). Risk ratio (RR) and 95% confidence interval (CI) were used for dichotomous variables. Weighed mean difference (WMD) and 95% CI were used for continuous variables if outcome measurements in all studies were conducted on the same scale. Otherwise, standardized mean difference (SMD) and 95% CI were used. $P \leq 0.05$ was considered statistically significant. Sensitivity analysis was examined by removing one individual study at one time to check heterogeneity that biased the overall estimate.

Results

Literature search
The literature search yielded 17 studies (7 randomized controlled trials, 10 comparative observational studies) enrolling a total of 2947 patients (Fig. 1).

Study description
There were 2947 patients enrolled in the 17 studies. Overall, 1436 (48%) patients with LSS received decompression surgery alone, compared to 1511 (52%) patients who underwent decompression plus fusion surgery. The number of females and males was available in 15 studies containing 1837 females and 861 males. Two studies do not give accurate gender data. While the likely dominant age was approximately 65 years, females were higher in numbers and average onset age than males. Characteristics of the 17 studies are shown in Table 1.
| Numbers | References | Year | Country | Design | Case number (D/DF) | Age (year) | Sex ratio (F/M) | Surgical types (D/DF) | Follow-ups (year) | Outcomes |
|---------|------------|------|---------|--------|-------------------|------------|----------------|----------------------|------------------|----------|
| 1       | Forsth et al.[6] | 2016 | Sweden  | RCT    | 66/67             | D: 67 ± 7; DF: 68 ± 7 | 73female / 60 male | D: Decompression alone; DF: Fusion plus decompression | 5 | Clinical, complication rate, reoperation rate, blood loss, operative time |
| 2       | Ghogawala et al.[11] | 2016 | America | RCT    | 35/31             | D: 66.5 ± 8.0; DF: 66.7 ± 7.2 | 53female / 13 male | D: Complete laminectomy with partial removal of the medial facet joint; DF: Laminectomy + instrumented fusion | 4 | Clinical, complications rate, reoperations rate, blood loss, operative time, hospital stay |
| 3       | Aleksandra et al.[12] | 2014 | Poland  | RCT    | 46/47             | D: 61.28 ± 12.08; DF: 57.74 ± 9.22 | NA | D: Decompression by fenestration; DF: PLIF and the use of porous ceramic corundum implants | 10 | Clinical, length of operation, blood loss, days of hospitalization |
| 4       | Kleinstueck et al.[13] | 2011 | Switzerland | RCT    | 56/157             | D: 73.0 ± 8.0; DF: 67.4 ± 9.4 | 155female / 58 male | D: Laminectomy + lateral recess decompression; DF: Decompression with TLIF, PLIF or PLF | 1 | Clinical, complication rate, blood loss |
| 5       | Grob et al.[14] | 1995 | Sweden  | RCT    | 15/30             | D: 66; DF: 71 | NA | D: Decompression; DF: Decompression + PLF | ≥ 2 | Clinical, complications rate, blood loss |
| 6       | Bridwell et al.[15] | 1993 | America | RCT    | 9/34              | NA | 32female / 11 male | D: Decompression; DF: Decompression + PLF | ≥ 2 | Clinical, complication rate, reoperation rate, and radiologic outcomes |
| 7       | Herkowitz et al.[16] | 1991 | America | RCT    | 25/25             | D: 65; DF: 68.5 | 36female / 14 male | D: Laminectomy; DF: Laminectomy + PLF | 3 | Clinical and radiologic outcomes |
| 8       | Thomas et al.[17] | 2019 | Canadian | R,OS   | 199/107           | D: 65.6 ± 11.6; DF: 63.2 ± 9.9 | 112female / 184 male | D: Decompression; DF: Decompression + Fusion | 2 | Clinical, complications rate, radiologic outcomes |
| 9       | Aihara et al.[18] | 2018 | Japan   | R,OS   | 25/16             | D: 63.0 ± 10.2; DF: 65.0 ± 9.15 | 21female / 20 male | D: Microendoscopic decompression; DF: Decompression + Fusion | 5 | Clinical, blood loss, operative time, hospital stay |
| 10      | Ulrich et al.[20] | 2017 | Switzerland | R,OS   | 85/46             | D: 75.4 ± 7.6; DF: 68.0 ± 7.8 | 76female / 55 male | D: Decompression; DF: Decompression + Fusion | 5 | Clinical, radiologic outcomes |
| 11      | Inui et al.[19] | 2016 | Japan   | R,OS   | 60/80             | D: 63.6 ± 8.4; DF: 69.3 ± 8.8 | 89female / 51 male | D: Decompression; DF: Decompression + PLIF | ≥ 1 | Clinical, complication rate, reoperation rate, radiologic outcomes |
| 12      | Sigmundsson et al.[20] | 2015 | Sweden  | R,OS   | 73/130            | D: 73.8 ± 9.3; DF: 68.8 ± 8.7 | 120female / 83 male | D: Decompression; DF: Decompression with PLIF | 2 | Clinical outcome |
We assessed the validity and the quality of the seven included RCTs, using Cochrane Risk of Bias tool provided in RevMan. One study was A-level quality, 3 articles were B-level, and 3 articles were C-level with a moderate risk of bias (Fig. 2). Ten observational studies were evaluated using Newcastle-Ottawa Scale (NOS), and we made the quality score table into a chart using the Revman system, which may be more intuitive. According to the NOS score, more than 6 points are considered as high-quality literature (Fig. 3). Stratification by design and meta-regression for quality was performed to identify and mitigate allocation and performance biases in each pooled estimate.

### Primary outcomes

#### Back pain

Eleven studies reported changes in back pain between the two subgroups, including 6 based on VAS, 3 based on JOA and 2 based on NRS. Because of the high reliability of randomized controlled trials, we divided the included studies into two subgroups. One is RCT, and the other is observational research. With regard to the overall results of heterogeneity testing, there was a statistically significant difference between the two groups ($P = 0.0002$, $I^2 = 71$%), and a random effects model was applied for meta-analysis (Fig. 4). Through the statistical analysis of preoperative and postoperative back pain, it was found that there was significant statistical significance between decompression and fusion groups in the subgroup analysis of RCT. The improvement of back pain in fusion group is better than that in decompression group. But in the subgroup analysis of comparative observational studies, there was no statistical significance between the two surgical methods (RCT subgroup, SMD = -0.42, 95% CI (-0.60, -0.23); $Z = 4.31, P < 0.0001$; comparative observational studies subgroup, SMD = -0.04, 95% CI (-0.23, 0.15); $Z = 0.44, P = 0.66$).

#### Leg pain

In the study we included, 5 articles used VAS to score leg pain, 2 articles used JOA to score leg pain, and 2 articles used NRS to score leg pain. A heterogeneity test indicated no statistically significant difference between the two groups ($P = 0.12$, $I^2 = 37$%). Although the combined effect of the study shows that the study is homogeneous, because the pain scoring system is used differently and the research type is different, in order to increase the credibility of the data analysis, we use the random effect model for meta-analysis (Fig. 5). In the RCT subgroup, SMD = -0.27, 95% CI (-0.55, 0.01), $Z = 1.88$, and $P = 0.06$; in the comparative observational studies subgroup, SMD = 0.04, 95% CI (-0.05, 0.13), $Z = 0.95$, and $P = 0.34$. These results demonstrated that the differences in pre- and post-operative leg pain were not significantly different between the two groups.

### ODI

Eight studies reported ODI in the two groups. The heterogeneity test showed a statistically significant difference between the two groups ($P = 0.001$, $I^2 = 71$%), and a random effects model was applied for meta-analysis (Fig. 6). There was no significant difference in ODI between the decompression group and the decompression plus fusion group (RCT subgroup, MD = 2.90, 95% CI (-3.24, 9.03), $Z = 0.93$, $P = 0.35$; comparative observational studies subgroup, MD = 1.58, 95% CI (-1.84, 5.00), $Z = 0.90$, $P = 0.37$).
EQ5D

Four studies reported EQ-5D in the two groups. There was no statistically significant heterogeneity between the two groups ($P = 0.68, I^2 = 0\%$), and a fixed effects model was applied for meta-analysis (Fig. 7). No statistically significant difference was identified between the two groups (RCT subgroup, MD = 0.06, 95% CI (−0.04, 0.16), $z = 1.17, P = 0.24$; comparative observational studies subgroup, MD = 0.01, 95% CI (−0.01, 0.02), $Z = 0.71, P = 0.48$).

Walking ability

Two comparative observational studies reported walking ability in the two groups. The heterogeneity test showed no statistically significant difference between the two groups ($P = 0.29, I^2 = 11\%$), and a fixed effects model was applied for meta-analysis (Fig. 8). There was no significant difference in walking ability between the decompression group and the decompression plus fusion group (MD = 0.01, 95% CI (−0.54, 0.56), $Z = 0.03, P = 0.98$).

Secondary outcomes

Intraoperative blood loss

Six studies reported the intraoperative blood loss in the two groups. There was statistically significant heterogeneity between the two groups ($P < 0.00001, I^2 = 99\%$), and a random effects model was applied for meta-analysis (Fig. 9). The intraoperative blood loss was demonstrated that the blood loss in the decompression alone group was significantly less than in the decompression plus fusion group (RCT subgroup, MD = 361.97, 95% CI (−637.16, -86.77), $Z = 2.58, P = 0.010$, comparative observational studies subgroup, MD = 322.99, 95% CI (−396.40, -249.58), $Z = 8.62, P < 0.00001$).

Length of hospital stay

Five studies reported the length of hospital stay in the two groups. Statistically significant heterogeneity was found between the two groups ($P < 0.003, I^2 = 76\%$). A random effects model was applied for meta-analysis (Fig. 10). The length of hospital stay was statistically different between the decompression alone group and decompression plus fusion group. (RCT group MD = -2.06, 95% CI (−3.03, -1.08), $Z = 4.13, P < 0.0001$. Comparative observational studies group (MD = -3.06, 95% CI (−4.25, -1.88), $Z = 5.06, P < 0.00001$). The Length of hospital stay in fusion group is much longer than decompression group.

Duration of operation

Six studies reported the duration of operation in the two groups. There was statistically significant heterogeneity between the two subgroups ($P < 0.00001, I^2 = 96\%$). A random effects model was applied for meta-analysis (Fig. 11), which indicated that the decompression plus fusion group underwent more operative time than the decompression alone group. (in RCT subgroup MD = -86.53, 95% CI (−167.68, -5.38), $Z = 2.09, P = 0.04$. In comparative observational studies group MD = 81.90, 95% CI (−102.25, -61.55), $Z = 7.89, P < 0.0001$).

Major complications

Nine studies reported major complications in the two groups with a heterogeneity test showing statistically significant heterogeneity between groups ($P < 0.00001, I^2 = 83\%$). A random effects model was applied for meta-analysis (Fig. 12), which indicated that there was no significant difference in Major complications between the decompression group and the decompression plus fusion group (RCT subgroup, RR = 1.62, 95% CI (0.77, 3.41), $z = 1.27, P = 0.20$. Comparative observational studies subgroup, RR = 0.47, 95% CI (0.17, 1.27), $z = 1.49, P = 0.14$).

Number of reoperation

Eight studies reported reoperation numbers in the two groups. Low heterogeneity was identified between the two groups ($P = 0.23, I^2 = 25\%$). Because the article is a two-category variable and the research types of the two subgroups are different, so a random effects model was applied for meta-analysis (Fig. 13). There was no statistically significant difference between the two groups (RCT subgroup, RR = 1.52, 95% CI (0.94, 2.46), $Z = 1.72, P = 0.09$. Comparative observational studies subgroup [RR = 0.65, 95% CI (0.1, 2.61), $Z = 0.61, P = 0.54$]).

Clinically satisfaction

Six studies reported the clinically satifactions in the two groups. A significantly different heterogeneity was found between the two subgroups ($P < 0.00001, I^2 = 84\%$), and a random effects model was applied for meta-analysis (Fig. 14). The clinical satisfaction in the decompression plus fusion group was not better than in the decompression alone group [RR = 0.83, 95% CI (0.60, 1.14), $Z = 1.15, P = 0.25$].

Sensitivity analysis

For the studies with $I^2 \geq 50\%$, we used the random effect model to analyze the heterogeneity, and we used the article-by-article elimination literature method to analyze the indicators with heterogeneity. Because of the statistical differences in back pain scores between the RCT subgroup and the observational subgroup, we focused on the source of their heterogeneity. There was no significant change in heterogeneity after excluding the sensitivity of literature analysis. The analysis of ODI, Major complications, Duration of operation and Clinically satisfaction showed that the slight change of heterogeneity was not statistically significant. This proves that our research results are more reliable.

Discussion
The debate on efficacy of decompression versus decompression plus fusion in lumbar spondylolisthesis has never stopped and more intensified over several decades. Hence, we performed a study design-specific evaluation to conduct a stratified analysis for an accurate conclusion. There are some differences between our meta-analyses and the previous analysis. First, the included studies were updated, and in order to increase the credibility of the article, we included 10 observational studies. These included studies with high quality in the current meta-analysis. Second, we compared all the clinical efficacy observation indicators and divided them into primary indicators and secondary indicators, which was not done in the previous article.

From the current available comparative studies, the present study showed that (1) in the analysis of back pain, we found that there was no difference between the decompression group and the fusion group in observational studies subgroup, but the curative effect of the fusion group was better than that of the decompression group in RCT subgroup. (2) No difference in leg pain scores, EQ-5D, walking ability, OD1, major complication, clinical satisfaction, and reoperation rate was found between decompression plus fusion and decompression alone; and (3) decompression alone was associated with significantly less intraoperative blood loss, operative time and hospital stay. In our meta-analysis the different conclusions of the low back pain score between the two subgroups may have the following points: (1) The scoring system for low back pain is different. (2) The surgical technique, experience, and surgical indications of fusion are different. (3) Different baseline characteristics amongst the included studies in this review might have influenced pain and disability outcome. Xu S et al[^26] demonstrated that the primary outcomes deciding the majority efficacy such as the improvement of VAS, OD1, and walking ability were of no difference through the meta-analysis of 9 articles of RCT. Relevant publications suggested decompression alone to be significantly less invasive than that combined with fusion[^27,28,29].

Stability is an inevitable topic as a potential factors indicating the approach selection. Some scholars have reported that the probability of lumbar spondylolisthesis after simple decompression is as high as 31%[^4]. In order to reduce the occurrence of instability, spinal fusion was initially used by Harms and Rolinger to treat spondylolistheses[^30].

With the overuse of lumbar fusion, some studies have shown that spinal fusion is a more traumatic operation than decompression alone, which requires longer operation time, more blood loss, undue complications, and the misallocation of resources[^6,8]. As an invasive procedure, fusion has many uncertainties that can greatly influence the final outcomes of LSS. The altered biomechanical function of the spine, such as loss of motion at the fused levels, was compensated for by increased motion at the unfused segments. This process caused certain mechanical stresses, which then accelerated adjacent lumbar level fusion problems and produced back pain and leg pain[^31]. Gogawala et al[^11] also confirmed this change in a long-term RCT. The most important disadvantage of fusion was the co-existence of other complications, higher reoperation rates, and heavier financial costs. Yagi et al[^32] suggested that the cost-utility of elective spine surgery for DS over a three-year postoperative period did not differ significantly between decompression and fusion. Two randomized controlled trials published in New England also found there was no significant difference in complications between the two groups[^6,11]. Our meta-analysis has come to the same conclusion.

A large registry study of 9051 LSS patients shows that a good clinical effect can be achieved by simple decompression for patients with simple stenosis without spondylolisthesis[^33]. Scholler et al[^34] suggested that patients with LSS, a minimally invasive laminotomy is associated with lower reoperation and fusion rates, less slip progression, and greater patient satisfaction than open surgery. Theoretically, compared with decompression, spinal fusion requires more aggressive intervention produces, and longer operative time, and often involves insertion of spinal implants. So all this may increase the risk of complications. Therefore, surgeons should exercise great caution while performing spinal fusion in patients with LSS. The surgeon must consider: the height of the disk, the degeneration of facet joints and ligaments, the presence of osteoporosis, but also the structure of the whole column and then the sagittal balance. The ultimate goal of treating LSS need always focus on the balance between decompression of the compressed nerve and adequate bone retention for spinal mechanical stability[^35]. Identifying preoperative radiographic features that predict delayed instability after surgical decompression would better guide surgeons in determining the appropriate surgical procedure. Blumenthal et al[^36] found that Patients with motion at spondylolisthesis > 1.25 mm, disc height > 6.5 mm, and facet angle > 50° are more likely to experience instability following decompression alone surgery for grade I lumbar spondylolisthesis. Patients with all 3 risk factors for instability had a 75% rate of reoperation, whereas patients with no risk factors for instability had a 0% rate of reoperation. Forst et al[^6] reports a 7.4 mm slip in both the decompression and decompression with concomitant fusion group without showing differences in clinical outcome after surgery. Although fusion for treating delayed instability was associated with significant improvement in outcome, the identification of risk factors for developing instability upfront might help improve patient selection for decompression alone and reduce the number of reoperations following treatment for degenerative lumbar spondylolisthesis. Further research is necessary to identify these anatomical characteristics that justify additional fusion.

The present study is also restricted by several limitations. According to our search results and inclusion criteria, seven RCTs and ten comparative observational studies were selected for analysis. Therefore, selection bias inherent to these observational studies would decrease the strength of analysis. The limitations of our study were: (1) The various complications and nonconformity of assessment criteria in clinical satisfaction, which shared some inner inconsistencies that may have contributed to risk bias. (2) Insufficient data in walking ability, and clinically satisfaction. (3) There is heterogeneity among the included studies with regard to patients’ characteristics, inconsistent inclusion and exclusion criteria, and different surgical procedures. (4) Variations in duration of follow-up and inconsistent reporting of pain score outcomes. (5) Our study follow-up period was less than 1 years. A longer-term analysis, including more comparative trials with moderate and high grade evidence, would be expected to improve the validity and reliability of our outcome.

**Conclusion**

In the present systematic review and meta-analysis, moderate-quality evidence from seven RCTs and ten observational studies showed that decompression plus fusion yielded no better clinical results than decompression alone in treating LSS. But resulting in a longer duration of operation, more blood loss, and a higher Length of hospital stay. We think that for patients with simple stenosis, satisfactory clinical results can be achieved by decompression alone. We
suggested that the least invasive and least costly procedure, being decompression alone, is preferred in patients with degenerative lumbar spinal stenosis. We expect more controlled trials, prospective studies, and multi-center studies to further testify the long-term outcomes of additional fusion. More research is required to delineate the precise surgical protocol for LSS.

**Abbreviations**

- lumbar spinal stenosis (LSS);
- randomized controlled trials (RCTs);
- quality-of-life EuroQol-5 Dimensions (EQ-5D);
- Oswestry Disability Index (ODI) scores;
- Visual analogue scale (VAS);
- Numerical Rating Scale (NRS);
- Japanese Orthopaedic Association (JOA) scores;
- confidence interval (CI);
- Weighted mean difference (WMD);
- standardized mean difference (SMD);

**Declarations**

**Ethical Approval**

This study is retrospective, so it does not need ethical approval.

**Consent to Participate**

This is a meta-analysis. All data are from published studies.

**Consent to publish**

This is a meta-analysis. All data are from published studies.

**Competing interests**

The authors declare that they do not have any competing interests.

**Funding**

No commercial, public, or nonprofit organizations financially supported this research.

**Availability of data and materials**

All data analyzed during this study are included within the manuscript. The datasets used and/or analyzed during this study are available from the first author on reasonable request. Our data can also submit to Springer Nature.

**Authors' contributions**

STT, YY and QC designed this study. YY, QC, ZJY, and FC were responsible for collecting, analyzing, and interpreting the data, and writing the manuscript. YY and QC identified the case, performed the operation, and made contributions to revising the manuscript for crucial intellectual content. The final version of the text has been reviewed and approved by all authors.

**Acknowledgments**

The authors thank Alison Sherwin, PhD, from Liwen Bianji, Edanz Group China (www.liwenbianji.co/ac) for editing the English text of a draft of this manuscript.

**Authors’ Information**

Yang Yang 1278590247@qq.com
References

1. Matz PG, Meagher RJ, Lamer T. Guideline summary review: an evidence-based clinical guideline for the diagnosis and treatment of degenerative lumbar spondylolisthesis. Spine J. 2016;16:439–48.

2. Weinstein JN, Lurie JD, Tosteson TD. Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis. Four-year results in the Spine Patient Outcomes Research Trial (SPORT) randomized and observational cohorts. Bone Joint J Surg Am J. 2009;91:1295–304.

3. Deyo RA, Mirza SK, Martin BI. (2010) Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA, 303:1259–65.

4. Munting E, Roder C, Sobottke R. (2015) Patient outcomes after laminotomy, hemilaminectomy, laminectomy and laminectomy with instrumented fusion for spinal canal stenosis: a propensity score-based study from the Spine Tango registry. Eur Spine J, 24:358–368.

5. Yoshihara H, Yoneoka D. (2015) National trends in the surgical treatment for lumbar degenerative disc disease: United States, 2000 to 2009. Spine J, 15(2):265–271.

6. Försth P, Öläfsson G, Carlsson T. A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. N Engl J Med. 2016;374:1413–23.

7. Shen JL, Xu S, Xu SX. (2018) Fusion or Not for Degenerative Lumbar Spinal Stenosis: A Meta-Analysis and Systematic Review. Pain Physician, 21:1–7.

8. Xavin D, Casha S, Wiebe S. (2017) Lumbar Fusion for Degenerative Disease: A Systematic Review and Meta-Analysis. Neurosurgery, 80:701–715.

9. Higgins JP, Altman DG, Gotzsche PC. (2011) The Cochrane Collaboration’s tool for assessing risk of bias in randomised trials. BMJ, 343:d5928.

10. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;25:603–5.

11. Ghogawala Z, Dzura J, Butler WE. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. N Engl J Med. 2016;374:1424–34.

12. Aleksandra T, Kazimiiercz, Stanislaw L. (2014) Evaluation of Functional Outcomes in Individuals 10 Years after Posterior Lumbar Interbody Fusion with Corundum Implants and Decompression: A Comparison of 2 Surgical Techniques. J Clinical Research J, 20:1400–1406.

13. Kleinsteuck FS, Fekete TF, Mannion AF. To fuse or not to fuse in lumbar degenerative spondylolisthesis: do baseline symptoms help provide the answer? Eur Spine J. 2011;21:268–75.

14. Grob D, Humke T, Dvorak J. Degenerative lumbar spinal stenosis. Decompression with and without arthrodesis. Bone Joint Surg Am J. 1995;77:1036–41.

15. Bridwell KH, Sedgewick TA, O’Brien MF. The role of fusion and instrumentation in the treatment of degenerative spondylolisthesis with spinal stenosis. Spinal Discord J. 1993;6:461–72.

16. Herkowitz HN, Kurz LT (1991) Degenerative lumbar spondylolisthesis with spinal stenosis. A prospective study comparing decompression with decompression and intertransverse process arthrodesis. Bone Joint Surg Am J, 73:802–8.

17. Thomas K, Manners S, Bailey CS. (2019) Decompression alone vs. decompression plus fusion for claudication secondary to lumbar spinal stenosis. The Spine Journal, 19:1633–1639.

18. Aihara T, Toyone T, Aoki Y. (2018) Surgical management of degenerative lumbar spondylolisthesis: a comparative study of outcomes following decompression with fusion and microendoscopic decompression. Musculoskeletal Res J, 12:132–139.

19. Inui T, Murakami M, Nagao N. (2016) Lumbar Degenerative Spondylolisthesis: Changes in Surgical Indications and Comparison of Instrumented Fusion with Two Surgical Decompression Procedures. SPINE J, 4:1–27.

20. Sigmundsson FG, Jonsson B, Stromqvist B. (2015) Outcome of decompression with and without fusion in spinal stenosis with degenerative spondylolisthesis in relation to preoperative pain pattern: a register study of 1624 patients. Spine J, 15:638–646.

21. Park JH, Hyun SJ, Roh SW. (2012) A comparison of unilateral laminectomy with bilateral decompression and fusion surgery in the treatment of grade I lumbar degenerative spondylolisthesis. Acta Neurochir (Wien) J, 154:1205–1212.

22. Matsudaika K, Yamazaki T, Seichi A. Spinal stenosis in grade I degenerative lumbar spondylolisthesis: a comparative study of outcomes following laminoplasty and laminectomy with instrumented spinal fusion. Orthop Sci J. 2005;10:270–6.

23. Inose H, Kato T, Yuasa M. Comparison of Decompression, Decompression Plus Fusion, and Decompression Plus Stabilization for Degenerative Spondylolisthesis A Prospective, Randomized Study. Clin Spine Surg J. 2018;31:E347–52.

24. Forsyth P, Michaelsson K, Sanden B. (2013) Does fusion improve the outcome after decompressive surgery for lumbar spinal stenosis? A two-year follow-up study involving 5390 patients. Bone J, 95:960–965.

25. Ghogawala Z, Benzel EC, Amin-Hanjani S, et al. Prospective outcomes evaluation after decompression with or without instrumented fusion for lumbar stenosis and degenerative Grade I spondylolisthesis. J Neurosurg Spine J. 2004;3:267–72.

26. Xu S, Wang JY, Liang Y. Decompression with fusion is not in superiority to decompression alone in lumbar stenosis based on randomized controlled trials A PRISMA-compliant meta-analysis. Medicine J. 2019;46:1–11.
Figures

Flow diagram of studies included in the systematic review
Figure 2

Risk of bias summary. The review authors’ judgments about each risk of bias item for each included study: + is “yes,” – is “no,” ? is “unclear.”
Figure 3

Methodological quality of included comparative observational studies based on the Newcastle–Ottawa Scale for assessing the quality of studies. "Green" for 2, "Red" for 1, and "Yellow" for 0.
Figure 4
Forest plot illustrating back pain scores of decompression alone and fusion

| Study or Subgroup | decompression | fusion | Std. Mean Difference | Std. Mean Difference |
|-------------------|---------------|--------|----------------------|----------------------|
|                   | Mean | SD | Total | Mean | SD | Total | Weight | N, Random, 95% CI | N, Random, 95% CI |
| 2.1.1 RCT          |      |    |       |      |    |       |        |                  |                  |
| Forth 2018        | 2.9  | 3.1 | 66    | 3.2  | 3  | 87    | 10.0%  | -6.10 [-0.44, 0.24] |                  |
| Heibertz 1991     | 2.3  | 2.1 | 25    | 2.8  | 1.7 | 25    | 4.4%   | -0.71 [-1.28, 0.13] |                  |
| Meindersma 2011   | 3.1  | 3.6 | 58    | 3.6  | 3.4 | 157   | 11.8%  | -6.32 [-0.54, 0.07] |                  |
| Subtotal (95% CI) | 147  |    | 249   | 26.0% |   | -0.27 [-0.55, 0.01] |                  |
| Heterogeneity: Tau^2 = 0.02; Chi^2 = 3.21, df = 2 (P = 0.26), I^2 = 39% |
| Test for overall effect: Z = 1.88 (P = 0.06) |

2.1.2 comparative observational studies

| Study        | decompression | fusion | Std. Mean Difference |
|--------------|---------------|--------|----------------------|
|              | Mean | SD | Total | Mean | SD | Total | Weight | N, Random, 95% CI |
| Forth 2013   | 3.5  | 3.621 | 655 | 3.2  | 4.075 | 651 | 27.8% | 0.08 [0.03, 0.18] |
| Inui 2016    | 1.9  | 0.8  | 60  | 1.9  | 0.9  | 80  | 10.3% | 0.00 [0.33, 0.33] |
| Matsuda 2005 | 1.1  | 0.6  | 10  | 0.4  | 0.4  | 19  | 2.5%  | 0.16 [-0.45, 0.04] |
| Park 2012    | 2.4  | 2.53 | 20  | 2.5  | 1.6  | 25  | 4.2%  | -0.05 [-0.63, 0.54] |
| Sigmundsson 2013 | 3.49 | 3.56 | 66  | 3.86 | 3.41 | 126 | 12.3% | 0.11 [0.10, 0.41] |
| Thomas 2019  | 7.3  | 2.1  | 199 | 7.6  | 2.1  | 207 | 16.0% | -0.14 [-0.38, 0.09] |
| Subtotal (95% CI) | 1020 |    | 1011 | 74.0% |   | 0.04 [0.05, 0.13] |                  |
| Heterogeneity: Tau^2 = 0.00; Chi^2 = 3.39, df = 6 (P = 0.84), I^2 = 0% |
| Test for overall effect: Z = 0.95 (P = 0.34) |

Total (95% CI) 1107 1280 100.0% -0.05 [-0.18, 0.08] 1 -0.5 0 0.5 1 Favoirs decompression Favoirs fusion

Figure 5
Forest plot illustrating leg pain scores of decompression alone and fusion

| Study or Subgroup | decompression | fusion | Std. Mean Difference | Std. Mean Difference |
|-------------------|---------------|--------|----------------------|----------------------|
|                   | Mean | SD | Total | Mean | SD | Total | Weight | N, Random, 95% CI | N, Random, 95% CI |
| 3.1.1 RCT          |      |    |       |      |    |       |        |                  |                  |
| Aleksandria 2014  | 22.36| 11.18| 49   | 16.3 | 7 | 47    | 13.9%  | 0.66 [0.75, 10.37] |                  |
| Forth 2016        | 21   | 18  | 86   | 25   | 19 | 87    | 19.4%  | -4.29 [0.89, 9.36] |                  |
| Ogawa 2004        | 12.8 | 9.47 | 32   | 12.5 | 13.8 | 45   | 19.7%  | 0.93 [0.12, 11.97] |                  |
| Subtotal (95% CI) | 147  |    | 147   | 35.0% |   | 2.98 [3.26, 9.53] |                  |
| Heterogeneity: Tau^2 = 1.34; Chi^2 = 7.41, df = 6 (P = 0.02), I^2 = 73% |
| Test for overall effect: Z = 0.91 (P = 0.35) |

3.1.2 comparative observational studies

| Study         | decompression | fusion | Std. Mean Difference |
|---------------|---------------|--------|----------------------|
|              | Mean | SD | Total | Mean | SD | Total | Weight | N, Random, 95% CI |
| Forth 2013    | 27   | 20.4 | 655 | 20.41| 651 | 17.7% | 0.080 [2.22, 2.22] |
| Ogawa 2004    | 27.4 | 15.7 | 29  | 15.7 | 14 | 25    | 5.5%  | 12.40 [2.06, 24.12] |
| Park 2012     | 16.65| 7.08 | 29  | 7.08 | 11 | 25    | 14.2% | 3.76 [-0.29, 9.81] |
| Sigmundsson 2015 | 25 | 17.8 | 70 | 23.4 | 17.8 | 125 | 12.2% | 1.86 [3.83, 8.89] |
| Thomas 2019   | 47.7 | 15.3 | 169 | 47.7 | 14.8 | 117 | 15.4% | -3.30 [5.52, 8.62] |
| Subtotal (95% CI) | 1064 |    | 992   | 65.0% |   | 1.58 [1.83, 5.99] |                  |
| Heterogeneity: Tau^2 = 0.52; Chi^2 = 13.19, df = 4 (P = 0.01), I^2 = 78% |
| Test for overall effect: Z = 0.90 (P = 0.37) |

Total (95% CI) 1111 1067 100.0% 2.16 [0.80, 5.11] 1 -0.5 0 0.5 1 Favoirs decompression Favoirs fusion

Figure 6
Forest plot illustrating ODI of decompression alone and fusion
Figure 7
Forest plot illustrating EQ-5D of decompression alone and fusion.

Figure 8
Forest plot illustrating walking ability of decompression alone and fusion.

Figure 9
Forest plot illustrating intraoperative blood loss of decompression alone and fusion.
Figure 10

Forest plot illustrating length of hospital stay of decompression alone and fusion.

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|-------------------|------|----|-------|------|----|-------|----------------|----------------|
| Decompression     |      |    |        | Fusion |     |        | IV, Random, 95% CI | IV, Random, 95% CI |
| 9.1.1 RCT          |      |    |        |        |      |        |                |                |
| Aleksandra 2014   | 5.2  | 2.1| 50     | 7.8   | 1.5| 50     | -2.60 [-3.32, -1.86] |                |
| Ghogomewa 2016    | 2.6  | 0.9| 35     | 4.2   | 0.8| 31     | -1.60 [-2.04, -1.16] |                |
| Subtotal (95% CI) | 85   |    | 81     | 56.3% |    | 56.3% | -2.06 [-3.08, -1.04] |                |
| Heterogeneity: $I^2 = 91$; $C^2 = 5.48$; $df = 1$ ($P = 0.02$); $I^2 = 92$
| Test for overall effect: $Z = 4.13$ ($P < 0.0001$) |                |

9.1.2 Comparative observational studies

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|-------------------|------|----|-------|------|----|-------|----------------|----------------|
| Akhtar 2018       | 9.4  | 0.63 | 25 | 16.6 | 7.16 | 16 | 2.2% | -7.30 [-12.09, -2.32] |                |
| Inoue 2018        | 11.6 | 2.5 | 20 | 14.1 | 3.6 | 31 | 15.5% | -2.50 [-4.06, -0.94] |                |
| Thomas 2018       | 1    | 1.5 | 196| 4    | 4 | 107 | 25.4% | -3.00 [-3.79, -2.21] |                |
| Subtotal (95% CI) | 253  |    | 154 | 43.7% |    | 54.6% | -3.06 [-4.25, -1.89] |                |
| Heterogeneity: $I^2 = 94$; $C^2 = 3.24$; $df = 2$ ($P = 0.20$); $I^2 = 36$
| Test for overall effect: $Z = 5.60$ ($P < 0.0001$) |                |

Total (95% CI)

| Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|------|----|-------|------|----|-------|----------------|----------------|
| 338  | 235 | 100.0% | -2.51 [-3.36, -1.67] |                |

Heterogeneity: $I^2 = 93$; $C^2 = 10.42$; $df = 4$ ($P = 0.003$); $I^2 = 70$

Test for overall effect: $Z = 5.60$ ($P < 0.0001$)

Test for subgroups differences: $C^2 = 1.84$; $df = 1$ ($P = 0.20$); $I^2 = 39$

Figure 11

Forest plot illustrating duration of operation of decompression alone and fusion.

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|-------------------|------|----|-------|------|----|-------|----------------|----------------|
| 5.1.1 RCT          |      |    |        |        |      |        | IV, Random, 95% CI | IV, Random, 95% CI |
| Aleksandra 2014   | 41   | 3.2 | 92     | 11.4 | 5  | 50     | -41.60 [-44.28, -37.72] |                |
| Forth 2016        | 95   | 49  | 66     | 144  | 44 | 67     | -54.60 [-59.81, -10.4] |                |
| Ghogomewa 2016    | 124  | 34.2| 35     | 269.6| 66.3| 31     | -105.20 [-191.14, -13.28] |                |
| Subtotal (95% CI) | 151  |    | 148   | 50.4% |    | 64.53  | [-67.66, -5.38] |                |
| Heterogeneity: $I^2 = 4075.50$; $C^2 = 87.01$; $df = 2$ ($P = 0.00001$); $I^2 = 96$
| Test for overall effect: $Z = 2.09$ ($P = 0.04$) |                |

5.1.2 Comparative observational studies

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|-------------------|------|----|-------|------|----|-------|----------------|----------------|
| Akhtar 2016       | 87.5 | 29.7| 25    | 152  | 45 | 16    | -64.50 [-80.81, -48.19] |                |
| Inoue 2010        | 148  | 48  | 29    | 244  | 50 | 31    | -96.00 [-120.28, -71.71] |                |
| Thomas 2013       | 91   | 95  | 193   | 179  | 171.3| 107   | -87.00 [-122.94, -51.08] |                |
| Subtotal (95% CI) | 253  |    | 154   | 49.6% |    | 41.00 | [-80.25, -61.55] |                |
| Heterogeneity: $I^2 = 1293.31$; $C^2 = 3.33$; $df = 2$ ($P = 0.19$); $I^2 = 40$
| Test for overall effect: $Z = 7.89$ ($P < 0.0001$) |                |

Total (95% CI)

| Mean | SD | Total | Mean | SD | Total | Mean Difference | Mean Difference |
|------|----|-------|------|----|-------|----------------|----------------|
| 464  | 302| 100.0% | -81.34 [-124.42, -44.27] |                |

Heterogeneity: $I^2 = 2273.85$; $C^2 = 113.37$; $df = 6$ ($P = 0.000001$); $I^2 = 96$

Test for overall effect: $Z = 4.17$ ($P < 0.0001$)

*Test for subgroups differences: $C^2 = 0.91$; $df = 1$ ($P = 0.35$); $I^2 = 6$
Figure 12

Forest plot illustrating major complications of decompression alone and fusion.

| Study or Subgroup | decompression | fusion | Risk Ratio |
|-------------------|---------------|--------|------------|
|                  | Events | Total | Events | Total | Weight | M H, Random, 95% CI |
| 10.1.1 RCT       |        |       |        |       |        |                      |
| Aleksandri 2014  | 9      | 46    | 8      | 47    | 13.7%  | 1.53 [0.53, 3.96]    |
| Bridwell1993     | 0      | 9     | 6      | 34    | 5.3%   | 0.27 [0.02, 4.36]    |
| Ghogawala 2016   | 2      | 35    | 1      | 31    | 0.5%   | 1.77 [0.3, 16.00]    |
| Grob 1985        | 13     | 15    | 7      | 30    | 13.8%  | 3.71 [1.03, 12.72]   |
| Kleinsteck 2011  | 10     | 56    | 27     | 157   | 14.0%  | 1.04 [0.54, 2.01]    |
| Subtotal (95% CI)| 161    | 299   | 52.4%  | 1.62 [0.77, 3.41] |
| Total events     | 34     | 47    |        |       |        | 1.27 (P = 0.20)      |

Heterogeneity: Tau² = 0.36, CH² = 9.43, df = 4 (P = 0.05), I² = 50%
Test for overall effect Z = 1.27 (P = 0.20)

10.1.2 comparative observational studies

| Study or Subgroup | decompression | fusion | Risk Ratio |
|-------------------|---------------|--------|------------|
|                  | Events | Total | Events | Total | Weight | M H, Random, 95% CI |
| Ghogawala 2004   | 3      | 20    | 2      | 14    | 9.2%   | 1.05 [0.20, 5.41]    |
| Inoue 2016       | 2      | 29    | 16     | 31    | 10.5%  | 0.13 [0.03, 0.53]    |
| Thomas 2019      | 19     | 199   | 35     | 167   | 14.6%  | 0.22 [0.10, 0.48]    |
| Ulrich 2017      | 16     | 85    | 7      | 46    | 13.3%  | 1.24 [0.55, 2.78]    |
| Subtotal (95% CI)| 333    | 198   | 47.6%  | 0.47 [0.17, 1.27] |
| Total events     | 40     | 60    |        |       |        | 1.40 (P = 0.14)      |

Heterogeneity: Tau² = 0.72, CH² = 12.63, df = 3 (P = 0.006), I² = 76%
Test for overall effect Z = 1.40 (P = 0.14)

Total (95% CI) 494 497 100.0% 0.86 [0.39, 1.89]

Test for subgroups differences: CH² = 3.81, df = 1 (P = 0.05), I² = 73.7%

Figure 13

Forest plot illustrating number of reoperation of decompression alone and fusion.

| Study or Subgroup | decompression | fusion | Risk Ratio |
|-------------------|---------------|--------|------------|
|                  | Events | Total | Events | Total | Weight | M H, Random, 95% CI |
| 8.1.1 RCT         |        |       |        |       |        |                      |
| Aleksandri 2014   | 9      | 46    | 5      | 47    | 14.0%  | 1.94 [0.87, 4.37]    |
| Bridwell1993      | 0      | 9     | 1      | 34    | 3.0%   | 1.17 [0.05, 26.49]   |
| Forsth 2016       | 17     | 117   | 13     | 111   | 10.4%  | 1.24 [0.63, 2.32]    |
| Ghogawala 2016    | 12     | 35    | 4      | 31    | 19.2%  | 2.96 [0.98, 3.99]    |
| Grob 1985         | 6      | 15    | 4      | 30    | 3.6%   | 0.22 [0.01, 4.75]    |
| Subtotal (95% CI) | 222    | 253   | 75.6%  | 1.52 [0.94, 2.46] |
| Total events      | 36     | 27    |        |       |        | 1.22 (P = 0.24)      |

Heterogeneity: Tau² = 0.00, CH² = 3.46, df = 4 (P = 0.49), I² = 0%
Test for overall effect Z = 1.22 (P = 0.24)

8.1.2 comparative observational studies

| Study or Subgroup | decompression | fusion | Risk Ratio |
|-------------------|---------------|--------|------------|
|                  | Events | Total | Events | Total | Weight | M H, Random, 95% CI |
| Ghogawala 2004    | 3      | 29    | 0      | 14    | 3.5%   | 5.60 [0.28, 93.40]   |
| Inoue 2016        | 4      | 69    | 11     | 00    | 17.6%  | 0.48 [0.16, 1.49]    |
| Maludamna 2005    | 6      | 18    | 2      | 19    | 3.3%   | 0.21 [0.01, 4.11]    |
| Subtotal (95% CI) | 98     | 131   | 44.8%  | 0.65 [0.16, 2.61] |
| Total events      | 7      | 13    |        |       |        | 1.61 (P = 0.54)      |

Heterogeneity: Tau² = 0.49, CH² = 2.74, df = 2 (P = 0.25), I² = 27%
Test for overall effect Z = 0.61 (P = 0.54)

Total (95% CI) 320 366 100.0% 1.22 [0.76, 2.13]

Total events 45 40

Heterogeneity: Tau² = 0.15, CH² = 9.29, df = 7 (P = 0.23), I² = 25%
Test for overall effect Z = 1.70 (P = 0.04)
Test for subgroups differences: CH² = 1.26, df = 1 (P = 0.26), I² = 22.3%
Figure 14

Forest plot illustrating clinically satisfaction of decompression alone and fusion.