Effective of Fusion in the Treatment of Lumbar Spinal Stenosis—A Systematic Review Andmeta-Analysis

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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, major complication, clinical satisfactions 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 result 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 can not 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^[1]. 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, the 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 that 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.

Table 1
Description of the main characteristics of the studies included in the meta-analysis

Numbers	References	Years	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, operation 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, operation time,hospital stay
3	Aleksandra et al.[12]	2014	Poland	RCT	46/47	D:51.28 ± 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 /58male	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,complication rate,blood loss
6	Bridwell et al.[15]	1993	America	RCT	9/34	NA	32female/ 11male	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: 63.5	36female /14male	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/ 184male	D: decompression DF:decompression + fusion	2	Clinical,complication 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/ 20male	D: microendoscopic decompression DF:decompression + fusion	5	Clinical,blood loss,operative time,hospital stay
140	Ulrich et al.	2017	Switzerland	R,OS	85/46	D:75.4 ± 7.6 DF:68.0 ± 7.8	76female/ 55male	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/ 51male	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/ 83male	D: decompression DF: decompression with PLIF	2	Clinical outcome

Numberss	References	Years	Country	Design	Case number (D/DF)	Age (year)	Sex ratio (F/M)	Surgical types (D/DF)	Follow-ups (year)	outcomes
13	Park et al.[21]	2012	Korea	R,OS	20/25	D:67.65 DF:661.92	37female /8male	D: unilateral laminotomy for bilateral dcompression (ULBD) DF: laminectomy with PLIF	≥ 3	Clinical and radiologic outco
14	Matsudaira et al.[22]	2005	Japan	R,OS	18/19	D: 68 ± 7 DF: 67 ± 7	22female /15 male	D: decompression with preservation of the posterior elements DF: laminectomy with PLF	2	Clinical, complication rat reoperation rate, radiological outcomes
15	Inose et al. [23]	2018	Japan	P,OS	29/31	D:63.4 ± 8.6 DF:61.2 ± 6.7	32female/ 28male	D: decompression DF: decompression plus fusion	5	Clinical, complication rat reoperation rate, radiological outcomes
16	Forsth et al. [24]	2013	Sweden	P,OS	655/651	D: 70 DF: 67	956female /350 male	D: decompression DF: decompression plus fusion	2	Clinical, reoperat rate
17	Ghogawala et al.[25]	2004	America	P,OS	20/14	NA	23female /11 male	D: laminectomy DF:laminectomy + PLF	1	Clinical, complication rat reoperation rate

Risk of bias

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 *atisfactions* 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 spondylosis 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, ODI, major complication, clinical satisfactions 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, ODI, and walking ability were of no difference through the meta analysis of 9 articles of RCT. Relevant publication 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 treatment 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]. Ghogawala et al^[11] also confirmed this change in a longterm 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 in 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 up front 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 followup 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.

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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.

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Figures

Figure 1

Flow diagram of studies included in the systematic review

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Aleksandra 2014	+	+	+	+	+	+	+
Bridwell1993	+	?	?	?	+	+	+
Forsth 2016	+	+	?	?	+	+	+
Ghogawala 2016	+	+	-	-	+	+	+
Grob 1995	+	+	-	-	+	+	+
Herkowitz 1991	+	?	-	-	+	+	+
Kleinstueck 2011	+	+	?	?	+	+	+

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."

	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Outcome of interest was not present at start of study	Comparability(score) Based on the design or analysis	Assessment of outcome	Follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts
Aihara 2018	●	●	●	●	+	?	+	●
Forsth 2013	●	●	●	●	●	●	●	●
Ghogawala 2004	●	●	●	●	+	●	?	●
Inose 2018	+	●	●	●	+	?	+	●
Inui 2016	●	●	●	●	●	●	●	●
Matsudaira 2005	●	●	●	●	+	●	●	●
Park 2012	●	●	●	●	●	●	●	●
Sigmundsson 2015	●	●	●	●	●	●	●	?
Thomas 2019	●	●	?	●	●	?	●	●
Ulrich 2017	●	●	?	●	+	?	●	●

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

Figure 5

Forest plot illustrating leg pain scores of decompression alone and 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.

Figure 11

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

Figure 12

Forest plot illustrating major complications of decompression alone and fusion.

Figure 13

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

Figure 14

Forest plot illustrating clinically satisfaction of decompression alone and fusion.