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Surgical options for lumbar spinal stenosis (Review)

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TABLE OF CONTENTS

[Intervention Review]

Surgical options for lumbar spinal stenosis

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ABSTRACT

Background

Hospital charges for lumbar spinal stenosis have increased significantly worldwide in recent times, with great variation in the costs and rates of different surgical procedures. There have also been significant increases in the rate of complex fusion and the use of spinal spacer implants compared to that of traditional decompression surgery, even though the former is known to incur costs up to three times higher. Moreover, the superiority of these new surgical procedures over traditional decompression surgery is still unclear.

Objectives

To determine the efficacy of surgery in the management of patients with symptomatic lumbar spinal stenosis and the comparative effectiveness between commonly performed surgical techniques to treat this condition on patient-related outcomes. We also aimed to investigate the safety of these surgical interventions by including perioperative surgical data and reoperation rates.

Search methods

Review authors performed electronic searches of the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, Embase, CINAHL, AMED, Web of Science, LILACS and three trials registries from their inception to 16 June 2016. Authors also conducted citation tracking on the reference lists of included trials and relevant systematic reviews.

Selection criteria

This review included only randomised controlled trials that investigated the efficacy and safety of surgery compared with no treatment, placebo or sham surgery, or with another surgical technique in patients with lumbar spinal stenosis.

Data collection and analysis

Two reviewers independently assessed the studies for inclusion and performed the 'Risk of bias' assessment, using the Cochrane Back and Neck Review Group criteria. Reviewers also extracted demographics, surgery details, and types of outcomes to describe the characteristics of included studies. Primary outcomes were pain intensity, physical function or disability status, quality of life, and recovery. The secondary outcomes included measurements related to surgery, such as perioperative blood loss, operation time, length of hospital stay, reoperation

rates, and costs. We grouped trials according to the types of surgical interventions being compared and categorised follow-up times as short-term when less than 12 months and long-term when 12 months or more. Pain and disability scores were converted to a common 0 to 100 scale. We calculated mean differences for continuous outcomes and relative risks for dichotomous outcomes. We pooled data using the random-effects model in Review Manager 5.3, and used the GRADE approach to assess the quality of the evidence.

Main results

We included a total of 24 randomised controlled trials (reported in 39 published research articles or abstracts) in this review. The trials included 2352 participants with lumbar spinal stenosis with symptoms of neurogenic claudication. None of the included trials compared surgery with no treatment, placebo or sham surgery. Therefore, all included studies compared two or more surgical techniques. We judged all trials to be at high risk of bias for the blinding of care provider domain, and most of the trials failed to adequately conceal the randomisation process, blind the participants or use intention-to-treat analysis. Five trials compared the effects of fusion in addition to decompression surgery. Our results showed no significant differences in pain relief at long-term (mean difference (MD) -0.29, 95% confidence interval (CI) -7.32 to 6.74). Similarly, we found no between-group differences in disability reduction in the long-term (MD 3.26, 95% CI -6.12 to 12.63). Participants who received decompression alone had significantly less perioperative blood loss (MD -0.52 L, 95% CI -0.70 L to -0.34 L) and required shorter operations (MD -107.94 minutes, 95% CI -161.65 minutes to -54.23 minutes) compared with those treated with decompression plus fusion, though we found no difference in the number of reoperations (risk ratio (RR) 1.25, 95% CI 0.81 to 1.92). Another three trials investigated the effects of interspinous process spacer devices compared with conventional bony decompression. These spacer devices resulted in similar reductions in pain (MD -0.55, 95% CI -8.08 to 6.99) and disability (MD 1.25, 95% CI -4.48 to 6.98). The spacer devices required longer operation time (MD 39.11 minutes, 95% CI 19.43 minutes to 58.78 minutes) and were associated with higher risk of reoperation (RR 3.95, 95% CI 2.12 to 7.37), but we found no difference in perioperative blood loss (MD 144.00 mL, 95% CI -209.74 mL to 497.74 mL). Two trials compared interspinous spacer devices with decompression plus fusion. Although we found no difference in pain relief (MD 5.35, 95% CI -1.18 to 11.88), the spacer devices revealed a small but significant effect in disability reduction (MD 5.72, 95% CI 1.28 to 10.15). They were also superior to decompression plus fusion in terms of operation time (MD 78.91 minutes, 95% CI 30.16 minutes to 127.65 minutes) and perioperative blood loss (MD 238.90 mL, 95% CI 182.66 mL to 295.14 mL), however, there was no difference in rate of reoperation (RR 0.70, 95% CI 0.32 to 1.51). Overall there were no differences for the primary or secondary outcomes when different types of surgical decompression techniques were compared among each other. The quality of evidence varied from 'very low quality' to 'high quality'.

Authors' conclusions

The results of this Cochrane review show a paucity of evidence on the efficacy of surgery for lumbar spinal stenosis, as to date no trials have compared surgery with no treatment, placebo or sham surgery. Placebo-controlled trials in surgery are feasible and needed in the field of lumbar spinal stenosis. Our results demonstrate that at present, decompression plus fusion and interspinous process spacers have not been shown to be superior to conventional decompression alone. More methodologically rigorous studies are needed in this field to confirm our results.

PLAIN LANGUAGE SUMMARY

Effectiveness of surgery for people with leg or back pain due to symptomatic spinal stenosis

Review question

How well do different types of surgery work for lumbar spinal stenosis?

Background

Spinal stenosis is the narrowing of the spinal canal in the lower back region caused by thickening of the soft tissues and bones. It is a common condition for which surgery is usually performed after non-surgical treatments (such as physiotherapy) have failed to bring sufficient relief to patients. Spinal stenosis is a common cause of low back pain that radiates to the legs, and it is more common in older adults. Surgery for lumbar spinal stenosis normally involves taking pressure off the spinal cord or spinal nerves (known as decompression) by removing bone and soft tissues from around the spinal canal. Another common surgical approach is to fuse two or more vertebrae together after decompression in the patient whose spine seems to be unstable. The usefulness of some types of surgery for lumbar spinal stenosis, however, has been questioned, and previous studies have reported that patients who receive fusion are more likely to have major complications and higher costs when compared with patients who undergo decompression only. More recently, spinal implants were created to help indirectly reduce pressure in the spinal canal and at the same time stabilise the bones. However, these implants have also been linked to worse outcomes (e.g., higher reoperation rates) when compared to conventional decompression.

Search date

This review includes all trials published up to June 2016.

Study characteristics

We included all trials that compared any surgical technique with no surgery or placebo surgery, and also trials comparing different surgical techniques with each other, including fusion and spinal implants. All the patients included in these studies were diagnosed with lumbar spinal stenosis and had symptoms in the leg or thigh that worsened by walking or standing and were generally relieved by a change in position, such as bending forward or sitting. The main measure we used to compare how well the different types of surgery worked was how much less pain people felt as they went about their daily lives. We also looked at whether their leg pain improved, how much blood they lost during surgery, how long the surgery took, how long they had to stay in hospital, how many patients had to have another operation for the problem and how much the treatment cost.

Key results and quality of the evidence

Twenty-four randomised controlled trials were included with a total of 2352 people. We did not find trials that compared surgery with no treatment or placebo surgery, so all included trials compared different surgical techniques. The quality of the evidence from these studies varied from very low quality to high quality. This large variation was mainly due to different study protocols, surgical techniques and quality of reporting according to the 'Risk of bias' assessment. We found that patients who had decompression plus fusion fared no better than those who underwent decompression surgery alone. In fact, decompression plus fusion resulted in more blood loss during surgery than decompression alone. Although the spinal spacers were slightly better than decompression plus fusion in terms of improvements on daily activities, there were no differences when they were compared with decompression alone. Finally, we found no differences between different forms of decompression.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. SUMMARY OF FINDINGS FOR DECOMPRESSION VERSUS FUSION

Decompression alone compared with decompression plus fusion for lumbar spinal stenosis

Patient or population: patients with lumbar spinal stenosis

Settings: inpatient care

Intervention: decompression alone

Comparison: decompression plus fusion

Outcomes	Comparisons		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Decompression	Decompression with fusion				
Pain **Long-term (≥ 12 months)** Pain scores converted to 0 to 100 scale to allow for comparison of different disability scales (VAS, NRS)	The mean pain score ranged across decompression groups from **9.50 to 48.10** points	The mean pain in the decompression with fusion groups was **0.29 higher** (6.74 lower to 7.32 higher)	**Mean difference** -0.29 (-7.32, 6.74)	380 (4)	⊕⊝⊝⊝ **Very low**	The difference is not statistically or clinically significant
Disability **Long-term (≥ 12 months)** Disability scores converted to 0 to 100 scale to allow for comparison of different disability scales (RMDQ, ODI, JOA)	The mean pain score ranged across decompression groups from **17.90 to 56.29** points	The mean disability score in the decompression with fusion group was **3.26 lower** (6.12 lower to 12.63 higher)	**Mean difference** 3.26 (-6.12, 12.63)	335 (3)	⊕⊝⊝⊝ **Very low**	The difference is not statistically or clinically significant
Operation time Duration of operation reported in minutes	The mean operation time ranged across decompression groups from **88.46 minutes to 124.40 minutes**	The mean operation time in the decompression with fusion groups was **107.94 higher** (54.23 to 161.65 higher)	**Mean difference** -107.94 (-161.65, -54.23)	381 (4)	⊕⊝⊝⊝ **Very low**	The difference is clinically significant

Blood loss Amount of perioperative blood loss reported in L	The mean perioperative blood loss ranged across decompression groups from **0.08 to 0.34** L	The mean perioperative blood loss in the decompression with fusion groups was **0.52 L higher** (0.34 L to 0.70 L higher)	**Mean difference** -0.52 (-0.70, -0.34)	383 (4)	⊕⊝⊝⊝ **Very low**	The difference is clinically significant
Reoperations Number of patients requiring a revision surgery	**36 of 185** (19 per 100) participants had reoperation	**38 of 258** (15 per 100) participants had reoperation	**Risk ratio** 1.25 (0.81, 1.92)	443 (5)	⊕⊕⊕⊝ **Moderate**	The difference is not statistically or clinically significant

CI: confidence interval; **VAS:** visual analogue scale; **NRS:** numerical rating scale**; RMDQ:** Roland-Morris Disability Questionnaire; **ODI:** Oswestry Disability Index; **JOA:** Japanese Orthopedic Association

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

Summary of findings 2. SUMMARY OF FINDINGS FOR DECOMPRESSION VERSUS INTERSPINOUS SPACERS

Decompression compared with interspinous spacers for lumbar spinal stenosis

Patient or population: patients with lumbar spinal stenosis

Settings: inpatient care

Intervention: decompression

Comparison: interspinous process spacer devices

Outcomes	**Comparisons**		**Relative effect (95% CI)**	**Number of participants (studies)**	**Quality of the evidence (GRADE)**	**Comments**
	Assumed risk	**Corresponding risk**				
	Decompression	**Interspinous spacers**				
Pain **Long-term (≥ 12 months)** Pain scores converted to 0 to 100 scale to allow for	The mean pain score ranged across decompression groups from **21.65 to 32.00** points	The mean pain score in the interspinous spacers groups was **0.55 higher** (6.99 lower to 8.08 higher)	**Mean difference** -0.55 (-8.08, 6.99)	328 (3)	⊕⊕⊕⊝ **Moderate**	The difference is not statistically or clinically significant

comparison of different disability scales (VAS, NRS)						
Disability **Long-term (≥ 12 months)** Disability scores converted to 0 to 100 scale to allow for comparison of different disability scales (RMDQ, ODI, JOA)	The mean disability score ranged across decompression groups from **18.30 to 45.00** points	The mean disability score in the interspinous spacers groups was **1.25 lower** (6.98 lower to 4.48 higher)	**Mean difference** 1.25 (-4.48, 6.98)	327 (3)	⊕⊕⊖⊖ **Low**	The difference is not statistically or clinically significant
Operation time Duration of operation reported in minutes	The mean operation time ranged across decompression groups from **43.00 to 112.90** minutes	The mean operation time in the interspinous spacers groups was **39.11 minutes lower** (19.43 to 58.78 lower)	**Mean difference** 39.11 (19.43, 58.78)	340 (3)	⊕⊕⊖⊖ **Low**	The difference is clinically significant
Blood loss Amount of perioperative blood loss reported in mL	The mean perioperative blood loss in the decompression group was **184** mL	The mean perioperative blood loss in the interspinous spacers group was **144 mL lower** (209.74 mL lower to 497.74 mL higher)	**Mean difference** 144.00 (-209.74, 497.74)	81 (1)	⊕⊕⊖⊖ **Low**	The difference is not statistically or clinically significant
Reoperations Number of patients requiring a revision surgery	**11 of 163** (7 per 100) participants had reoperation	**44 of 163** (27 per 100) participants had reoperation	**Risk ratio** 0.25 (0.14, 0.47)	326 (3)	⊕⊕⊕⊕ **High**	The difference is clinically significant

CI: confidence interval; **VAS:** visual analogue scale; **NRS:** numerical rating scale**; RMDQ:** Roland-Morris Disability Questionnaire; **ODI:** Oswestry Disability Index; **JOA:** Japanese Orthopedic Association

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

Summary of findings 3. SUMMARY OF FINDINGS FOR FUSION VERSUS INTERSPINOUS SPACERS

Decompression plus fusion compared with interspinous spacers for lumbar spinal stenosis

Patient or population: patients with lumbar spinal stenosis

Settings: inpatient care

Intervention: decompression plus fusion

Comparison: interspinous process spacer devices

Outcomes	Comparisons		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Decompression and fusion	Interspinous spacer devices				
Pain **Long-term (≥ 12 months)** Pain scores converted to 0 to 100 scale to allow for comparison of different disability scales (VAS, NRS)	The mean pain score ranged across fusion groups from **24.10 to 35.50** points	The mean pain score in the interspinous spacers groups was **5.35 lower** (11.88 lower to 1.18 higher)	**Mean difference** 5.35 (-1.18, 11.88)	308 (2)	⊕⊕⊖⊖ **Low**	The difference is not statistically or clinically significant
Disability **Long-term (≥ 12 months)** Disability scores converted to 0 to 100 scale to allow for comparison of different disability scales (RMDQ, ODI, JOA)	The mean disability score ranged across fusion groups from **26.70 to 34.50** points	The mean disability score in the interspinous spacers groups was **5.72 lower** (1.28 to 10.15 lower)	**Mean difference** 5.72 (1.28, 10.15)	308 (2)	⊕⊕⊖⊖ **Low**	The difference is not clinically significant
Operation time Duration of operation reported in minutes	The mean operation time ranged across fusion groups from **150.00 to 153.20** minutes	The mean operation time in the interspinous spacers groups was **78.91 lower** (30.16 to 127.65 lower)	**Mean difference** 78.91 (30.16, 127.65)	381 (2)	⊕⊖⊖⊖ **Very low**	The difference is clinically significant
Blood loss Amount of perioperative blood loss reported in mL	The mean perioperative blood loss in the fusion group was **348.60** mL	The mean perioperative blood loss in the interspinous spacers groups was **238.90 mL lower** (182.66 to 295.14 mL lower)	**Mean difference** 238.90 (182.66, 295.14)	320 (1)	⊕⊕⊕⊖ **Moderate**	The difference is clinically significant
Reoperations Number of patients requiring a revision surgery	**8 of 107** (7 per 100) participants had reoperation	**23 of 215** (11 per 100) participants had reoperation	**Risk ratio** 0.70 (0.32, 1.51)	322 (1)	⊕⊕⊕⊕ **High**	The difference is not statistically or clinically significant

CI: confidence interval; **RR:** risk ratio; **VAS:** visual analogue scale; **NRS:** numerical rating scale**; RMDQ:** Roland-Morris Disability Questionnaire; **ODI:** Oswestry Disability Index; **JOA:** Japanese Orthopedic Association

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

BACKGROUND

Description of the condition

Lumbar spinal stenosis is a narrowing of the spinal canal or the intervertebral foramina by surrounding bone and soft tissues that compromises neural structures (Bailey 1911; Portal 1803). Although it can be an incidental finding (Boden 1990), lumbar spinal stenosis may cause leg or lower back symptoms and disability, particularly in the older population (Kalichman 2009; Katz 2008). Radiographic findings of spinal stenosis are highly prevalent among those older than 60 years of age and can be as high as 80% in specific populations (Ishimoto 2013). Only 30%, however, present severe lumbar stenosis and about 17% have long-term symptoms of intermittent neurogenic claudication. Neurogenic claudication is the most important feature of lumbar spinal stenosis as it limits patients' walking ability and causes a major impact on their quality of life. Intermittent neurogenic claudication is defined as uni- or bilateral radicular pain during walking or standing that is relieved by sitting down or flexing the lumbar spine (Blau 1961).

The differential diagnosis from vascular intermittent claudication is sometimes challenging as poor circulation in the muscles of the legs might mimic neurogenic claudication. Pain sensation while standing and pain relief with lumbar flexion are important characteristics of neurogenic claudication that may help distinguish between these conditions. Lumbar spinal stenosis can be classified as primary (congenital) or secondary stenosis (degenerative, iatrogenic, spondylotic, post-traumatic and miscellaneous; Arnoldi 1976; Katz 2008; Siebert 2009). It is also anatomically classified as central, lateral or foraminal and it can be a result of multiple factors, such as intervertebral disc protrusion, loss of intervertebral space height, hypertrophy of joint capsules and ligaments, and osteophytes (Siebert 2009).

Description of the intervention

Bony decompression by laminectomy was first described by Alban Smith (Smith 1829), and first reported in a patient with spinal stenosis in 1893 (Lane 1893). This surgical procedure is still considered the gold standard of surgery and the most common technique for lumbar spinal stenosis (Gibson 2005; Jansson 2003). After intubation and anaesthesia the patient is positioned prone on the operating table, and imaging techniques guide a midline or posterolateral muscle splitting incision. The paraspinal muscles are stripped to expose the lamina and retracted laterally. The surgeon performs partial removal of both osseous (vertebrae lamina, spinous process, facet joints) and soft tissue elements (posterior ligamentous complex), but at least 50% of each facet joint complex is preserved to avoid iatrogenic instability. In cases of instability, lumbar fusion may be necessary in addition to decompression (Taylor 1994), which usually involves the use of spinal implants to stabilise the fused segments, though recent trials have questioned this view (Forsth 2016; Ghogawala 2016). In the United States, the rate of fusion for lumbar spinal stenosis has increased significantly in recent times (Deyo 2010). However, this procedure is associated with higher reoperation rates, post-surgical complications, and costs when compared with decompression alone (Deyo 2013). Furthermore, it is still debatable whether the addition of fusion is more effective than decompression alone. To overcome the complications associated with fusion, less invasive surgical techniques have been developed, such as the interspinous process spacer devices (Coflex, Paradigm Spine USA and X-Stop, Medtronic Spine USA). These spacer devices were created to promote an indirect decompression and provide stabilisation while preserving the bony structures of the spinal column (Senegas 1991). However, the most recent evidence on this topic has shown that these spacer devices alone are not only more costly than conventional decompression, but are also associated with higher reoperation rates (Deyo 2013).

Alternatives to conventional decompression by laminectomy have been developed to minimise the damage on posterior structures of the lumbar spine. Minimally invasive decompressive techniques used to treat lumbar spinal stenosis include uni- or bilateral laminotomies and spinal process-splitting laminectomy. These techniques are also frequently performed with the use of an endoscope or microscope. The bilateral laminotomy technique preserves the neural arch of the vertebrae and protects the dura. In multisegmental stenosis this technique allows the reattachment of the paravertebral muscles to the spinous processes. The surgeon partially removes the laminae and ligamentum flavum but preserves the facet joint complex and the muscles attached to it (Aryanpur 1988). Unilateral laminotomy refers to partial resection of the facets and the medial portion of the lamina, and complete removal of the ligamentum flavum (Spetzger 1997). This technique was developed to overcome the disadvantage of surgically induced instability (Spetzger 1997a). More recently, the spinous process-splitting laminectomy was developed (Watanabe 2005). In this technique, the lamina is exposed by longitudinally splitting the spinous process into halves, allowing muscles and ligamentous attachments to be left intact. Recently, another Cochrane review showed that these posterior decompression techniques delivered no different results in terms of leg pain or disability reduction compared to conventional laminectomy (Overdevest 2015).

How the intervention might work

Increasing the cross-sectional area of the spinal canal at the level of stenosis (decompression) may decrease pain that is generated from increased pressure on the nerves within the stenosed segment. The complete removal of the vertebrae lamina and spinal process in an extensive conventional laminectomy is, however, linked to postsurgical spinal instability (Abumi 1990; Hopp 1988; Lee 1983). Therefore, techniques that increase spinal stability after decompression, such as fusion, might have an advantage compared with decompression alone. In a conventional laminectomy procedure, the paraspinal muscles are detached extensively from the spinal processes, vertebrae lamina and facets. Such muscle damage is associated with significant atrophy of paraspinal muscles (Kawaguchi 1996; See 1975), and the spinal process-splitting decompression technique has been proposed to preserve muscle integrity. In addition, other minimally invasive decompression techniques (e.g., uni- or bilateral laminotomies) preserve spinal integrity and are potentially capable of reducing postoperative complications such as muscle atrophy, weakness, postoperative pain, perioperative blood loss, operation time and length of hospital stay. Endoscopic assisted decompressive surgery has also been proposed to avoid scaring of the epidural space (Cooper 1991).

Why it is important to do this review

Surgery for lumbar spinal stenosis is believed to be more effective than conservative treatment when the latter has failed for up to six months (Kovacs 2011; May 2013). However, the most

recent evidence does not confirm this belief. For instance, in the Spine Patient Outcomes Research Trial (SPORT) patients treated surgically did not report any difference in outcomes compared with those treated non-surgically in the intention-to-treat analyses, although the as-treated analyses showed statistically significant but small differences in terms of pain and function favouring surgery (Weinstein 2008). Further, a recent trial has also shown that surgical decompression yielded similar effects to a physiotherapy programme (Delitto 2015). In this review we did not include trials comparing surgery with non-surgical interventions, because this is covered in another Cochrane review (Zaina 2016). Given most of the evidence supporting the use of surgery for lumbar spinal stenosis comes largely from trials comparing surgery with non-surgical interventions, it is not possible to distinguish the specific effects of surgery from the effects of time, regression to the mean, or placebo effects (Flum 2006). Moreover, many surgical techniques are available for the management of lumbar spinal stenosis, and the lack of evidence to support the rapid evolution of surgical techniques has led clinicians to rely on their own opinions and experiences to choose the surgical technique for their patients (Katz 1997), which leads to practice variation. The conflicting results from current randomised trials (Cavusoglu 2007; Grob 1995; Stromqvist 2013), and the emerging evidence on this topic (Forsth 2016; Ghogawala 2016) demand a synthesis of the available evidence.

OBJECTIVES

To determine the efficacy of surgery (i.e., surgery versus no treatment, or placebo/sham surgery) in the management of patients with symptomatic lumbar spinal stenosis and the comparative effectiveness of commonly performed surgical techniques to treat this condition on patient-related outcomes. We also aimed to investigate the safety of these surgical interventions by including perioperative surgical data and reoperation rates.

METHODS

Criteria for considering studies for this review

Types of studies

We only included published randomised controlled trials.

Types of participants

The participants included in our review consisted of adults with symptomatic degenerative lumbar spinal stenosis, despite its anatomical classification (central, foraminal or lateral) or diagnostic criteria (physical examination or radiographic imaging). There were no restrictions regarding intensity or duration of symptoms. Studies of participants with trauma, tumour and previous spine surgery were excluded. As degenerative spondylolisthesis is a common finding in patients with lumbar spinal stenosis, only trials including participants with spondylolisthesis up to Meyerding grade I (translation of the cranial vertebra of up to 25%) were included (Meyerding 1932).

Types of interventions

We considered studies that compared the efficacy of surgery with no treatment, placebo or sham surgery. We also included trials that compared the effectiveness of different surgical techniques for lumbar spinal stenosis. However, trials comparing different fusion techniques or interspinous spacer devices, and surgery for cervical spinal stenosis, were excluded. We also excluded trials that compared surgery with non-surgical interventions, as this is covered in another recent Cochrane review (Zaina 2016).

Types of outcome measures

We included patient-centred outcomes of clinical relevance, as well as safety and perioperative surgical outcomes. We did not consider radiographic and biomechanical outcomes.

Primary outcomes

The primary outcomes of this review comprised:

- pain intensity;
- physical function or disability status;
- quality of life; and
- recovery.

Pain intensity outcomes were back pain, leg pain or overall pain reported in visual analogue scales or numeric rating scales. Disability outcomes measures included Roland-Morris Disability Questionnaire (RMDQ), Owestry Disability Index (ODI) or any other disability instrument used in low back pain research, and walking ability. Physical function was included if measured using the Zurich Claudication Questionnaire (ZCQ). Quality of life outcomes were, for example, total scores of the 36-item or 12-item Short Form Health Survey (SF-36, SF-12), or the EuroQol questionnaire (EQ-5D). Trials that reported individual item scores, rather than the total scores, of the quality of life scales were not included in the meta-analysis. Recovery was measured using the differences between preoperative and postoperative Japanese Orthopaedic Association (JOA) scores as reported by the included trials.

Secondary outcomes

Secondary outcomes were:

- perioperative blood loss;
- operation time;
- length of hospital stay;
- reoperation rate; and
- costs.

Search methods for identification of studies

Electronic searches

Review authors developed the search strategy based on the Back and Neck Review Group methods guidelines and a specialist was consulted to revise it. Electronic searches of the following databases were performed up to 16 June 2016:

- Cochrane Back and Neck Review Group Trials Register (OvidSP, 1991 to May 2016).
- Cochrane Central Register of Controlled Trials (CENTRAL; OvidSP, Issue 5, 2016).
- MEDLINE (OvidSP, 1946 to June Week 2 2016).
- Embase (Embase.com, 1947 to 16 June 2016).
- CINAHL (EBSCO, 1981 to 16 June 2016).
- AMED (OvidSP, 1985 to 16 June 2016).
- Web of Science (Thomson Reuters, 1900 to 16 June 2016).

- Latin American and Caribbean Health Sciences Literature (LILACS; 1967 to 16 June 2016).

There were no restrictions on language or publication date. The search strategy for each database can be found in Appendix 1.

Searching other resources

Authors also searched ClinicalTrials.gov, Australian New Zealand Clinical Trials Registry (ANZCTR), and World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) for registered, ongoing or completed trials and contacted the main investigators of the relevant trials to identify any publication of the study. The keywords used for these searches included spinal stenosis, surgery and decompression.

Data collection and analysis

Selection of studies

One reviewer (GM) performed the first screening for relevant records based on titles and abstracts. Two independent reviewers (GM and MP/MR/RY) performed the screening of full texts, used consensus to resolve any disagreement and consulted a third reviewer (MF) when consensus could not be reached.

Data extraction and management

Using a standardised data extraction form, two reviewers (GM and MP/RY) independently extracted data from each included study and used consensus to resolve any disagreement. From each study, the reviewers extracted participants' characteristics (age, disease duration and diagnostic criteria), type of surgery, type of comparison and outcomes. Pain and disability outcome measures were converted to scales from 0 (no pain or disability) to 100 (worst possible pain or disability).

Assessment of risk of bias in included studies

Reviewers evaluated the risk of bias in the included trials using the 'Risk of bias' assessment tool as recommended in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011) and the Cochrane Back and Neck Review Group (Furlan 2015). Two reviewers (GM and MP/RY) independently performed the 'Risk of bias' assessment of the included trials, used consensus if there was any disagreement and consulted a third reviewer (MF) when consensus could not be reached. We scored each study as having 'high', 'low' or 'unclear' risk of bias for each criterion (see Table 1 and Table 2).

Measures of treatment effect

Trials were grouped according to the types of surgical interventions being compared, outcomes and assessment time points. We extracted sample sizes, means (final values) and standard deviations (SD) for continuous outcomes and quantified the treatment effects as mean differences (MD), or standardised mean differences (SMD) when trials used different methods to assess the same outcome. For dichotomous outcomes, the number of cases and the total sample size were used to estimate risk ratios (RR). We, therefore, used MD, SMD or RR and 95% confidence intervals (CI) as measures of treatment effects.

Unit of analysis issues

We did not include cluster-randomised trials or cross-over trials. When multiple pain measures were reported we extracted the most severe measure at baseline. For disability, we chose the scale defined in the study as the primary outcome. For data synthesis, follow-up times were categorised as short-term (closest to three months) and long-term (closest to 12 months). When studies reported results for more than two intervention groups, we combined similar groups according to the recommendations in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Dealing with missing data

If trials reported incomplete data, we contacted authors to request further information. If authors were unavailable or when authors refused to provided data, we imputed data according to recommendations in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). For example, we calculated missing SDs from reported standard errors or 95% CIs and sample size, or we imputed missing SDs from the average SD reported in similar studies. We also estimated SDs from graphs when these estimates were missing in tables or not reported in the text of included trials. When studies reported medians and interquartile ranges (IQR), we considered that the median was equivalent to the mean and the IQR was 1.35 times the SD (Higgins 2011).

Assessment of heterogeneity

We grouped similar trials (e.g., similar types of surgical comparison, outcomes, and assessment time points) into clusters and performed a separate analysis for each cluster. To assess heterogeneity for each pooled analysis we used the I^2 statistic to estimate the total variation across studies that was due to heterogeneity, and considered heterogeneity values greater than 50% to be high (Higgins 2002).

Assessment of reporting biases

We planned to assess reporting bias for each meta-analysis with a minimum of 10 trials using visual inspection of funnel plots and Egger's test. However, the number of studies in each meta-analysis was insufficient for assessing this type of bias.

Data synthesis

Treatment effects were calculated using random-effects models with inverse variance weighting for all meta-analyses. A summary of findings table was created in Review Manager 5.3 and we used the Grading of Recommendations Assessment, Development and Evaluation (GRADE, see Appendix 2) to assess the quality of the evidence for each outcome measure (Guyatt 2008). The quality of evidence was downgraded by one level according to the following criteria: limitation of study design (> 25% of the studies with high risk of bias (at least one of the bias domain judged as high risk)), inconsistency of results (statistically significant heterogeneity (I^2 > 50%) or ≤ 75% of trials with findings in the same direction), and imprecision (wide confidence intervals or the total number of participants was fewer than 400 participants in the comparison for continuous data or fewer than 300 events for dichotomous data for each pooled analysis). The indirectness criterion was not considered in this review because we included a specific population with relevant outcomes and direct comparisons. Where only single trials were available, evidence from studies with less

than 400 participants was downgraded for imprecision and rated as 'moderate quality' evidence. The quality of the evidence could be further downgraded to 'low quality' evidence if limitations of study design were found. The quality of evidence was defined as: 'high quality', 'moderate quality', 'low quality' or 'very low quality' (Guyatt 2008).

Subgroup analysis and investigation of heterogeneity

Subgroup analysis was planned according to type of surgical intervention (e.g., decompression alone versus decompression plus fusion) for all outcomes and duration of follow-up (e.g., short-term and long-term). Although we planned analyses of sources of heterogeneity according to different factors (e.g., surgeon's experience) we did not have enough studies in each meta-analysis to report accurate results.

Sensitivity analysis

We aimed to perform sensitivity analysis to investigate whether our judgment of risk of bias of individual studies and time point definition would affect our conclusions. However, this analysis was not possible due to the limited number of studies in each meta-analysis.

RESULTS

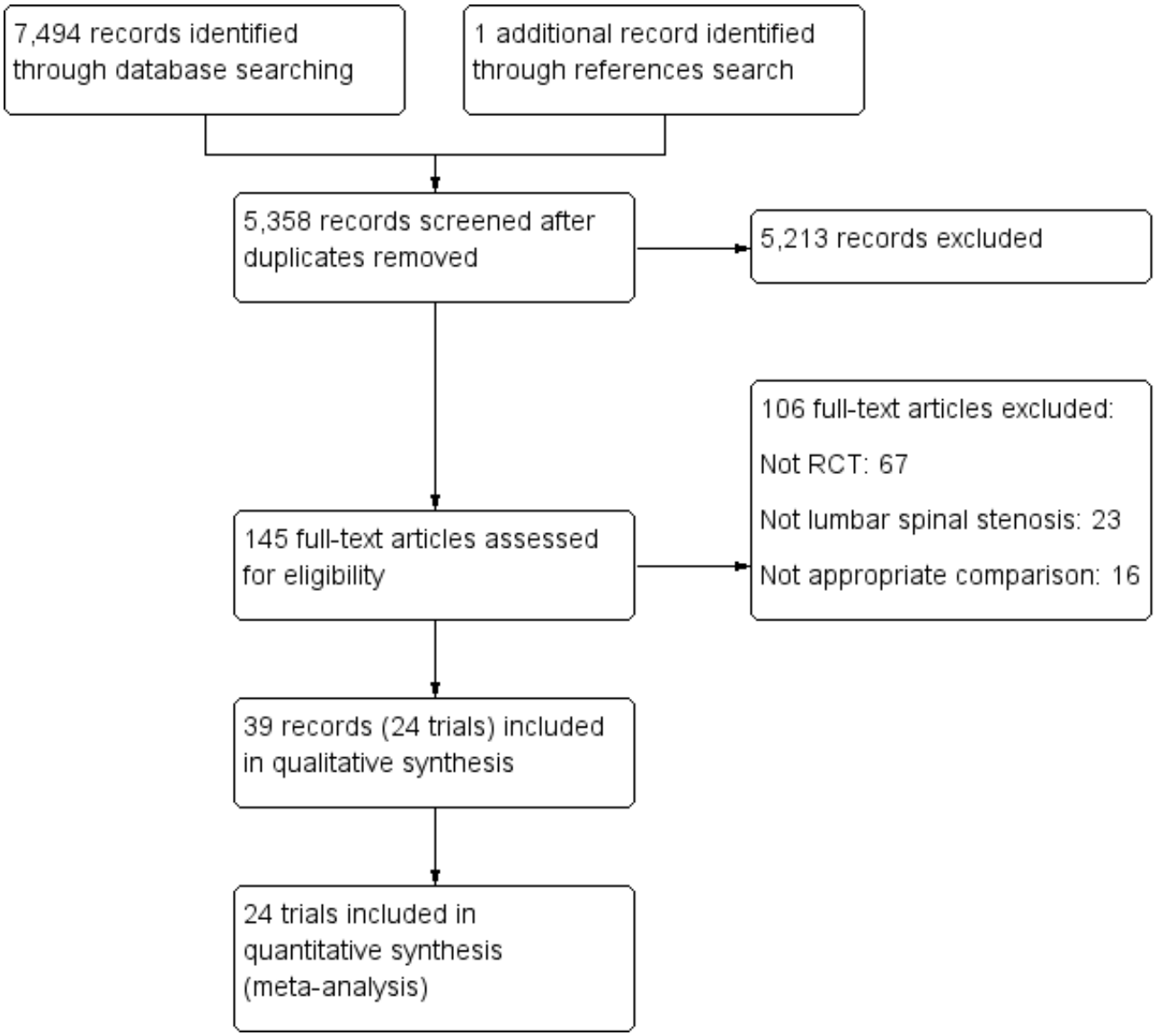
Description of studies

The description of included studies is summarised in Characteristics of included studies.

Results of the search

Our search identified a total of 7494 records. After excluding duplicates, we screened 5358 titles and abstracts, and assessed 145 full text records. Of these, 24 randomised controlled trials (reported in 39 published research articles or abstracts) remained eligible for inclusion in our review (Azzazi 2010; Bridwell 1993; Cavusoglu 2007; Celik 2010; Cho 2007; Davis 2013; Forsth 2016; Ghogawala 2016; Grob 1995; Gurelik 2012; Hallett 2007; Komp 2015; Liu 2013; Lonne 2015; Mobbs 2014; Moojen 2013; Postacchini 1993; Rajasekaran 2013; Ruetten 2009; Stromqvist 2013; Thome 2005; Usman 2013; Watanabe 2011; Yagi 2009). The flow chart of studies with the main reasons for exclusion are shown in Figure 1. All trials included in this review were published in English and therefore no translation was required.

Figure 1. Study flow diagram.



Included studies

The 24 included trials investigated a total of 2352 participants and most studies defined lumbar spinal stenosis based on clinical assessment with a concordant imaging diagnosis (Azzazi 2010; Bridwell 1993; Cavusoglu 2007; Celik 2010; Cho 2007; Davis 2013; Grob 1995; Gurelik 2012; Forsth 2016; Ghogawala 2016; Hallett 2007; Lonne 2015; Mobbs 2014; Moojen 2013; Rajasekaran 2013; Ruetten 2009; Stromqvist 2013; Thome 2005; Usman 2013; Watanabe 2011; Yagi 2009). One study included participants based solely on imaging diagnosis (Postacchini 1993), and two studies used clinical assessment only (Komp 2015; Liu 2013). Nineteen out of 24 trials (80%) explicitly reported including only participants who had failed to improve with conservative treatment (Azzazi 2010; Bridwell 1993; Cavusoglu 2007; Celik 2010; Cho 2007; Davis 2013; Grob 1995; Gurelik 2012; Hallett 2007; Komp 2015; Lonne 2015; Moojen 2013; Rajasekaran 2013; Ruetten 2009; Stromqvist 2013; Thome 2005; Usman 2013; Watanabe 2011; Yagi 2009). The mean age of participants in included trials ranged from 56 to 73 years, and trials were conducted in a range of countries, including the United States, Australia, Turkey, Pakistan, Switzerland, Sweden, the United Kingdom, and Japan. See Characteristics of included studies for additional information.

Excluded studies

We excluded 106 reports from our review; see Characteristics of excluded studies. The reasons for exclusion were:

- not a randomised controlled trial (67): Abdu 2009; Anderson 2011; Asazuma 2004; Bazan 2002; Blumenthal 2013; Bresnahan 2009; Cakir 2009; Cannone 2010; Carrasco 1986; Cassinelli 2007; Choi 2009; Dantas 2007; Delank 2002; Desai 2012; Epstein 2006; Escobar 2003; Fan 2009; Fast 1985; Fitzgerald 1976; Försth 2013; Fu 2008; Fujiya 1990; Ghahreman 2010; González 1992; Gotfryd 2012; Gotfryd 2012a; Gu 2009; Halm 2010; Herkowitz 1991; Hong 2010; Hong 2011; Ikuta 2005; Imagama 2009; Ito 2010; Katz 1997; Kawaguchi 2004; Kim 2007; Kim 2007a; Konno 2000; Kornblum 2004; Lee 2009; Liao 2011; Pappas 1994; Parker 2013; Radcliff 2012; Rapp 2009; Rapp 2011; Richter 2010; Rompe 1995; Rosa

2012; Rowland 2009; Satomi 1992; Schnake 2006; Sengupta 2006; Skidmore 2011; Smoljanovic 2010; Smorgick 2013; Steffee 1993; Tani 2002; Tenhula 2000; Tsutsumimoto 2009; Valesin 2009; Wang 1998; Willén 2008; Yamada 2012; Yang 2011; Yu 2008;

- not lumbar spinal stenosis (23): Andersen 2008; Aoki 2012; Arriagada 2000; Benli 2006; Bjarke 2002; Carragee 1997; Carreon 2009; Chen 2010; Cheng 2009; Dahdaleh 2013; Delawi 2010; Dimar 2009; Feng 2011; Hwang 2010; Kim 2006; Korovessis 2004; Lian 2010; Ledonio 2012; Michielsen 2013; Videbaek 2010; Xiao 2007; Xiao 2007a; Zdeblick 1993; and
- inappropriate comparison (16): Auerbach 2012; Altaf 2011; Auerbach 2011; Dirisio 2011; Dryer 2012; Haley 2012; Haley 2012a; Mahir 2012; McConnell 2011; Radcliff 2011; Repantis 2009; Sears 2012; Shapiro 2005; Weinstein 2007; Whang 2013; Zucherman 2004.

Risk of bias in included studies

As blinding of the therapist in surgical trials is not possible, we judged all studies to be at high risk of bias for this domain. We judged half of the included trials to be at low or unclear risk for all of the remaining domains of the 'Risk of bias' assessment. Only one trial (Moojen 2013) had all bias domains (except therapist blinding) judged as low risk. Most of the trials failed to adequately conceal the randomisation process, blind the participants or use an intention-to-treat analysis. The results from the risk of bias assessments for the included studies are summarised in Figure 2.

Figure 2. 'Risk of bias' summary: review authors' judgements about each risk of bias item for each included study.

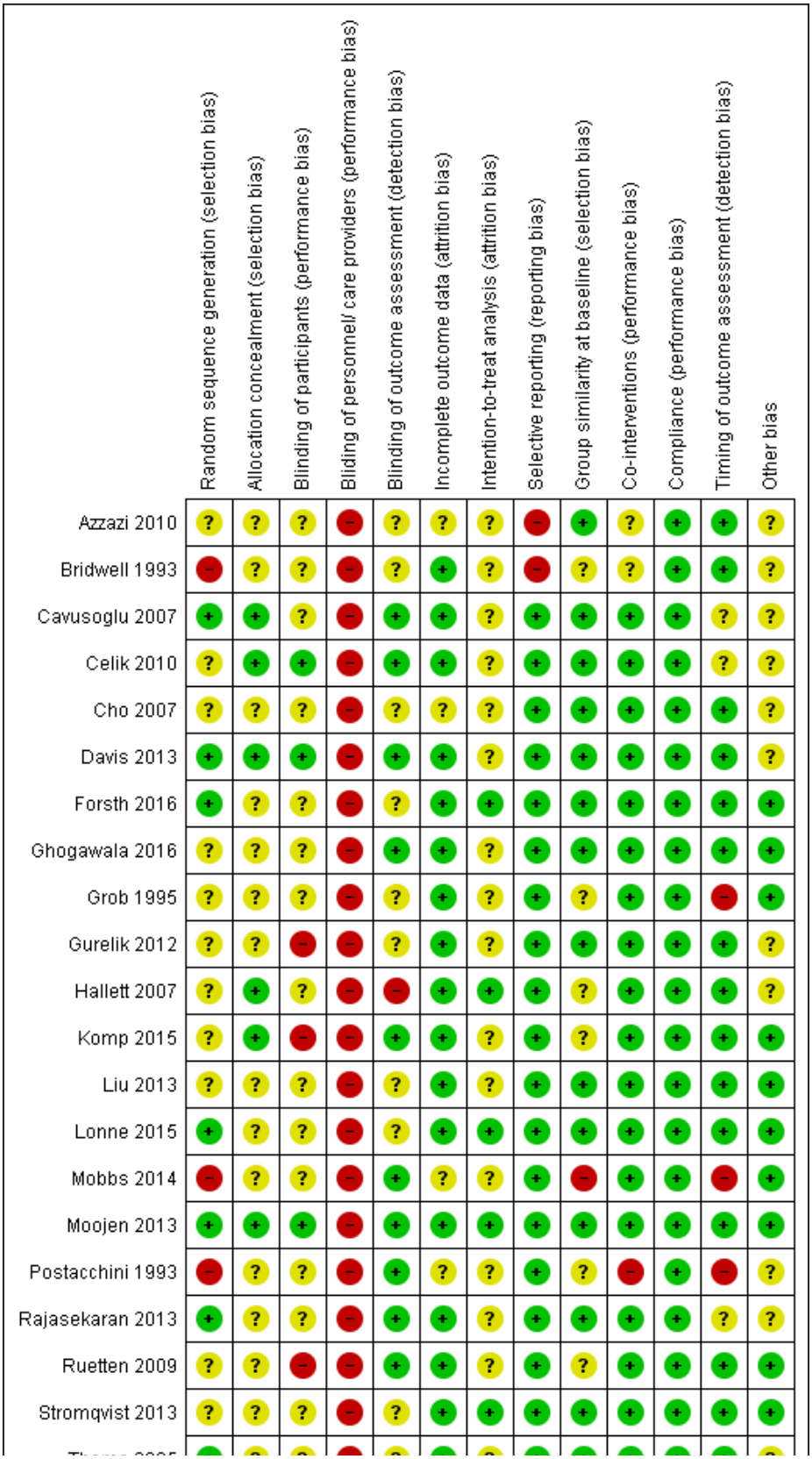
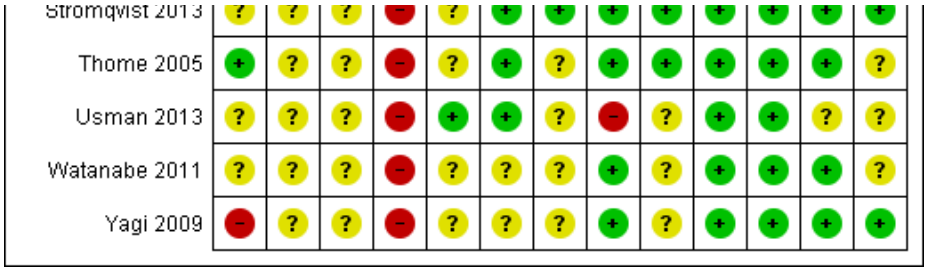


Figure 2. (Continued)



Allocation

Only seven trials reported an appropriate method of randomisation, such as a computer-generated randomisation list. Although 13 trials mentioned that study participants were randomised, they failed to describe the method used for randomisation and we therefore judged them to be at unclear risk of bias. Two trials reported that participants were randomly allocated according to the sequence of presentation to study site and we therefore considered them to be at high risk of bias (Mobbs 2014; Yagi 2009). In two trials, the authors reported that the randomisation protocol was broken and we also considered these trials at high risk of selection bias (Bridwell 1993; Postacchini 1993). Only six trials reported an appropriate method of allocation concealment, and 18 failed to report the method (Figure 2).

Blinding

In surgical clinical trials, it is not possible to blind care providers (i.e., surgeons), therefore we judged all included studies to be at high risk of bias for this domain. Only three studies blinded participants (Celik 2010; Davis 2013; Moojen 2013), while three trials reported not blinding participants leading us to judge them as being at high risk of bias (Gurelik 2012; Komp 2015; Ruetten 2009). The remaining 18 trials failed to provide information on blinding of participants, so we considered them to be at unclear risk for this bias domain. Eleven trials reported blinding of outcome assessors; 12 did not report this information and so we judged them as being at unclear risk of bias. Only one trial mentioned that outcome assessors were not blinded and we therefore considered it to be at high risk of bias (Hallett 2007).

Incomplete outcome data

We considered most of the trials (n = 17) to be at low risk of bias as they reported less than 15% drop-out. One study reported that nearly 22% of participants were lost, but the number of drop-outs and reasons were similar between the groups, therefore we judged this trial as being at low risk of bias for this outcome (Mobbs 2014). Six trials did not mention the number of participants withdrawn from the study and we thus judged them as being at unclear risk.

Selective reporting

We judged three trials as being at high risk of bias for selective reporting. Azzazi 2010 mentioned collecting short-term follow-up data in the methods section, but failed to report results. Also, although the authors mentioned measuring the amount of blood lost during surgery, these data were not reported in the published manuscript. Bridwell 1993 failed to report relevant patient-related outcome measures (i.e., pain, disability), and Usman 2013 reported that recovery rate was one of the outcome measures of the trial, but it was not reported in the results section. We attempted to contact authors in order to have access to these data, but none replied.

Other potential sources of bias

Eleven trials reported not receiving funds for conducting the trial or disclosed any conflicts of interest; we therefore judged them as being at low risk of bias. The remaining trials did not provide a conflict of interest or funding statement so we considered them to be at unclear risk for other sources of bias.

Effects of interventions

See: **Summary of findings for the main comparison** SUMMARY OF FINDINGS FOR DECOMPRESSION VERSUS FUSION; **Summary of findings 2** SUMMARY OF FINDINGS FOR DECOMPRESSION VERSUS INTERSPINOUS SPACERS; **Summary of findings 3** SUMMARY OF FINDINGS FOR FUSION VERSUS INTERSPINOUS SPACERS

We did not identify trials comparing surgery with no treatment, placebo or sham surgery. Therefore, all trials included in this review compared different types of surgical interventions for lumbar spinal stenosis. We divided the included trials into six comparisons according to the surgical techniques being compared.

Decompression alone *versus* decompression plus fusion

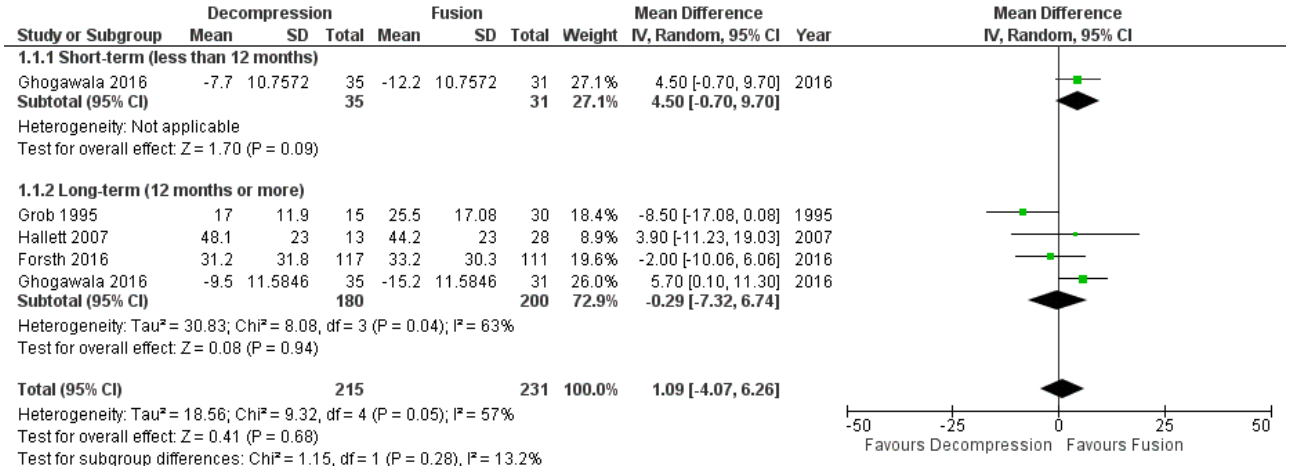
The addition of fusion to bony decompression by either conventional laminectomy (Bridwell 1993; Forsth 2016; Ghogawala 2016; Grob 1995) or foraminotomy (Hallett 2007) was investigated in five randomised trials reporting data from 446 participants. Overall, the studies included in this review were fairly homogeneous, thus most of our meta-analyses revealed no important heterogeneity (I^2 < 50%). A few pooled analyses resulted in considerable heterogeneity however (I^2 > 75%), especially the analysis on operation time, where a great variability of estimates were reported in included trials.

Primary outcomes

Our analyses showed no difference between groups on pain reduction in the short- (MD 4.50, 95% CI -0.70 to 9.70; Ghogawala 2016) and long-term (MD -0.29, 95% CI -7.32 to 6.74; see Figure 3). Similarly, we found that decompression plus fusion was not superior to decompression alone on disability reduction at both short- (MD 5.20, 95% CI -3.50 to 13.90; Ghogawala 2016) and long-term follow-up (MD 3.26, 95% CI -6.12 to 12.63). We judged the quality of evidence in the short-term for both outcomes as 'low quality' (downgraded for imprecision and inconsistency), and further downgraded it to 'very low quality' for limitation of study design in the long-term. Three trials evaluated the effects of decompression plus fusion compared with decompression alone

on walking ability (i.e., participants were considered improved when able to increase their walking distance by 50% at follow-up). This analysis provided 'very low quality' evidence (downgraded for imprecision, inconsistency, and limitation of study design) of no difference between groups (RR 0.99, 95% CI 0.79 to 1.24; see Summary of findings for the main comparison).

Figure 3. Forest plot of comparison: 1 Decompression alone versus decompression plus fusion, outcome: 1.1 Pain.



Secondary outcomes

Two trials reported the mean direct surgery cost per patient. Forsth 2016 showed lower costs for decompression alone (USD 10,392) compared with decompression plus fusion (USD 16,115). Similarly, Hallett 2007 revealed that decompression incurred half the cost of fusion surgery (USD 5,400 versus USD 12,200). However, no measures of variability or inferential statistics were reported for this outcome. We found 'very low quality' evidence (downgraded for imprecision, inconsistency, and limitation of study design) that decompression alone required shorter operation time (MD -107.94 minutes, 95% CI -161.65 minutes to -54.23 minutes;) and was associated with less perioperative blood loss (MD -0.52 L, 95% CI -0.70 L to -0.34 L) compared with decompression plus fusion. 'Moderate quality' evidence (downgraded for limitation of study design) revealed no difference in the number of reoperations (RR 1.25, 95% CI 0.81 to 1.92), and 'low quality' evidence (downgraded for imprecision and inconsistency) showed shorter hospital stays after decompression alone (MD -1.69 days, 95% CI -2.12 days to -1.26 days) compared with decompression plus fusion operations.

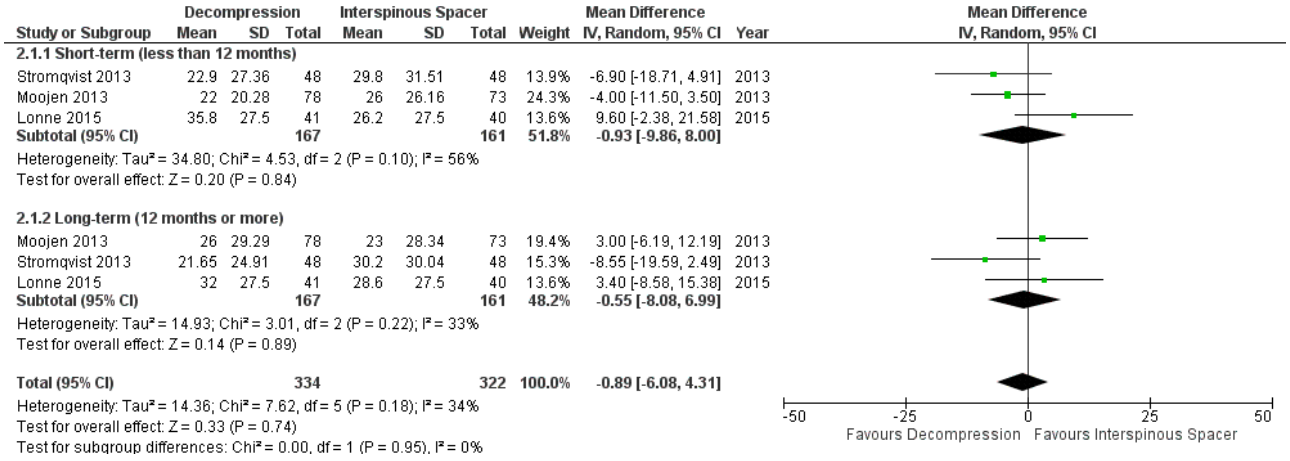
Decompression *versus* interspinous spacer

Three trials reported data of 355 participants comparing bony decompression (laminectomy or laminotomy) with the X-Stop or Coflex interspinous process spacer devices (Lonne 2015; Moojen 2013; Stromqvist 2013).

Primary outcomes

At short-term, 'low quality' evidence (downgraded for imprecision and inconsistency) showed no difference on pain reduction (MD -0.93, 95% CI -9.86 to 8.00). Likewise, 'moderate quality' evidence (downgraded for imprecision) revealed no long-term difference on pain between the groups (MD -0.55, 95% CI -8.08 to 6.99; see Figure 4). For disability, 'moderate quality evidence' (downgraded for imprecision) did not reveal any difference in the short-term (MD 1.30, 95% CI -3.64 to 6.25), and 'low quality' evidence (downgraded for imprecision and inconsistency) also showed no superior benefits of interspinous spacers in the long-term (MD 1.25, 95% CI -4.48 to 6.98). Pooling revealed 'moderate quality' evidence (downgraded for imprecision) that improvement of function (as measured by the ZCQ function sub scale) was similar in the two groups at short- (MD -0.06, 95% CI -0.27 to 0.14) and long-term follow-up (MD -0.00, 95% CI -0.30 to 0.29). One study (Lonne 2015) provided 'moderate quality' evidence (downgraded for imprecision) that there were no differences between decompression and interspinous spacers for quality of life improvement in the short- (MD -0.12, 95% CI -0.25 to 0.01) and long-term (MD -0.05, 95% CI -0.18 to 0.07; see Summary of findings 2).

Figure 4. Forest plot of comparison: 2 Decompression versus interspinous spacer, outcome: 2.1 Pain.



Secondary outcomes

Results from 'low quality' evidence (downgraded for imprecision and inconsistency) showed that participants receiving interspinous spacers required longer operation time (MD 39.11 minutes, 95% CI 19.43 minutes to 58.78 minutes), but there were no differences in terms of length of hospital stay (MD 0.51 days, 95% CI -0.58 days to 1.60 days) and perioperative blood loss (MD 144.00 mL, 95% CI -209.74 mL to 497.74 mL). However, 'high quality' evidence demonstrated higher reoperation rates after interspinous spacers (RR 3.95, 95% CI 2.12 to 7.37) compared with conventional decompression. Two trials (Lonne 2015; Moojen 2013) providing 'moderate quality' evidence (downgraded for imprecision) reported the total health care cost associated with surgical procedures, and revealed a significantly higher cost associated with the interspinous spacers; the incremental cost for an implant was estimated at EUR 2,856.34 (95% CI EUR 1,970.40 to EUR 3,742.28) or USD 3,103.84 (95% CI USD 2,141.14 to USD 4,066.55).

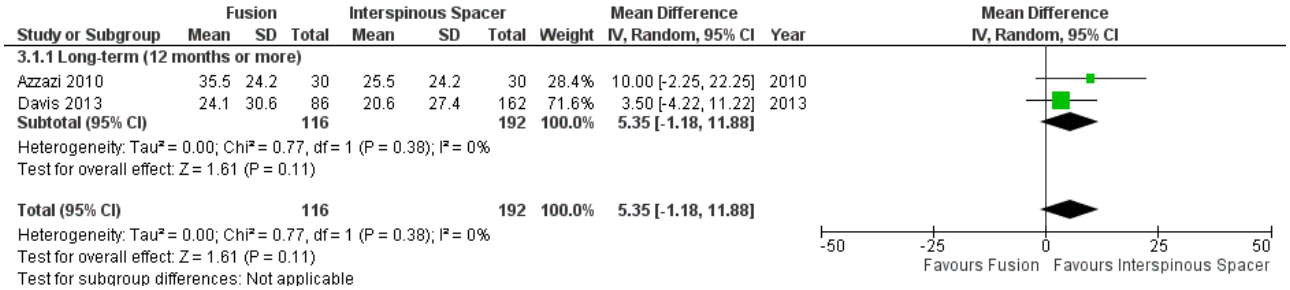
Decompression plus fusion *versus* interspinous spacer

Two trials compared decompression plus fusion with the X-Stop or Coflex interspinous spacer devices (Azzazi 2010; Davis 2013), including a total of 382 participants analysed at long-term follow-up only.

Primary outcomes

There was 'low quality' evidence (downgraded for imprecision and limitation of study design) of no difference between groups on pain reduction (MD 5.35, 95% CI -1.18 to 11.88; see Figure 5), and 'moderate quality' evidence (downgraded for imprecision) also showed no superior benefit of interspinous spacers in terms of quality of life (MD -3.10, 95% CI -6.30 to 0.10). However, we found 'low quality' evidence (downgraded for imprecision and limitation of study design) that interspinous spacers were slightly more effective than fusion on disability reduction (MD 5.72, 95% CI 1.28 to 10.15; see Summary of findings 3).

Figure 5. Forest plot of comparison: 3 Decompression plus fusion versus interspinous spacer, outcome: 3.1 Pain.



Secondary outcomes

We found 'moderate quality' evidence (downgraded for imprecision) that decompression plus fusion resulted in more perioperative blood loss (MD 238.90 mL, 95% CI 182.66 mL to 295.14 mL; Davis 2013) compared with interspinous spacers. 'Very low quality' evidence (downgraded for imprecision, inconsistency and limitation of study design) revealed longer operation time (MD 78.91 minutes, 95% CI 30.16 minutes to 127.65 minutes) and length of hospital stay (MD 1.58 days, 95% CI 0.90 days to 2.27 days) for decompression plus fusion. However, there was no difference in reoperation rates between the two groups (RR 0.70, 95% CI 0.32 to 1.51; Davis 2013) from 'high quality' evidence.

Laminectomy *versus* laminotomy

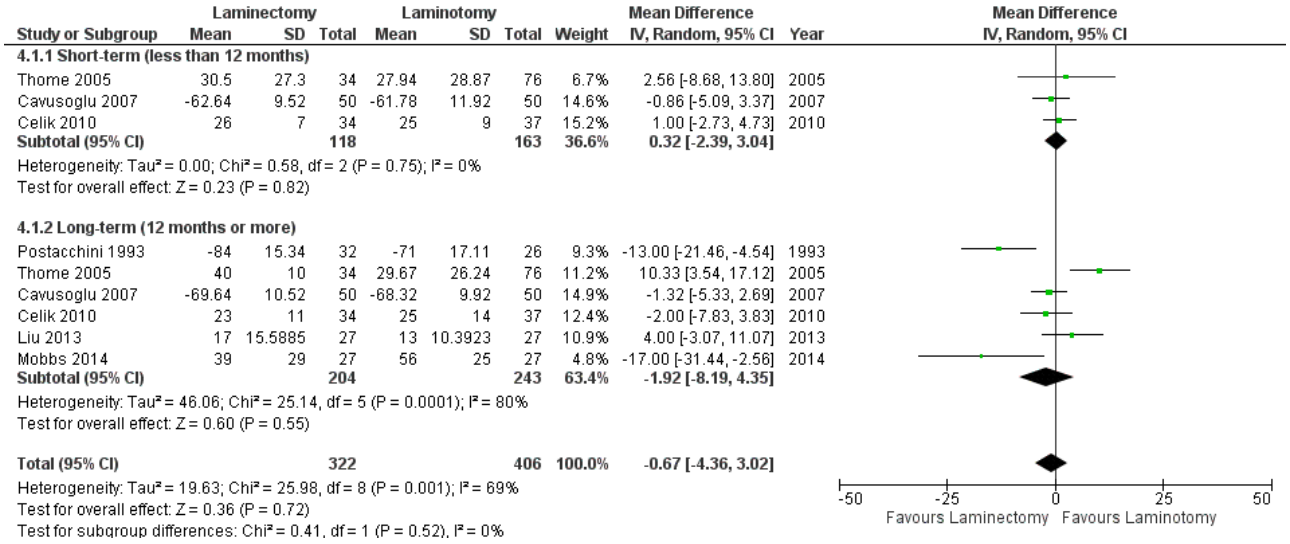
Six randomised controlled trials reporting data from 475 participants compared laminectomy to unilateral (Cavusoglu 2007; Gurelik 2012; Liu 2013; Thome 2005) or bilateral laminotomy (Celik 2010; Postacchini 1993; Thome 2005). Data from unilateral and bilateral laminotomy groups were combined according to

recommendations in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Primary outcomes

We found 'moderate quality' evidence (downgraded for imprecision) that laminotomy is not superior to laminectomy in reducing pain in the short-term (MD 0.32, 95% CI -2.39 to 3.04), and 'low quality' evidence (downgraded for inconsistency and limitation of study design) of no difference in the long-term (MD -1.92, 95% CI -8.19 to 4.35; see Figure 6). Likewise, 'moderate quality' evidence (downgraded for imprecision) revealed no between-group differences on disability reduction at short- (MD 1.56, 95% CI -1.02 to 4.13) and long-term follow-up (MD -0.43, 95% CI -4.37 to 3.52). For walking ability (i.e., walking distance in metres without radicular pain), we found 'low quality' evidence (downgraded for imprecision and limitation of study design) of no difference between these techniques in the short-term (SMD -0.07, 95% CI -0.33 to 0.20). 'Moderate quality' evidence (downgraded for imprecision) also showed no difference in walking ability in the long-term (SMD -0.02, 95% CI -0.33 to 0.28).

Figure 6. Forest plot of comparison: 4 Laminectomy versus laminotomy, outcome: 4.1 Pain.



Secondary outcomes

Our results revealed 'low quality' evidence (downgraded for imprecision and limitation of study design) of no difference between the two surgical procedures on the duration of operation (MD -6.25 minutes, 95% CI -13.76 minutes to 1.27 minutes). However, there was significantly more blood loss (MD 38.80 mL, 95% CI 17.81 mL to 59.80 mL) and longer hospital stay (MD 1.55, 95% CI 0.61 to 2.50) for laminectomy when compared with laminotomy. 'Moderate quality' evidence (downgraded for imprecision) demonstrated no difference in the number of participants having a revision surgery (RR 2.61, 95% CI 0.78 to 8.78).

Decompression *versus* split-decompression

Four trials reported data of 218 participants comparing decompression (laminectomy) with spinous process split-decompression (Cho 2007; Liu 2013; Rajasekaran 2013; Watanabe 2011). Only long-term follow-up data was available in included trials.

Primary outcomes

Pooling showed 'low quality' evidence (downgraded for inconsistency and imprecision) of no differences between treatments on pain reduction (MD 6.35, 95% CI -3.35 to 16.04). 'Moderate quality' evidence (downgraded for imprecision) also revealed no differences between the two groups on disability reduction (MD 1.87, 95% CI -2.82 to 6.57). 'Low quality' evidence (downgraded for inconsistency and imprecision) suggested no superior benefits of split-decompression on long-term recovery (MD -5.18, 95% CI -19.81 to 9.45), as assessed by the JOA recovery score (range 0 to 100), compared with conventional decompression.

Secondary outcomes

We found no differences between the two groups based on 'low quality' evidence (downgraded for inconsistency and imprecision) in terms of operation time (MD -10.57 minutes, 95% CI -34.39 minutes to 13.25 minutes), perioperative blood loss (MD -1.83 mL, 95% CI -27.65 mL to 23.98 mL), and length of hospital stay (MD 1.49 days, 95% CI -1.70 days to 4.67 days). 'Moderate quality' evidence (downgraded for imprecision) also demonstrated that the number of participants requiring reoperation was similar between the groups (RR 1.22, 95% CI 0.22 to 6.85).

Decompression *versus* endoscopic decompression

The efficacy of endoscopic–assisted decompression was investigated in three randomised trials including 393 participants (Komp 2015; Ruetten 2009; Yagi 2009).

Primary outcomes

Our meta-analysis revealed 'low quality evidence' (downgraded for imprecision and limitation of study design) of a small but significant short-term disability reduction of endoscopic approaches compared with conventional decompression (MD 4.12, 95% CI 0.91 to 7.33). However, 'very low quality evidence' (downgraded for inconsistency, imprecision and limitation of study design) showed no difference between these surgical interventions for disability

in the long-term (MD 1.44, 95% CI -2.66 to 5.54). Komp 2015 did not report estimates of between-group differences or measures of variability for each treatment group, therefore we could not calculate a treatment effect for this trial.

Secondary outcomes

'Very low quality' evidence (downgraded for inconsistency, imprecision, and limitation of study design) showed no between-group difference on operation time (MD 10.05 minutes, 95% CI -2.09 minutes to 22.18 minutes). However, Yagi 2009 provided 'low quality' evidence (downgraded for imprecision and limitation of study design) that conventional decompression was associated with more perioperative blood loss (MD 34.00 mL, 95% CI 30.40 mL to 37.60 mL) and longer hospital stay (MD 8.56 days, 95% CI 6.78 days to 10.34 days) compared with endoscopic decompression. 'Moderate quality' evidence (downgraded for limitation of study design) suggested that the number of participants having a revision surgery was similar between the surgical interventions (RR 0.81, 95% CI 0.22 to 2.97).

DISCUSSION

Summary of main results

Our results revealed a paucity of evidence on the efficacy of surgery for lumbar spinal stenosis. We found no trials investigating the efficacy of surgery for lumbar spinal stenosis compared with no treatment, placebo or sham surgery. Therefore, the effects of time, regression to the mean, and patients' expectations (placebo effect) regarding surgery remain unknown. Previous research has shown that placebo-controlled trials in surgery are feasible and a powerful tool to show the efficacy of surgical interventions (Wartolowska 2014). We identified 24 published randomised trials that compared the effects of different surgical techniques for this condition. In our main comparison, we found that fusion does not add benefits in terms of pain or disability reduction compared with decompression alone for the treatment of lumbar spinal stenosis. In addition, we found no differences on pain, disability and quality of life between interspinous process spacer devices and conventional bony decompression. However, the interspinous spacers resulted in significantly higher reoperation rates. We found no further differences in outcomes among the other surgical decompression techniques for lumbar spinal stenosis. In sum, at present, newer surgical techniques have not proven superior to conventional decompression for patients with lumbar spinal stenosis.

Overall completeness and applicability of evidence

Given the number of surgical techniques for the treatment of lumbar spinal stenosis, the need for placebo-controlled trials has never been greater. Through our search, we could not find published placebo-controlled surgical trials in patients with lumbar spinal stenosis. Previous studies have demonstrated the appropriate ethical considerations for placebo surgery (Horng 2003), and confirmed their feasibility (Wartolowska 2014). Such trials, investigating the efficacy of surgery compared with placebo for other spinal conditions, such as painful osteoporotic vertebral fractures, have been conducted and recently published. Buchbinder 2009 performed sham surgery by inserting a blunt stylet and gently tapping the vertebral body and compared this with conventional vertebroplasty. Likewise, Flum 2006 has suggested performing minimally invasive approaches simulating the decompressive technique to the spine for patients with lumbar spinal stenosis, but without actually removing any bone tissue.

The addition of fusion to decompression is commonly performed in this population, although a recent study has shown that fusion is not only more costly but highly associated with major complications and deaths when compared with decompression alone (Deyo 2010). Our review provides relevant information on this topic, showing that the addition of fusion was not associated with better outcomes (pain or disability) compared with decompression alone. In fact, fusion was significantly associated with longer operation time (nearly two hours difference) and more blood loss during operation (over 500 mL difference), confirming the higher risk for complications when performing this type of surgery. However, more studies are needed as we only included five trials providing 'very low quality' to 'moderate quality' evidence. For patients who present spinal instability and thus require stabilisation of spinal segments after decompression, the interspinous spacer devices might be an alternative as they were linked to less perioperative blood loss and shorter operation time and hospital length of stay. The interspinous spacer devices, however, should not replace conventional decompression surgery when only decompression of the spinal canal is warranted (i.e., no further fusion). These devices failed to be superior to conventional decompression on patient-relevant outcomes, and resulted in significantly higher reoperation rates. Moreover, our results showed that these implants can cost on average 1.5 times more than conventional decompression. Considering the higher risks and costs, we would not recommend the spacer devices as an alternative to conventional decompression surgery for lumbar spinal stenosis.

One may argue that differences in the proportion of patients with mild spondylolisthesis included in the trials may affect the results. In trials that investigated fusion compared with interspinous spacers, both Davis 2013 and Azzazi 2010 included only participants with up to grade I stable degenerative spondylolisthesis. In Davis 2013, the proportion of participants with spondylolisthesis was 47%; however, Azzazi 2010 did not report the proportion of these participants. In the other included trials, the proportion of participants with up to grade I spondylolisthesis varied. For example, Ghogawala 2016 included only participants with lumbar spinal stenosis and grade I spondylolisthesis, whereas Forsth 2016 stratified the randomisation process to the presence or absence of degenerative spondylolisthesis, and Cavusoglu 2007 reported that 15% of included participants had mild spondylolisthesis. Although the differences between groups for some outcomes were not statistically significant, some might be considered clinically relevant. As most studies were very small, they were likely underpowered. Larger studies are needed to confirm these findings, for example the difference in revision rates between laminectomy and laminotomy.

This review provides valuable information for clinical decision making regarding the best surgical technique for patients with lumbar spinal stenosis, and should be used to inform clinical practice guidelines about the benefits and harms of different surgical options for this condition.

Quality of the evidence

Overall, the methodological quality of included studies was poor. Whereas blinding of the caregiver in surgical trials is typically

not possible, eleven trials reported blinding of outcome assessors and only three studies reported that participants were blinded. The quality of the available evidence (GRADE) ranged from 'high quality' to 'very low quality'. In most cases where the evidence was downgraded, this was done because we found inconsistency of findings (I^2 > 50%) or imprecision (pooled sample size < 300 or 400), hence the evidence was judged as 'moderate quality'. In some pooled analyses, the evidence was downgraded for both inconsistency and imprecision, being judged as 'low quality'. In a few cases, evidence was further downgraded by one level because of limitation of study design, resulting in 'very low quality' evidence. More high quality trials comparing the effects between surgical techniques are needed to support our findings.

Potential biases in the review process

Although we tried to minimise various biases during the review process, the reporting of data was poor among some included studies, and in some circumstances we had to estimate data of treatment effects from graphs or use imputation of data from similar included trials. To overcome this issue, we recommend that future clinical trial authors adequately follow the instructions outlined in the CONSORT statement (Schulz 2010). It is also possible that we have underestimated the rates of reoperation, and our conclusions on harms of included interventions should be interpreted with caution. This is because safety reporting across included trials varied largely and not all trials have reported this outcome. Information on safety of surgical procedures is paramount for clinical decision making, therefore future trials should include complications and reoperations as outcomes and report them appropriately (Ioannidis 2004). We acknowledge the limited number of trials in each comparison, which also limited our ability to perform additional subgroup or sensitivity analyses. The search strategy was limited to humans in some of the databases (MEDLINE, EMBASE), so it is possible that we missed potentially relevant studies not indexed as humans. However, we searched a variety of sources as a way of trying to capture all relevant studies.

Agreements and disagreements with other studies or reviews

This review is an update of a recently published systematic review (Machado 2015), and included an additional seven randomised trials (10 records). A recent Cochrane review has also investigated the effects of decompression techniques for lumbar spinal stenosis, but limited the inclusion criteria to posterior decompression techniques that did not involve fusion or the use of interspinous process spacer devices (Overdevest 2015). Our results agree with those from this recent publication showing that different decompression techniques have similar effects on functional disability and leg pain.

Another systematic review has also investigated the effectiveness of interspinous process spacer devices for lumbar spinal stenosis, suggesting that spacer devices are superior to bony decompression (Chou 2011). However, this review could not find randomised trials that made a direct comparison between spacer devices and conventional decompression, therefore its conclusions were based on indirect comparisons through a network meta-analysis. Similarly, a second systematic review failed to identify trials directly comparing these two techniques (Moojen 2011). As the first randomised trial comparing these techniques was published in 2013, these older systematic reviews did not include any randomised studies. More recently, a systematic review of direct comparisons was published (Wu 2014), but included both randomised and non-randomised studies in their meta-analysis. Results of this review also found higher reoperation rates and costs associated with spacer devices when compared with conventional decompression.

AUTHORS' CONCLUSIONS

Implications for practice

There is relatively limited evidence to guide the use of surgery for the management of lumbar spinal stenosis, as there are no published placebo-controlled trials investigating the effects of surgery for this condition. Most of the evidence supporting the use of surgery comes from randomised trials comparing surgery with non-surgical interventions, with conflicting conclusions. The addition of fusion to decompression is not only more costly, but also leads to more intraoperative blood loss and longer operation time, and fails to result in superior clinical outcomes when compared with decompression alone. Operation using interspinous spacer devices is quicker, and results in less blood loss and shorter hospital length of stay than fusion. These devices, however, do not provide better outcomes than conventional decompression, and are associated with higher reoperation rates. This review provides valuable information for patients and clinicians to help decide the best surgical option for this condition.

Implications for research

Future research should include high quality randomised placebo-controlled trials, and trials comparing surgery with conservative care in order to investigate the specific effects of surgery for lumbar spinal stenosis. More methodologically rigorous studies are needed to compare the effects of the addition of fusion to decompression as we only identified five trials. Trials should incorporate a double-blinded (patient and assessors) design and include an adequate randomisation process. The standardisation of outcomes is also crucial and trials should report patient-related outcome measures, such as leg pain intensity using a visual analogue pain scale; function measured by the ZCQ or the ODI; walking ability using accelerometers; quality of life as reported using the SF-36 or the EQ-5D; as well as surgically relevant outcomes (i.e., perioperative blood loss, operation time, length of hospital stay), and reoperation rates. Also, future trials should include and report clinically important complications, such as infections, blood transfusions, and dural tears. Most included trials in this review reported one- or two-year follow-up, so future research should focus on longer follow-up times (i.e., five years) to establish the long-term effects of surgery in this population.

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CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Azzazi 2010

Methods	Single-centre RCT **Setting:** not reported **Country:** Egypt **Period:** March 2005 to May 2007
Participants	**Number:** 60 patients (30/30) **Diagnosis:** physical and neurological examinations and assessment of imaging studies (computerized tomography and magnetic resonance imaging) **Included:** degenerative spondylolisthesis up to grade I; lateral or central spinal stenosis; predominant component of leg pain (preoperative score of 40 mm on a 100 mm VAS) rather than back pain symptoms; moderate disability; unresponsive to conservative treatment for a minimum of three months

Azzazi 2010 *(Continued)*

	Excluded: previous lumbar fusion, decompression or total facetectomy; trauma; diseases that preclude surgical management; patients younger than 20 years or older than 80 years of age; BMI greater than 40 **Age (years):** mean (range) 56.3 (27–79) **BMI (kg/m²):** mean 27/29 **Lumbar stenosis duration (years):** mean (range) 5.3 (0.2–36.9)
Interventions	**Group 1:** decompression plus transpedicular screw fixation **Group 2:** interspinous process spacer device (X-Stop) **Follow-up:** 24 months
Outcomes	**Pain:** 100 mm visual analogue scale leg pain **Disability:** ODI **Operation time** **Complications** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "60 patients enrolled and randomized to be treated with either..."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No information about drop-outs.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	High risk	The authors report in the methods that perioperative blood loss was recorded and patients returned for follow-up evaluations 3 weeks, then 3, 6, 12 and

Azzazi 2010 *(Continued)*

		24 months after surgery. The results for blood loss were not reported and only 24-month data were reported. Attempts to access these data from the authors was unsuccessful.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Unclear risk	Not mentioned.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Bridwell 1993

Methods	Single-centre RCT **Setting:** Barnes-Jewish Hospital, St. Louis Missouri **Country:** USA **Period:** February 1985 to March 1990
Participants	**Number:** 44 patients (9/11/24) **Diagnosis:** magnetic resonance and computed tomographic imaging. Spinal claudication caused by spinal stenosis at the spondylolisthesis level **Included:** no previous spine surgery **Excluded:** not reported **Age (years):** mean (range) 66.1 (46-79)
Interventions	**Group 1:** decompression alone. Surgical decompression comprised of laminectomy with preservation of bilateral facet joints without discectomy or extensive foraminotomy **Group 2:** decompression plus posterolateral (transverse processes) fusion without instrumentation or posterolateral (facets and transverse processes) fusion with instrumentation. All fusions were performed with autogenous iliac bone graft. **Follow-up:** 37.2 months
Outcomes	**Disability:** Walking ability: worse, same or significantly better after surgery **Complications** **Reoperations**
Notes	**Surgeon's experience:** not reported **Funding:** Conflict of interest and financial support were not reported in this study.
Risk of bias	

Bridwell 1993 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Quote: "the patients were randomized so that". The authors report an error in the randomisation process.
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	43/44=97.7% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	High risk	Protocol not available, and relevant outcomes were not reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patient characteristics at baseline.
Co-interventions (performance bias)	Unclear risk	Only the surgical technique differed between treatment groups. No concomitant discectomy, but foraminotomy was performed in some patients.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest not reported. Financial support was not reported in this study.

Cavusoglu 2007

Methods	Single-centre RCT **Setting:** Sisli Etfal State Hospital, Istanbul **Country:** Turkey **Period:** January 2000 to January 2002
Participants	**Number:** 100 patients (50/50)

Cavusoglu 2007 *(Continued)*

	Diagnosis: physical examination, preoperative radiological investigations with plain roentgenogram, magnetic resonance and computed tomographic images **Included:** symptoms of neurogenic claudication or radiculopathy; radiological/neuroimaging evidence of lumbar stenosis; absence of associated pathology; no history of spinal surgery; non-respondents to minimal 3 months of conservative care **Excluded:** not reported **Age (years):** mean (SD) 69.2 (12.2) **Lumbar stenosis duration (years):** range 0.7 to 5.0
Interventions	**Group 1:** hemi-laminectomy with preservation of posterior midline structures **Group 2:** unilateral laminotomy for bilateral decompression. Decompression of the lateral recess was performed in the unilateral laminectomy group preserving the facet joints, and discectomy was performed if necessary. **Follow-up:** 64.8 months
Outcomes	**Pain:** 100-point SF-36 body pain **Disability:** ODI **Complications**
Notes	**Surgeon's experience: n**ot reported **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "a concealed computer-generated randomization list was used to assign the patient to one of the two treatment groups"
Allocation concealment (selection bias)	Low risk	Quote: "a concealed computer-generated randomization list..."
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "a single radiologist blinded to the clinical results of decompression reviewed all pre and postoperative studies"
Incomplete outcome data (attrition bias) All outcomes	Low risk	97/100 = 97% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.

Cavusoglu 2007 *(Continued)*

Selective reporting (reporting bias)	Low risk	It was clear that the published report included all expected outcomes.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Unclear risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Celik 2010

Methods	Single-centre RCT **Setting:** Department of Neurosurgery, Beyoglu State Hospital, Istanbul **Country:** Turkey **Period:** July 2001 to May 2003
Participants	**Number:** 80 patients (40/40) **Diagnosis:** dynamic x-rays, thin-sliced CT and MRI; severe back/leg pain and neurogenic claudication; anteroposterior diameter less than 10 mm of the lumbar spinal canal by CT scan and MRI **Included:** patients who had not responded to conservative medical therapy and physical therapy; more than 41% in ODI; more than 7 in VAS pain; walking distance less than 30 meters; severe lumbar spinal stenosis clinically **Excluded:** patients requiring discectomy or showing any kind of instability before the surgery **Age (years):** mean (SD) 61 (13)/59 (14)
Interventions	**Group 1:** total laminectomy **Group 2:** bilateral micro decompressive laminotomy. Medial facetectomy and wide foraminotomies were performed at the level of stenosis, preserving the lateral aspect of the facet joints. No patient received discectomy. **Follow-up:** 60 months
Outcomes	**Pain:** 10 cm VAS leg pain **Disability:** ODI, walking distance **Operation time** **Perioperative blood loss** **Complications** **Reoperations**

Celik 2010 *(Continued)*

Notes	**Surgeon's experience:** "both groups of patients were operated by the same senior surgeon in the same time period" **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "a chart system was used to process randomizaton".
Allocation concealment (selection bias)	Low risk	Quote: "a registered nurse informed surgeons about the type of surgery before the operation".
Blinding of participants (performance bias) All outcomes	Low risk	Quote: "patients were not informed as which group they would be placed".
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "the patients were preoperative examined and followed at regular intervals by the operating neurosurgeons and by a neurology specialist blinded to the study protocol."
Incomplete outcome data (attrition bias) All outcomes	Low risk	71/80 = 89% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	It was clear that the published report included all expected outcomes.
Group similarity at baseline (selection bias)	Low risk	There were no preoperative differences between groups, based on Tables 1 to 3.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Unclear risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Cho 2007

Methods	Single-centre RCT **Setting:** China Medical University and Hospital

Cho 2007 *(Continued)*

	Country: China **Period:** May 2005 to January 2006
Participants	**Number:** 70 patients (30/40) **Diagnosis:** CT and MRI: antero-posterior diameter of the spinal canal less than 11 mm, an interpedicular distance of less than 16 mm, and a lateral recess distance of less than 3 mm; clinical symptoms of lumbago and intermittent claudication **Included:** patients with lumbar stenosis with surgical indication for repair **Excluded:** patients > 80 years of age with high anaesthetic risks or severe co-morbidity; patients requiring concomitant fusion **Age (years):** mean (SD) 61 (11)/59 (15) **Lumbar stenosis duration (years):** mean (SD) 4.0 (0.7)/5.3 (0.7)
Interventions	**Group 1:** laminectomy **Group 2:** split-spinous process laminotomy **Follow-up:** 15 months
Outcomes	**Disability:** JOA **Operation time** **Perioperative blood loss** **Complications** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not mentioned.
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.

Cho 2007 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No information about drop-outs.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	It was clear that the published report included all expected outcomes.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on the Table 3.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups. Similar percentage of concomitant discectomy. All participants received the same postoperative care.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Davis 2013

Methods	Multi-centre RCT **Setting:** 21 sites in the United States **Country:** USA **Period:** 2006 to 2010
Participants	**Number:** 322 patients (215/107) **Diagnosis:** central, foraminal or lateral stenosis; more than 25% reduction of the anteroposterior dimension compared with the next adjacent normal level, with nerve root crowding compared with the normal level, as determined by the investigator on CT or MRI **Included:** patients with moderate radiographical diagnosis of spinal stenosis with low back pain; spondylolisthesis up to Meyerding grade I; minimum ODI of 20 (0-50), and VAS back pain score of 50 or more (0-100); minimum 6 months of conservative care **Excluded:** prior lumbar surgery; trauma or tumour; isthmic spondylolisthesis; spondylolysis; scoliosis > 25 degrees; disc herniation; serious disease **Age (years):** mean (SD) 64.1 (9.0)/62.1 (9.2)
Interventions	**Group 1:** decompression plus transpedicular screw fixation **Group 2:** Coflex interspinous process spacer device (Paradigm spine, LLC, New York, NY) **Follow-up:** 24 months
Outcomes	**Pain:** 100 mm VAS leg pain **Disability:** ODI

Davis 2013 *(Continued)*

	Operation time
	Perioperative blood loss
	Complications
	Reoperations
	Length of hospital stay
Notes	**Surgeon's experience:** not reported
	Funding: "Paradigm Spine, LLC (New York, NY) funds were received in support of this work. Relevant financial activities outside the submitted work: consultancy, royalties, payment for lecture, payment for manuscript preparation, patents, payment for development of educational presentations"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "computer generated randomization codes"
Allocation concealment (selection bias)	Low risk	Quote: "centralized by the study sponsor"
Blinding of participants (performance bias) All outcomes	Low risk	Quote: "study subjects were blinded until after surgery"
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "site study personnel were blinded to the treatment assignment up until 5 days prior to surgery"
Incomplete outcome data (attrition bias) All outcomes	Low risk	89% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Tables 4 to 9.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.

Davis 2013 *(Continued)*

Other bias	Unclear risk	Quote: "Paradigm Spine, LLC (New York, NY) funds were received in support of this work. Relevant financial activities outside the submitted work: consultancy, royalties, payment for lecture, payment for manuscript preparation, patents, payment for development of educational presentations."

Forsth 2016

Methods	Multi-centre RCT **Setting:** 7 Swedish hospitals **Country:** Sweden **Period:** October 2006 to June 2012
Participants	**Number:** 247 patients (124/123) **Diagnosis:** pseudoclaudication and image findings as per inclusion criteria **Included:** pseudoclaudication in one or both legs and back pain (score on VAS > 30), 1 or 2 adjacent stenotic segments (cross-section area of the dural sac ≤ 75 mm^2) between L2 and the sacrum on MRI, duration of symptoms > 6 months **Excluded:** spondylolysis, degenerative lumbar scoliosis, history of lumbar spinal surgery for spinal stenosis or instability, stenosis not caused by degenerative changes, stenosis caused by a herniated disk, other specific spinal conditions, history of vertebral compression fractures in affected segments, psychological disorders **Age (years):** mean (SD) 66.0 (8.0)/66.0 (9.0)
Interventions	**Group 1:** decompression alone **Group 2:** decompression plus fusion. The surgical technique was determined solely by the surgeon **Follow-up:** 24 months
Outcomes	**Pain:** 100 mm VAS leg pain **Disability:** ODI **Operation time** **Perioperative blood loss** **Complications** **Reoperations** **Length of hospital stay** **Costs**
Notes	**Surgeon's experience:** all the trial surgeons were senior consultants and were highly experienced in performing the two trial interventions **Funding:** funded by an Uppsala institutional Avtal om Läkarutbildning och Forskning

Risk of bias

Bias	Authors' judgement	Support for judgement

Forsth 2016 *(Continued)*

Random sequence generation (selection bias)	Low risk	Quote: "Simple randomization was performed with the use of a Web-based system that enabled computer-generated random treatment assignment"
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	92% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Low risk	Authors used a modified intention-to-treat analysis that included 9 patients who did not initially receive the assigned treatment but did undergo subsequent surgery.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 2.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "No institution or company had a role in the data analysis, the preparation of the manuscript, or the decision to submit the manuscript for publication."

Ghogawala 2016

Methods	Multi-centre RCT **Setting:** 5 hospitals **Country:** USA **Period:** March 2002 to August 2009
Participants	**Number:** 66 patients (35/31)

Ghogawala 2016 *(Continued)*

	Diagnosis: standardized radiographic and magnetic resonance images **Included:** patients with grade I lumbar spondylolisthesis (degree of spondylolisthesis: 3 to 14 mm) with lumbar stenosis and neurogenic claudication with or without lumbar radiculopathy **Excluded:** radiography revealed lumbar instability (motion of > 3 mm at the level of listhesis, as measured on flexion–extension radiographs of the lumbar spine), previous lumbar spinal surgery, severe systemic disease **Age (years):** mean (SD) 66.5 (8.0)/66.7 (7.2)
Interventions	**Group 1:** decompression alone by a complete laminectomy with partial removal of the medial facet joint **Group 2:** decompression plus fusion. Patients in the fusion group underwent a lumbar laminectomy as well as implantation of pedicle screws and titanium alloy rods across the level of listhesis, with a bone graft harvested from the iliac crest **Follow-up:** 24 months
Outcomes	**Pain:** SF-36 bodily pain subscale **Disability:** ODI **Operation time** **Perioperative blood loss** **Reoperations** **Length of hospital stay**
Notes	**Surgeon's experience:** all surgeons routinely performed both operations tested in the trial; each of the surgeons had performed at least 100 laminectomies and 100 posterolateral fusions for lumbar spondylolisthesis before joining the trial. **Funding:** There was no industry funding or any other industry involvement in the trial

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not mentioned.
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "independent study coordinator who was not aware of the study hypothesis"

Ghogawala 2016 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	88% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "There was no industry funding or any other industry involvement in the SLIP trial."

Grob 1995

Methods	Single-centre RCT **Setting:** Schutthess Hospital, Zurich **Country:** Switzerland **Period:** November 1989 to November 1990
Participants	**Number:** 45 patients (15/15/15) **Diagnosis:** history and clinical examination; CT and MRI (mid-sagittal diameter of the spinal canal of less than 11 mm) **Included:** degenerative spinal stenosis **Excluded:** systemic disease; instability of the spine; previous operation **Age (years):** mean (range) 67 (48-87) **Lumbar stenosis duration (years):** mean (range) 1.3 (0.5-3.1)
Interventions	**Group 1:** decompression alone. Decompression involved widening of the lateral recess, undercut of lamina, and discectomy or foraminotomy in some patients **Group 2:** decompression plus arthrodesis of the most stenotic segment **Group 3:** decompression plus arthrodesis of all of the decompressed vertebral segments **Follow-up:** 28 months
Outcomes	**Pain:** 10 cm VAS overall pain

Grob 1995 *(Continued)*

	Disability: walking ability
	Operation time
	Perioperative blood loss:
	Complications
	Reoperations
Notes	**Surgeon's experience:** All the operations were performed by the same surgeon
	Funding: "no funds were received in support to this study"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "the patients were randomly assigned to the three treatment groups."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	100% of the patients completed the follow-up.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patients characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups. Similar percentage of concomitant discectomy. All participants received the same postoperative care.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	High risk	Patients were assessed at different time points. The average duration of follow-up was 38 months (range: 24 to 32).

Grob 1995 *(Continued)*

Other bias	Low risk	Quote: "no funds were received in support to this study"

Gurelik 2012

Methods	Single-centre RCT **Setting:** Department of Neurosurgery, Van Training and Research Hospital, Van **Country:** Turkey **Period:** January 2006 to February 2009
Participants	**Number:** 52 patients (26/26) **Diagnosis:** MRI of degenerative lumbar spinal stenosis with symptoms of neurogenic claudication or radiculopathy **Included:** symptoms of neurogenic claudication or radiculopathy; radiological evidence of degenerative lumbar stenosis; absence of associated pathological entities such as instability and significant disc herniation; absence of previous surgery for lumbar spine disorder; non-respondents to conservative care **Excluded:** not reported **Age (years):** mean (SD) 57.5 (8.5)/60.7 (10.0)
Interventions	**Group 1:** laminectomy **Group 2:** unilateral laminotomy. Unilateral laminotomy was performed followed by ipsilateral medial facetectomy and foraminotomy, and the ligamentum flavum were resected partially. For both procedures, the medial aspects of the contralateral facet joints were resected partially. **Follow-up:** 6 months
Outcomes	**Disability:** ODI, walking distance
Notes	**Surgeon's experience:** "all operations were performed by one author" **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "patients were randomly assigned to one of the following groups"
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	High risk	Quote: "patients were made aware of the method" and "told which operative procedure they were going to have"
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.

Gurelik 2012 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	100% of the patients completed the follow-up.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Hallett 2007

Methods	Single-centre RCT **Setting:** Spinal Unit, Royal Infirmary of Edinburgh, Edinburgh **Country:** Scotland, UK **Period:** January 1998 to August 2001
Participants	**Number:** 44 patients (14/15/15) **Diagnosis:** plain radiographs and magnetic resonance images **Included:** foraminal stenosis; single-level degenerative disc disease; uni or bilateral leg pain, with or without positive root tension sign, muscle weakness and/or sensory loss; minimum 3 months of conservative care **Excluded:** spondylolisthesis Grade II or greater; vertebral translocation > 1 cm (instability); disc space narrowing of greater than 50%; serious disease **Age (years):** mean (range) 57 (34–75)
Interventions	**Group 1:** decompression (single or bilateral foraminotomy) **Group 2:** decompression plus instrumented pedicular postero-lateral fusion **Group 3:** decompression plus fusion with pedicular screw instrumentation with titanium interbody cages filled with autologous bone. Minimal microdiscectomy was performed if necessary

Hallett 2007 *(Continued)*

	Follow-up: 60 months
Outcomes	**Pain:** 10 cm VAS from the Low Back Outcome Score **Disability:** RMDQ **Costs** **Operation time** **Perioperative blood loss** **Reoperations**
Notes	**Surgeon's experience:** All surgery was performed by the same surgeon in a laminar ventilated theatre. **Funding:** "supported by a grant from DePuy Ltd., U.K. Corporate/Industry funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "type of treatment was randomly allocated immediately before surgery."
Allocation concealment (selection bias)	Low risk	Quote: "shuffled, closed, opaque envelopes, that were numbered 1 to 150 and opened in sequence."
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Quote: "the 3 observers were not blinded and any dispute was resolved by discussion."
Incomplete outcome data (attrition bias) All outcomes	Low risk	93.1% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Low risk	Quote: "analysis of the results was by intention to treat."
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patient characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups. Similar percentage of concomitant discectomy.

Hallett 2007 *(Continued)*

Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Quote: "supported by a grant from DePuy Ltd., U.K. Corporate/ Industry funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript."

Komp 2015

Methods	Single-centre RCT **Setting:** not reported **Country:** Germany **Period:** not reported
Participants	**Number:** 160 patients (80/ 80) **Diagnosis:** clinical assessment **Included:** predominant leg symptoms; neurogenic claudication with or without paresis; back pain maximum 30/100 on the VAS; conservative therapy exhausted or no longer indicated due to the symptoms; mono segmental central stenosis caused by facet hypertrophy; hypertrophy of the ligamentum flavum; and disc protrusions or a combination of those **Excluded:** predominant back pain, foraminal stenosis in the lower level, fresh soft disc herniations with bony stenosis; degenerative spondylolisthesis more than Meyerding Grade I; multidirectional rotation slide; scoliosis more than 20°; prior surgery in the same segment; and cauda equina syndrome **Age (years):** mean (SD) 62 (41-84) **Lumbar stenosis duration (months):** mean 17
Interventions	**Group 1:** conventional microsurgical interlaminar decompression. The conventional decompression operation was performed using the bilateral laminotomy technique with partial facetectomy and flavum resection **Group 2:** full-endoscopic interlaminar decompression. **Follow-up:** 24 months
Outcomes	**Pain:** 100 mm VAS leg pain **Disability:** ODI **Operation time** **Perioperative blood loss** **Complications** **Reoperations**
Notes	**Surgeon's experience:** All operations were performed by 2 surgeons with many years of experience in both techniques

Komp 2015 *(Continued)*

Funding: "there was no external funding in the preparation of this manuscript". The authors declared no conflicts of interest.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "the randomization was carried out as a block randomization."
Allocation concealment (selection bias)	Low risk	Quote: "the secretary provided scheduling in a closed envelope."
Blinding of participants (performance bias) All outcomes	High risk	Quote: "randomization was not blinded, since the patients may identify the operation procedure."
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "the follow-up investigators were not informed of which surgical procedure had been carried out."
Incomplete outcome data (attrition bias) All outcomes	Low risk	153/160 = 96% of the patients completed the 3-month follow-up and 84% completed the 24-month follow-up. The number of drop-outs was similar in each group and the reasons for drop-out are also reported and are unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patient characteristics at baseline
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups. Similar percentage of concomitant discectomy. All participants received the same postoperative care.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "there was no external funding in the preparation of this manuscript". The authors declared no conflicts of interest.

Liu 2013

Methods	Single-centre RCT

Liu 2013 *(Continued)*

	Setting: Department of Orthopedic Surgery, Qilu Hospital of Shandong University, Jinan, Shandong **Country:** China **Period:** not reported
Participants	**Number:** 56 patients (27/29) **Diagnosis:** lumbar spinal stenosis diagnosis by an experienced spine specialist **Included:** patients with lumbar spinal stenosis without degenerative spondylolisthesis or interbody instability **Excluded**: not reported **Age (years):** mean (SD) 59.4 (4.7)/61.1 (3.1) **Lumbar stenosis duration (years):** mean (range) 6.5/5.9 (0.6-13)
Interventions	**Group 1:** conventional laminectomy **Group 2:** spinous process-splitting unilateral laminotomy. The spinous process and the interspinous ligaments were split longitudinally, preserving the paraspinal muscles. Then unilateral laminotomy was conducted for bilateral decompression with removal of the cranial and the caudal portion of the ipsilateral lamina, ligamentum flavum, and medial part of the facet **Follow-up:** 24 months
Outcomes	**Pain:** 10 cm VAS leg pain **Disability:** JOA **Operation time** **Perioperative blood loss**
Notes	**Surgeon's experience:** all patients were diagnosed and assessed by experienced spine specialists **Funding:** "no funds were received in support of this work. No relevant financial activities outside the submitted work"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "the patients were randomly categorized into 2 groups."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias)	Unclear risk	No mention of any attempts to blind the assessors.

Liu 2013 *(Continued)*

All outcomes		
Incomplete outcome data (attrition bias) All outcomes	Low risk	54/57=94.7% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Tables 1 and 2.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "no funds were received in support of this work. No relevant financial activities outside the submitted work."

Lonne 2015

Methods	Multi-centre RCT **Setting:** 6 different Norwegian hospitals **Country:** Norway **Period:** June 2007 to September 2011
Participants	**Number:** 96 patients (49/47) **Diagnosis:** symptoms of neurogenic intermittent claudication and magnetic resonance images and radiographs **Included:** patients with 1 or 2 stenotic levels (from L2 to L5) and with minor spondylolisthesis (Meyerding, grade 1) **Excluded:** spinal stenosis at more than 2 levels; previous low back surgery; unilateral radiculopathy; severe paresis; cauda equina syndrome; degenerative spondylolisthesis > grade 1; isthmic spondylolisthesis; severe scoliosis, idiopathic or degenerative (Cobb angle > 10° or sagittally imbalanced); osteoporosis or suspected osteoporotic fractures in lumbar spine; symptomatic coxarthrosis; vascular intermittent claudication; polyneuropathy; malignant disease **Age (years):** mean (SD) 67 (8.7)/67 (8.8) **BMI (kg/m^2):** mean (SD) 28 (3.8)/28 (4.7) **Lumbar stenosis duration (years):** more than 2 years for the majority of patients in both groups
Interventions	**Group 1:** minimally invasive decompression (bilateral laminotomy). Decompression was performed by a partial excision of the lower part of the lamina and the medial aspects of the facet joint.

Lonne 2015 *(Continued)*

	Group 2: interspinous process spacer device (X-Stop). The X-Stop was inserted between the spinous processes through the interspinous ligament and was secured by the supraspinous ligament posteriorly and by the lamina anteriorly **Follow-up:** 24 months
Outcomes	**Pain:** 11-point numerical rating scale leg pain **Disability:** ODI **Quality of life:** EQ-5D **Costs** **Operation time** **Perioperative blood loss** **Complications** **Reoperations** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** "the study was supported by non-commercial organisations (South-East Regional Health Authority, Norway and the National Advisory Unit on Spinal Surgery, St. Olavs Hospital, Norway)"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "patients were randomized with randomly selected block sizes by a computer-based web solution."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	81/96 = 84% of the patients completed the follow-up. The number of drop-outs was similar in each group and the reasons for drop-out are also reported and are unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Low risk	Quote: "in the main evaluation, not only was an intention-to-treat analysis performed..."
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.

Lonne 2015 *(Continued)*

Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Tables 2 and 4.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "the study was supported by non-commercial organisations (South-East Regional Health Authority, Norway and the National Advisory Unit on Spinal Surgery, St. Olavs Hospital, Norway)."

Mobbs 2014

Methods	Single-centre RCT **Setting:** Prince of Wales Hospital, Randwick, Sydney **Country:** Australia **Period:** 2007 to 2009
Participants	**Number:** 79 patients (40/39) **Diagnosis:** clinical assessment, MRI and CT myelogram **Included:** symptomatic lumbar spinal stenosis with radiculopathy, neurogenic claudication, urinary dysfunction; radiologically confirmed spinal stenosis caused by degenerative changes; canal stenosis at a maximum of 2 levels **Excluded:** concomitant fusion, instrumentation placement or lumbar laminectomy involving discectomy; previous lumbar surgeries at the same level; spondylolisthesis of any grade or degenerative scoliosis; evidence of instability on dynamic radiographs **Age (years):** mean (SD) 65.8 (14.3)/72.7 (10.4)
Interventions	**Group 1:** conventional laminectomy. In the laminectomy group, the spinous process, lamina, ligamentum flavum and portion of the facet joints were removed **Group 2:** microscopic unilateral laminectomy for bilateral decompression. In the unilateral laminectomy group, a medial ipsilateral facetectomy was performed, and if necessary, a contralateral foraminotomy **Follow-up:** 44.3 (15)/36.9 (4.3) months
Outcomes	**Pain:** 10 cm VAS leg pain **Disability:** ODI **Perioperative blood loss** **Complications** **Length of hospital stay**

Mobbs 2014 *(Continued)*

Notes	**Surgeon's experience:** surgery performed by a single senior neurosurgeon with extensive experience in lumbar spine surgery and minimally invasive spine surgery **Funding:** The authors reported no conflict of interest

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Quote: "assigned to either open decompressive laminectomy or microscopic ULBD in a 1:1 split according to their sequence of presentation."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "the observer and statistician were blinded to treatment group by the use of reference numbers."
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	54/79 = 68.4%. Similar and proportional number of drop-outs in each group and similar reasons for withdraw.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	High risk	Patiant characteristics varied substantially for important variables, based on Table 3.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	High risk	Quote: "the mean duration of follow-up was higher in the open-surgery group than in the ULBD group."
Other bias	Low risk	The authors reported no conflict of interest.

Moojen 2013

Methods	Multi-centre double blinded RCT **Setting:** 5 neurosurgical centres in the Netherlands

Moojen 2013 *(Continued)*

	Country: Netherlands **Period:** October 2008 to September 2011
Participants	**Number:** 159 patients (79/80) **Diagnosis:** clinical diagnosis of neurogenic claudication by a neurologist with MRI findings of spinal canal stenosis **Included:** patients between 40 and 85 years; 3 months of neurogenic claudication; single or 2-level degenerative lumbar canal stenosis; indication for surgery **Excluded:** cauda equina syndrome; herniated disc needing discectomy; history of surgery; significant scoliosis **Age (years):** mean 64/66 **BMI (kg/m^2):** mean (range) 28 (20-37)/27 (20-48) **Lumbar stenosis duration (years):** mean (range) 1.9 (0.1-17)
Interventions	**Group 1:** decompression (laminotomy, flavectomy, facetectomy). In the decompression group, a partial resection of the adjacent laminas was executed, followed by a flavectomy with bilateral opening of the lateral recess and, if necessary, a medial facetectomy was done **Group 2:** interspinous process spacer device (Paradigm Spine, USA). In the experimental group, no bony decompression was done and the interspinous process device was implanted by a posterior midline approach. **Follow-up:** 12 months
Outcomes	**Pain:** 100 mm VAS leg pain **Disability:** RMDQ **Function:** ZCQ (physical function) **Costs** **Operation time** **Perioperative blood loss** **Complications** **Reoperations** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** "Paradigm Spine funded this trial. Paradigm Spine had no role in data collection, design of the study, data analysis, interpretation of data, or writing the report and had no influence over whether to submit the manuscript. All the researchers were individually independent from funders"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "randomized design with variable block sizes, with allocations stratified according to center."

Moojen 2013 *(Continued)*

Allocation concealment (selection bias)	Low risk	Quote: "opaque, coded and sealed envelopes". "After induction of anaesthesia, the prepared envelope was opened and the patient allocated to one of the treatment arms."
Blinding of participants (performance bias) All outcomes	Low risk	Quote: "patients, nurses on the hospital wards, and research nurses remained blind to the allocated treatment during the follow-up period of one year."
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "all caregivers blind to the allocated treatment."
Incomplete outcome data (attrition bias) All outcomes	Low risk	151/159 = 95% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Low risk	Quote: "we compared groups on the basis of an intention to treat analysis."
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups. All participants received the same postoperative care.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "Paradigm Spine funded this trial. Paradigm Spine had no role in data collection, design of the study, data analysis, interpretation of data, or writing the report and had no influence over whether to submit the manuscript. All the researchers were individually independent from funders."

Postacchini 1993

Methods	RCT **Setting:** not reported **Country:** Italy **Period:** not reported
Participants	**Number:** 67 patients (26/9/32)

Postacchini 1993 *(Continued)*

	Diagnosis: all patients had plain and flexion-extension radiographs of the lumbar spine with one or more of myelography, plain or contrast-enhanced computed tomographic, and magnetic resonance imaging **Included:** patients with central lumbar stenosis who required surgery **Excluded:** not reported **Age (years):** mean (range) 57 (43-79)
Interventions	**Group 1:** multiple laminotomies **Group 2:** scheduled multiple laminotomies converted to total laminectomy **Group 3:** total laminectomy. Disc excision was performed at a single level in four patients. A unilateral or bilateral intertransverse fusion was performed in four patients with degenerative spondylolisthesis **Follow-up:** 3.7 years (2.2-5.3)
Outcomes	**Pain:** 100 mm VAS leg pain (radicular symptoms) **Operation time** **Perioperative blood loss** **Complications**
Notes	**Surgeon's experience:** all the patients were operated on by the senior author. **Funding:** Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Quote: "we aimed to randomise the choice of surgical procedure, but had to allow the protocol to be broken when multiple laminotomy appeared to be inadequate to obtain sufficient decompression."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "at the latest follow-up, each patient was interviewed and examined by one of the authors, who was unaware of the type of decompression performed."
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	67/70 = 95.7% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.

Postacchini 1993 *(Continued)*

Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patient characteristics at baseline.
Co-interventions (performance bias)	High risk	Concomitant discectomy and fusion were performed at different rates between the groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	High risk	Quote: "the mean follow-up was 3.7 years (2.2 to 5.3)."
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Rajasekaran 2013

Methods	Singe-centre RCT **Setting:** Department of Orthopaedics and Spine Surgery, Ganga Hospital, Coimbatore, Tamil Nadu **Country:** India **Period:** not reported
Participants	**Number:** 51 patients (28/23) **Diagnosis:** MRI exam correlating with typical neurogenic claudication symptoms due to degenerative lumbar canal stenosis **Included:** degenerative lumbar canal stenosis affecting 3 or less levels; typical neurogenic claudication symptoms; MRI demonstrating good clinical correlation; and failure of conservative methods of treatment for a minimum period of 6 months **Excluded:** spondylolisthesis with slip Meyerding grade 2 or greater; instability at the level of stenosis (as defined by > 3 mm translation or > 10° angular change on flexion extension lateral radiographs); concomitant symptomatic cervical or thoracic stenosis; comorbidities such as cardiopulmonary insufficiency; peripheral neuropathy; peripheral vascular disease, prior lumbar spine surgery; severe hip or knee disease **Age (years):** mean (SD) 57.3 (11.2)/54.5 (8.2)
Interventions	**Group 1:** lumbar spinous process splitting decompression. In the experimental group, the interspinous and supra spinous ligaments were cut longitudinally in line with the spinous processes, then decompression proceeded according to the conventional method **Group 2:** conventional midline decompression. In the conventional decompression group the overhanging portion of the proximal spinous process, the interspinous and the supraspinous ligaments were removed, and the ligamentum flavum and the distal half of the proximal lamina were excised. Facetal undercutting was performed as needed **Follow-up:** 16 months
Outcomes	**Pain:** 10 cm VAS leg pain (neurogenic claudication) **Disability:** JOA

Rajasekaran 2013 *(Continued)*

	Recovery
	Operation time
	Perioperative blood loss
	Complications
	Reoperations
	Length of hospital stay
Notes	**Surgeon's experience:** not reported
	Funding: "AO Spine India research grant and the Ganga Orthopaedic Research and Education Foundation funds were received in support of this work"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "the study was a prospective randomized controlled study" and "surgical treatment method for the patients was determined by an automated computer-generated block randomization chart."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "patients outcomes were assessed by an independent observer who was blinded to the type of surgery that a particular patient has undergone."
Incomplete outcome data (attrition bias) All outcomes	Low risk	100% of the patients completed the follow-up.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Tables 1, 2 and 4.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).

Rajasekaran 2013 *(Continued)*

Timing of outcome assessment (detection bias)	Unclear risk	Quote: "the mean duration of follow-up was 14.2 ± 2.9 months (12–16 mo)."
Other bias	Unclear risk	Quote: "AO Spine India research grant and the Ganga Orthopaedic Research and Education Foundation funds were received in support of this work."

Ruetten 2009

Methods	Single-centre RCT **Setting:** Centre for Orthopaedics and Traumatology, St. Anna-Hospital Herne, University of Witten/Herdecke, Herne **Country:** Germany **Period:** 2003 to 2005
Participants	**Number:** 192 patients (100/92) **Diagnosis:** MRI and CT **Included:** neurogenic claudication with unilateral leg pain with or without paresis; back pain with maximum score of 20/100 points on the VAS; and conservative therapy exhausted or no longer indicated due to the symptoms; monosegmental recess stenosis; no foraminal stenosis in the lower level; no disc herniation; degenerative spondylolisthesis with maximum Meyerding Grade I; no multidirectional rotation slide; scoliosis with maximum curvature of 20°; no prior surgery in the same segment **Excluded:** not reported **Age (years):** mean (range) 64 (38-86) **Lumbar stenosis duration (years):** mean (range) 1.6 (0.17-6.5)
Interventions	**Group 1:** conventional microsurgical decompression. Decompression was accomplished by cranial and caudal laminotomy, partial facetectomy, and ligamentum flavum resection **Group 2:** full-endoscopic transforaminal decompression. The operating instruments and optics were products supplied by Richard Wolf GmbH **Follow-up:** 24 months
Outcomes	**Disability:** ODI **Operation time** **Complications** **Reoperations**
Notes	**Surgeon's experience:** all operations were performed by 2 surgeons who have many years of experience in both techniques. **Funding:** "the authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper". Financial support was not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement

Ruetten 2009 *(Continued)*

Random sequence generation (selection bias)	Unclear risk	Quote: "randomized assignment was made by nonphysician study staff. This was accomplished using balanced block randomization."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	High risk	Quote: "the patients are able to identify the surgical procedure."
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	"The later examiners were not informed about which operative procedure was applied."
Incomplete outcome data (attrition bias) All outcomes	Low risk	184/192 = 95.8% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patients characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "the authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper". Financial support was not reported in this study.

Stromqvist 2013

Methods	Multi-centre RCT **Setting:** 3 Swedish spine centres **Country:** Sweden **Period:** not reported
Participants	**Number:** 100 patients (50/50) **Diagnosis:** MRI verified spinal stenosis on 1 or 2 levels in the lumbar spine

Stromqvist 2013 *(Continued)*

	Included: symptoms of neurogenic claudication for minimum 6 months elicited by walking and relieved by flexion of the spine or sitting down; age 40 years or more was required; spinal stenosis was allowed to be present at maximum 2 levels and minor spondylolisthesis (Meyerding, grade 1) was accepted **Excluded:** Previous spine surgery (except for successful disc surgery); infection or malignant disorder; osteoporosis diagnosed before referral for surgery and subjected to medical treatment; stenosis of the L5–S1-level due to the small spinous process of S1 **Age (years):** mean (range) 69 (49-89)
Interventions	**Group 1:** decompression alone. The decompressive procedures were performed using laminectomy or laminotomies with facet-joint sparing techniques **Group 2:** interspinous process spacer device (X-Stop) All operations included open procedures **Follow-up:** 24 months
Outcomes	**Pain:** 100 mm VAS leg pain **Disability:** ZCQ (physical function) **Operation time** **Complications** **Reoperations**
Notes	**Surgeon's experience:** not reported **Funding:** "no funds were received in support of this work"

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "randomization was performed by using envelopes."
Allocation concealment (selection bias)	Unclear risk	Quote: "randomization was performed by using envelopes."
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	96/100 = 96% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.

Stromqvist 2013 *(Continued)*

Intention-to-treat analysis (attrition bias)	Low risk	Quote: "in the main evaluation, not only was intention-to-treat analysis used, but also as-treated analysis was performed."
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "no funds were received in support of this work."

Thome 2005

Methods	Single-centre RCT **Setting:** Departments of Neurosurgery, Neurology, and Neuroradiology, University Hospital Mannheim **Country:** Germany **Period:** not reported
Participants	**Number:** 120 patients (40/40/40) **Diagnosis:** Radiological/neuroimaging evidence of lumbar stenosis **Included:** symptoms of neurogenic claudication or radiculopathy; radiological/neuroimaging evidence of degenerative lumbar stenosis; absence of associated pathological entities such as disc herniations or instability; no history of surgery for lumbar stenosis or lumbar fusion **Excluded:** patients who required discectomy **Age (years):** mean (range) 68 (44-86) **BMI (kg/m^2):** mean (SD) 28 (4)/29 (6)/29 (4) **Lumbar stenosis duration (years):** mean (SD) 1.7 (2.5)
Interventions	**Group 1:** laminectomy **Group 2:** unilateral laminotomy **Group 3:** bilateral laminotomy An operating microscope and high-speed burrs and Kerrison rongeurs were used in all procedures. Special care was taken in all three groups to minimize facet joint resection by using an undercutting technique **Follow-up:** 12 months
Outcomes	**Pain:** 10 cm VAS overall pain

Thome 2005 *(Continued)*

	Disability: RMDQ
	Operation time
	Perioperative blood loss
	Complications
	Reoperations
Notes	**Surgeon's experience:** not reported
	Funding: Conflict of interest and financial support were not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "computer-generated randomization list was used to assign the patient to one of the treatment groups."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	110/120=91.6% of the patients completed the follow-up. The number of drop-outs is unlikely to affect the results.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Low risk	Patients did not differ in their baseline characteristics, based on the Table 1.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.

Thome 2005 *(Continued)*

Other bias	Unclear risk	Conflict of interest not reported. Financial support was not reported in this study.

Usman 2013

Methods	Single-centre RCT **Setting:** Neurosurgery department of PGMI, Lady Reading Hospital, Peshawar **Country:** Pakistan **Period:** January 2010 to December 2010
Participants	**Number:** 60 patients (30/30) **Diagnosis:** physical examination and radiological/neuroimaging evidence **Included:** patients with symptoms of radiculopathy or neurogenic claudication; radiological/neuroimaging evidence of lumbar spinal stenosis involving the central canal and/or foraminal stenosis; failure of conservative treatment with medication and physiotherapy for a minimum of three months **Excluded:** Patients with spondylolisthesis; associated co-morbid conditions; recurrent lumbar spinal stenosis **Age (years):** 73.4% between 31-50 years old
Interventions	**Group 1:** conventional laminectomy **Group 2:** unilateral approach for bilateral decompression. Unilateral laminotomy was performed with partial resection of the inferior aspect of the cranial hemilamina and the superior aspect of the caudal hemilamina. Bilateral flavectomy was performed, and the lateral recess and neural foramina were decompressed contralaterally **Follow-up:** minimum 3 months
Outcomes	**Operation time** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** Conflict of interest and financial support were not reported in this study

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "A total of 60 patients with lumbar stenosis were randomly assigned to undergo either a conventional laminectomy, or a unilateral approach."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.

Usman 2013 *(Continued)*

Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "a database was compiled using inpatients and outpatients medical records by an independent observer who was not part of the operative team and/or in patient care."
Incomplete outcome data (attrition bias) All outcomes	Low risk	100% of the patients completed the follow-up.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	High risk	In the methods the authors reported that recovery rate was assessed as an outcomes measure. However, in the results the authors do not report data for this outcome.
Group similarity at baseline (selection bias)	Unclear risk	No information about patients characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Unclear risk	Not mentioned.
Other bias	Unclear risk	Conflict of interest and financial support were not reported in this study.

Watanabe 2011

Methods	Single-centre RCT **Setting:** Department of Orthopaedic Surgery, National Hospital Organization, Murayama Medical Center, Tokyo **Country:** Japan **Period:** December 2004 to December 2005
Participants	**Number:** 41 (22/19) **Diagnosis:** radiography of the lumbar spine, myelography, CT and MRI **Included:** presence of neurogenic claudication; non-respondents to minimum 6 months of conservative care; clinical symptoms corresponding to MRI or myelography results; 1-2 level decompression necessary **Excluded:** spinal stenosis due to congenital, spondylolytic, traumatic and iatrogenic causes; previous surgery; presence of specific disorders; intermittent claudication due to arterial disease; severe osteoarthrosis or arthritis in the lower limbs; neurological disease causing impaired lower limb function; psychiatric disorders; 3 or more level requiring decompression

Watanabe 2011 *(Continued)*

	Age (years): mean (SD) 69 (10)/71 (8)
Interventions	**Group 1:** conventional laminectomy. In the conventional laminectomy group, the spinous processes were detached from the lamina Group 2: lumbar spinous process–splitting laminectomy. The cortex of the tip of the spinous process is removed at the midline using a high-speed drill with a fine 2 mm diamond-tipped bur, and then, using an osteotome, the spinous process is divided to the base and detached from the lamina. The supra- and interspinous ligaments were also split longitudinally with a scalpel **Follow-up:** 12 months
Outcomes	**Disability:** JOA **Recovery** **Operation time** **Perioperative blood loss** **Reoperations**
Notes	**Surgeon's experience:** not reported **Funding:** "The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper". Financial support was not reported in this study.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "prospective, randomized, controlled study."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	34/41 = 82.9%. "The reasons for the withdrawal were the extension of decompression levels or the conversion of the procedure from decompression to fusion after randomization. However, we do not think that these withdrawals had a major impact on the results."
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.

Watanabe 2011 *(Continued)*

Group similarity at baseline (selection bias)	Unclear risk	No information about patients characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Unclear risk	Quote: "The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper". Financial support was not reported in this study.

Yagi 2009

Methods	Single-centre RCT **Setting:** Department of Orthopedic Surgery, Kawasaki Municipal Hospital, Kawasaki city **Country:** Japan **Period:** not reported
Participants	**Number:** 41 patients (21/20) **Diagnosis:** computed tomographic myelography and MRI **Included:** symptoms of neurogenic claudication referable to the lumbar spine; failure of conservative treatments; absence of associated pathological condition; 1-level spondylosis **Excluded:** not reported **Age (years):** mean (range) 73.3 (63-79)/70.8 (66-73)
Interventions	**Group 1:** conventional laminectomy **Group 2:** median approach microendoscopic laminectomy. The operating microscope was moved into the field and centralized on the laminar base. An osteotomy of the spinous process at the involved level was performed **Follow-up:** 24 months
Outcomes	**Disability:** JOA **Operation time** **Perioperative blood loss** **Length of hospital stay**
Notes	**Surgeon's experience:** not reported **Funding:** "The authors received technical support from Medtronic Sofamor Danek. The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper"

Yagi 2009 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Quote: "patients were divided into 2 groups by turns when they came to our hospital."
Allocation concealment (selection bias)	Unclear risk	Not mentioned.
Blinding of participants (performance bias) All outcomes	Unclear risk	No mention of any attempts to blind the participants.
Bliding of personnel/ care providers (performance bias)	High risk	The surgeon could not have been blinded to the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No mention of any attempts to blind the assessors.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not mentioned.
Intention-to-treat analysis (attrition bias)	Unclear risk	No information about intention-to-treat analysis.
Selective reporting (reporting bias)	Low risk	All expected outcomes were reported.
Group similarity at baseline (selection bias)	Unclear risk	No information about patient characteristics at baseline.
Co-interventions (performance bias)	Low risk	Only the surgical technique differed between treatment groups.
Compliance (performance bias)	Low risk	Compliance in both treatment groups: 100% (surgery).
Timing of outcome assessment (detection bias)	Low risk	All important outcome assessments for both groups were measured at the same time.
Other bias	Low risk	Quote: "The authors received technical support from Medtronic Sofamor Danek. The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper."

RCT: randomized controlled trial
VAS: visual analogue scale
BMI: body mass index
ODI: Oswestry Disability Index
EQ-5D: EuroQol
SD: standard deviation
SF-36: Short Form (36-item) Health Survey
CT: computerized tomography
MRI: magnetic resonance imaging

JOA: Japanese Orthopedic Association scale
RMDQ: Roland-Morris Disability questionnaire
ZDQ: Zurich Claudication Questionnaire

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Abdu 2009	Not a randomised controlled trial
Altaf 2011	Not appropriate comparison
Andersen 2008	Not lumbar spinal stenosis
Anderson 2011	Not a randomised controlled trial
Aoki 2012	Not lumbar spinal stenosis
Arriagada 2000	Not lumbar spinal stenosis
Asazuma 2004	Not a randomised controlled trial
Auerbach 2011	Not appropriate comparison
Auerbach 2012	Not appropriate comparison
Bazan 2002	Not a randomised controlled trial
Benli 2006	Not lumbar spinal stenosis
Bjarke 2002	Not lumbar spinal stenosis
Blumenthal 2013	Not a randomised controlled trial
Bresnahan 2009	Not a randomised controlled trial
Cakir 2009	Not a randomised controlled trial
Cannone 2010	Not a randomised controlled trial
Carragee 1997	Not lumbar spinal stenosis
Carrasco 1986	Not a randomised controlled trial
Carreon 2009	Not lumbar spinal stenosis
Cassinelli 2007	Not a randomised controlled trial
Chen 2010	Not lumbar spinal stenosis
Cheng 2009	Not lumbar spinal stenosis
Choi 2009	Not a randomised controlled trial
Dahdaleh 2013	Not lumbar spinal stenosis
Dantas 2007	Not a randomised controlled trial

Study	Reason for exclusion
Delank 2002	Not a randomised controlled trial
Delawi 2010	Not lumbar spinal stenosis
Desai 2012	Not a randomised controlled trial
Dimar 2009	Not lumbar spinal stenosis
Dirisio 2011	Not appropriate comparison
Dryer 2012	Not appropriate comparison
Epstein 2006	Not a randomised controlled trial
Escobar 2003	Not a randomised controlled trial
Fan 2009	Not a randomised controlled trial
Fast 1985	Not a randomised controlled trial
Feng 2011	Not lumbar spinal stenosis
Fitzgerald 1976	Not a randomised controlled trial
Fu 2008	Not a randomised controlled trial
Fujiya 1990	Not a randomised controlled trial
Försth 2013	Not a randomised controlled trial
Ghahreman 2010	Not a randomised controlled trial
González 1992	Not a randomised controlled trial
Gotfryd 2012	Not a randomised controlled trial
Gotfryd 2012a	Not a randomised controlled trial
Gu 2009	Not a randomised controlled trial
Haley 2012	Not appropriate comparison
Haley 2012a	Not appropriate comparison
Halm 2010	Not a randomised controlled trial
Herkowitz 1991	Not a randomised controlled trial
Hong 2010	Not a randomised controlled trial
Hong 2011	Not a randomised controlled trial
Hwang 2010	Not lumbar spinal stenosis
Ikuta 2005	Not a randomised controlled trial

Study	Reason for exclusion
Imagama 2009	Not a randomised controlled trial
Ito 2010	Not a randomised controlled trial
Katz 1997	Not a randomised controlled trial
Kawaguchi 2004	Not a randomised controlled trial
Kim 2006	Not lumbar spinal stenosis
Kim 2007	Not a randomised controlled trial
Kim 2007a	Not a randomised controlled trial
Konno 2000	Not a randomised controlled trial
Kornblum 2004	Not a randomised controlled trial
Korovessis 2004	Not lumbar spinal stenosis
Ledonio 2012	Not lumbar spinal stenosis
Lee 2009	Not a randomised controlled trial
Lian 2010	Not lumbar spinal stenosis
Liao 2011	Not a randomised controlled trial
Mahir 2012	Not appropriate comparison
McConnell 2011	Not appropriate comparison
Michielsen 2013	Not lumbar spinal stenosis
Pappas 1994	Not a randomised controlled trial
Parker 2013	Not a randomised controlled trial
Radcliff 2011	Not appropriate comparison
Radcliff 2012	Not a randomised controlled trial
Rapp 2009	Not a randomised controlled trial
Rapp 2011	Not a randomised controlled trial
Repantis 2009	Not appropriate comparison
Richter 2010	Not a randomised controlled trial
Rompe 1995	Not a randomised controlled trial
Rosa 2012	Not a randomised controlled trial
Rowland 2009	Not a randomised controlled trial

Study	Reason for exclusion
Satomi 1992	Not a randomised controlled trial
Schnake 2006	Not a randomised controlled trial
Sears 2012	Not appropriate comparison
Sengupta 2006	Not a randomised controlled trial
Shapiro 2005	Not appropriate comparison
Skidmore 2011	Not a randomised controlled trial
Smoljanovic 2010	Not a randomised controlled trial
Smorgick 2013	Not a randomised controlled trial
Steffee 1993	Not a randomised controlled trial
Tani 2002	Not a randomised controlled trial
Tenhula 2000	Not a randomised controlled trial
Tsutsumimoto 2009	Not a randomised controlled trial
Valesin 2009	Not a randomised controlled trial
Videbaek 2010	Not lumbar spinal stenosis
Wang 1998	Not a randomised controlled trial
Weinstein 2007	Not surgical comparison
Whang 2013	Not appropriate comparison
Willén 2008	Not a randomised controlled trial
Xiao 2007	Not lumbar spinal stenosis
Xiao 2007a	Not lumbar spinal stenosis
Yamada 2012	Not a randomised controlled trial
Yang 2011	Not a randomised controlled trial
Yu 2008	Not a randomised controlled trial
Zdeblick 1993	Not lumbar spinal stenosis
Zucherman 2004	Not surgical comparison

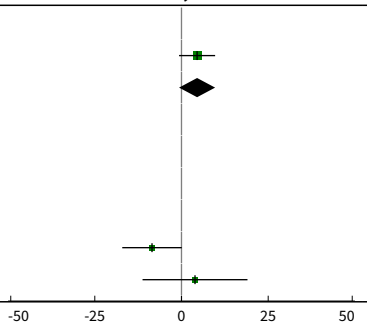
DATA AND ANALYSES

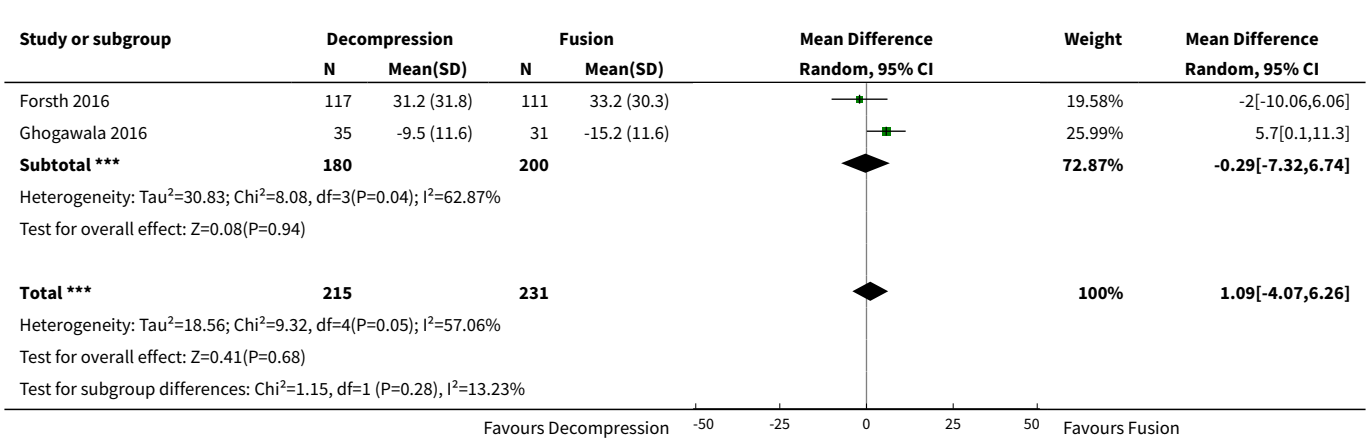
Comparison 1. Decompression alone versus decompression plus fusion

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	4	446	Mean Difference (IV, Random, 95% CI)	1.09 [-4.07, 6.26]
1.1 Short-term (less than 12 months)	1	66	Mean Difference (IV, Random, 95% CI)	4.50 [-0.70, 9.70]
1.2 Long-term (12 months or more)	4	380	Mean Difference (IV, Random, 95% CI)	-0.29 [-7.32, 6.74]
2 Disability	3	401	Mean Difference (IV, Random, 95% CI)	3.37 [-3.37, 10.11]
2.1 Short-term (less than 12 months)	1	66	Mean Difference (IV, Random, 95% CI)	5.2 [-3.50, 13.90]
2.2 Long-term (12 months or more)	3	335	Mean Difference (IV, Random, 95% CI)	3.26 [-6.12, 12.63]
3 Walking ability	3	316	Risk Ratio (IV, Random, 95% CI)	0.99 [0.79, 1.24]
3.1 Long-term (12 months or more)	3	316	Risk Ratio (IV, Random, 95% CI)	0.99 [0.79, 1.24]
4 Operation time	4	381	Mean Difference (IV, Random, 95% CI)	-107.94 [-161.65, -54.23]
5 Blood loss	4	383	Mean Difference (IV, Random, 95% CI)	-0.52 [-0.70, -0.34]
6 Reoperations	5	443	Risk Ratio (IV, Random, 95% CI)	1.25 [0.81, 1.92]
7 Hospitalisation	2	295	Mean Difference (IV, Fixed, 95% CI)	-1.69 [-2.12, -1.26]

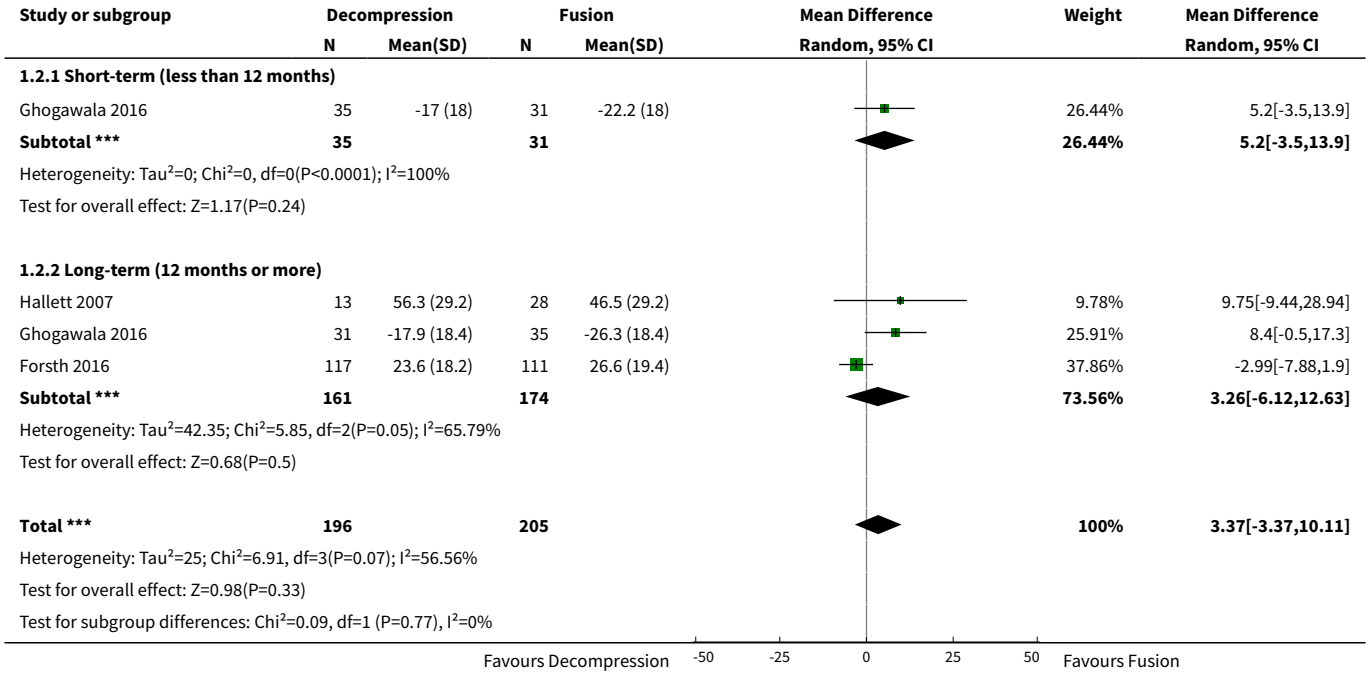
Analysis 1.1. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 1 Pain.

Study or subgroup	Decompression N	Decompression Mean(SD)	Fusion N	Fusion Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
1.1.1 Short-term (less than 12 months)							
Ghogawala 2016	35	-7.7 (10.8)	31	-12.2 (10.8)		27.13%	4.5[-0.7,9.7]
Subtotal ***	**35**		**31**			**27.13%**	**4.5[-0.7,9.7]**
Heterogeneity: Not applicable							
Test for overall effect: Z=1.7(P=0.09)							
1.1.2 Long-term (12 months or more)							
Grob 1995	15	17 (11.9)	30	25.5 (17.1)		18.41%	-8.5[-17.08,0.08]
Hallett 2007	13	48.1 (23)	28	44.2 (23)		8.89%	3.9[-11.23,19.03]

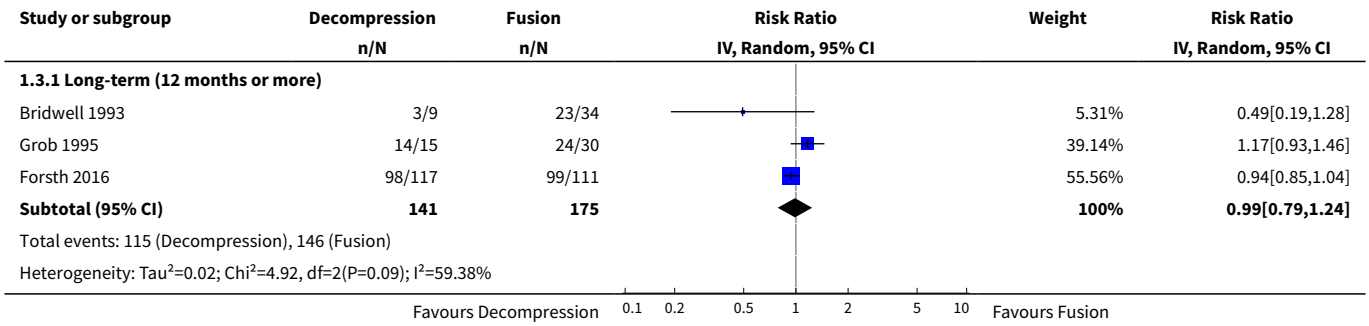


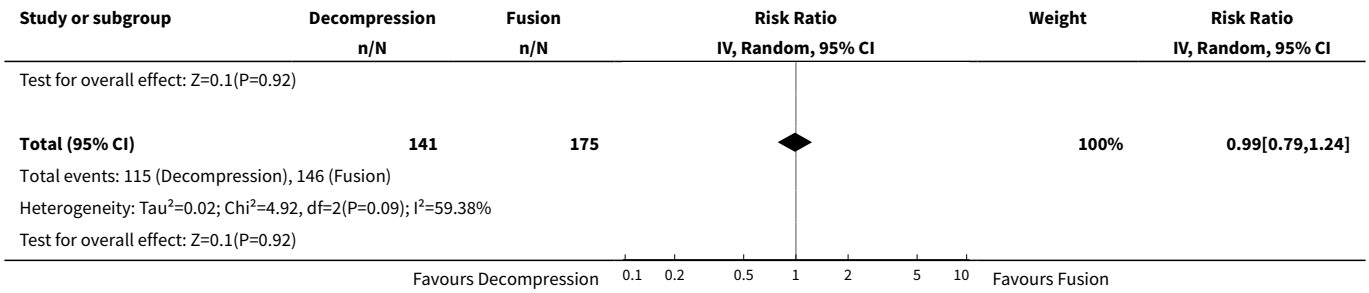


Analysis 1.2. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 2 Disability.

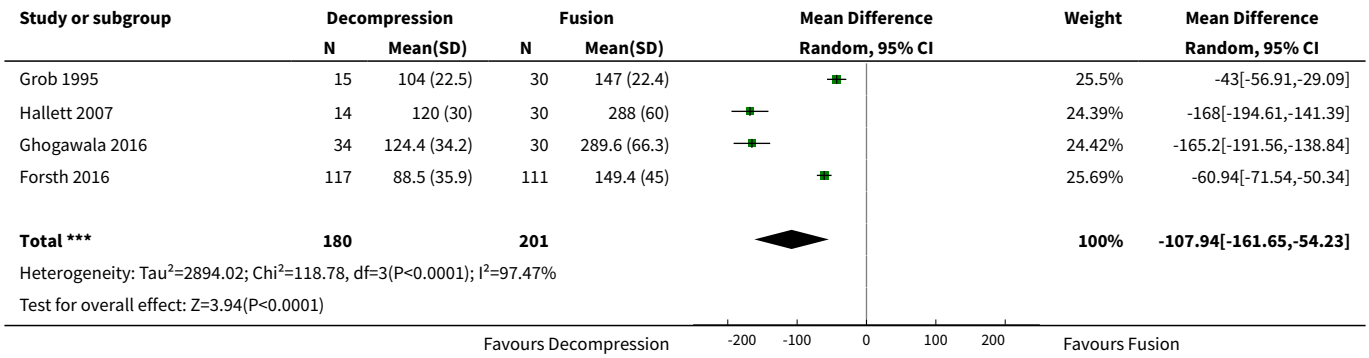


Analysis 1.3. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 3 Walking ability.

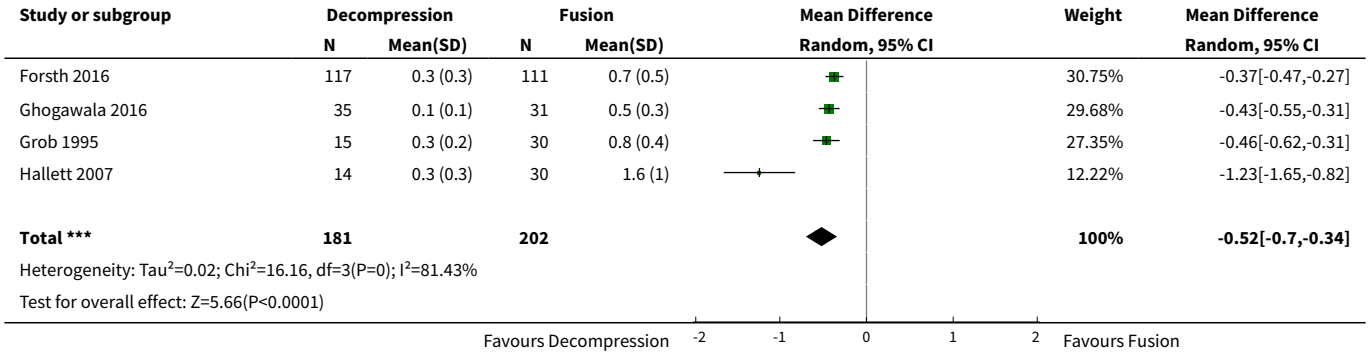




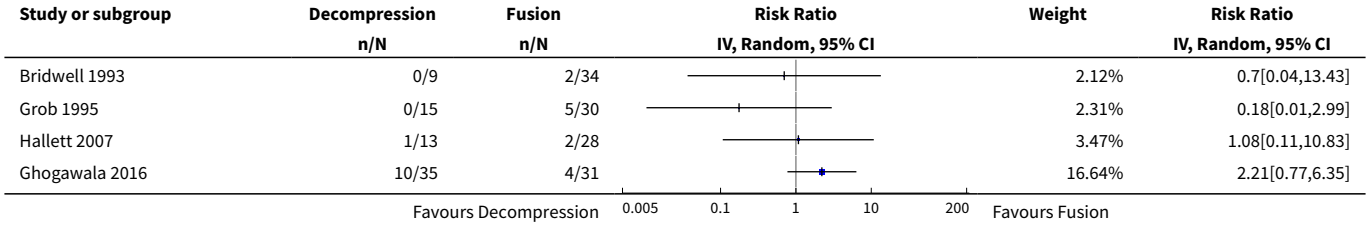
Analysis 1.4. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 4 Operation time.

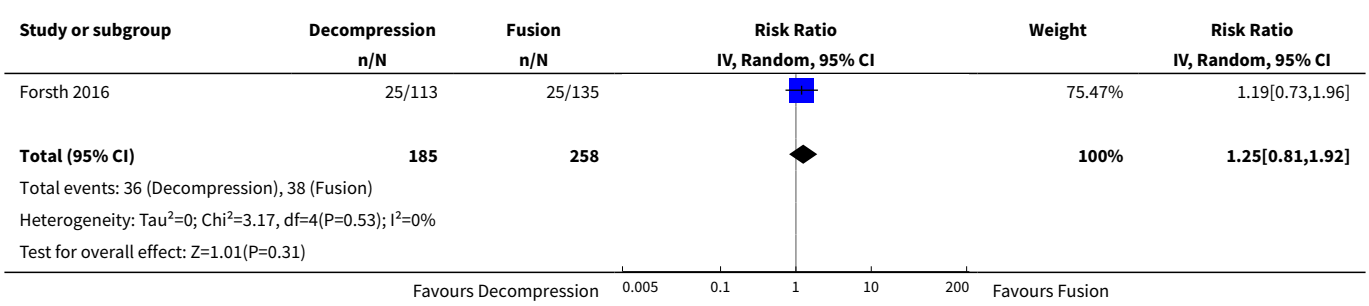


Analysis 1.5. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 5 Blood loss.

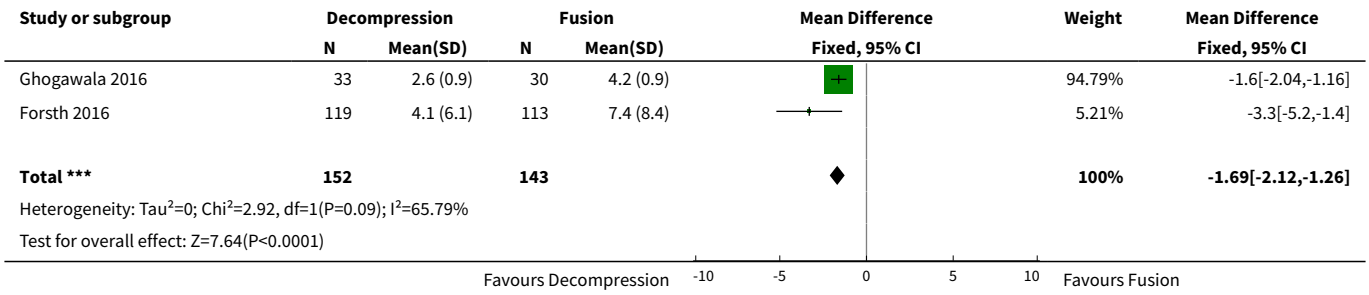


Analysis 1.6. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 6 Reoperations.





Analysis 1.7. Comparison 1 Decompression alone versus decompression plus fusion, Outcome 7 Hospitalisation.



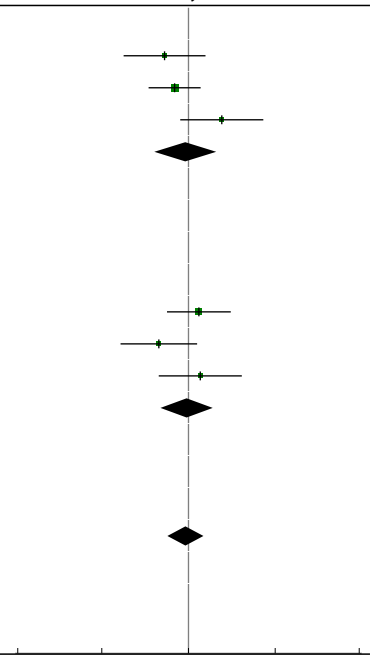
Comparison 2. Decompression versus interspinous spacer

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	3	656	Mean Difference (IV, Random, 95% CI)	-0.89 [-6.08, 4.31]
1.1 Short-term (less than 12 months)	3	328	Mean Difference (IV, Random, 95% CI)	-0.93 [-9.86, 8.00]
1.2 Long-term (12 months or more)	3	328	Mean Difference (IV, Random, 95% CI)	-0.55 [-8.08, 6.99]
2 Disability	3	656	Mean Difference (IV, Random, 95% CI)	1.34 [-2.01, 4.69]
2.1 Short-term (less than 12 months)	3	329	Mean Difference (IV, Random, 95% CI)	1.30 [-3.64, 6.25]
2.2 Long-term (12 months or more)	3	327	Mean Difference (IV, Random, 95% CI)	1.25 [-4.48, 6.98]
3 Function	2	360	Mean Difference (IV, Random, 95% CI)	-0.03 [-0.19, 0.12]
3.1 Short-term (less than 12 months)	2	185	Mean Difference (IV, Random, 95% CI)	-0.06 [-0.27, 0.14]
3.2 Long-term (12 months or more)	2	175	Mean Difference (IV, Random, 95% CI)	-0.00 [-0.30, 0.29]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
4 Quality of life	1	162	Mean Difference (IV, Random, 95% CI)	-0.09 [-0.18, 0.00]
4.1 Short-term (less than 12 months)	1	81	Mean Difference (IV, Random, 95% CI)	-0.12 [-0.25, 0.01]
4.2 Long-term (12 months or more)	1	81	Mean Difference (IV, Random, 95% CI)	-0.05 [-0.18, 0.07]
5 Costs	2	240	Mean Difference (IV, Random, 95% CI)	2856.34 [1970.40, 3742.28]
6 Operation time	3	340	Mean Difference (IV, Random, 95% CI)	39.11 [19.43, 58.78]
7 Blood loss	1	81	Mean Difference (IV, Random, 95% CI)	144.0 [-209.74, 497.74]
8 Reoperations	3	326	Risk Ratio (IV, Random, 95% CI)	3.95 [2.12, 7.37]
9 Hospitalisation	2	240	Mean Difference (IV, Random, 95% CI)	0.51 [-0.58, 1.60]

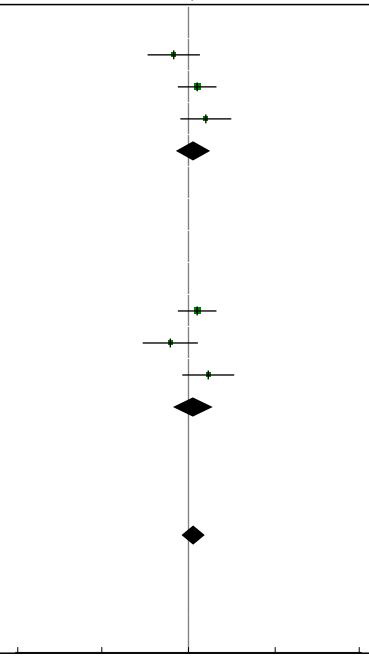
Analysis 2.1. Comparison 2 Decompression versus interspinous spacer, Outcome 1 Pain.

Study or subgroup	Decompression N	Decompression Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
2.1.1 Short-term (less than 12 months)							
Stromqvist 2013	48	22.9 (27.4)	48	29.8 (31.5)		13.9%	-6.9[-18.71,4.91]
Moojen 2013	78	22 (20.3)	73	26 (26.2)		24.26%	-4[-11.5,3.5]
Lonne 2015	41	35.8 (27.5)	40	26.2 (27.5)		13.61%	9.6[-2.38,21.58]
Subtotal ***	**167**		**161**			**51.77%**	**-0.93[-9.86,8]**
Heterogeneity: Tau^2=34.8; Chi^2=4.53, df=2(P=0.1); I^2=55.8%							
Test for overall effect: Z=0.2(P=0.84)							
2.1.2 Long-term (12 months or more)							
Moojen 2013	78	26 (29.3)	73	23 (28.3)		19.35%	3[-6.19,12.19]
Stromqvist 2013	48	21.7 (24.9)	48	30.2 (30)		15.27%	-8.55[-19.59,2.49]
Lonne 2015	41	32 (27.5)	40	28.6 (27.5)		13.61%	3.4[-8.58,15.38]
Subtotal ***	**167**		**161**			**48.23%**	**-0.55[-8.08,6.99]**
Heterogeneity: Tau^2=14.93; Chi^2=3.01, df=2(P=0.22); I^2=33.46%							
Test for overall effect: Z=0.14(P=0.89)							
Total ***	**334**		**322**			**100%**	**-0.89[-6.08,4.31]**
Heterogeneity: Tau^2=14.36; Chi^2=7.62, df=5(P=0.18); I^2=34.4%							
Test for overall effect: Z=0.33(P=0.74)							
Test for subgroup differences: Chi^2=0, df=1 (P=0.95), I^2=0%							



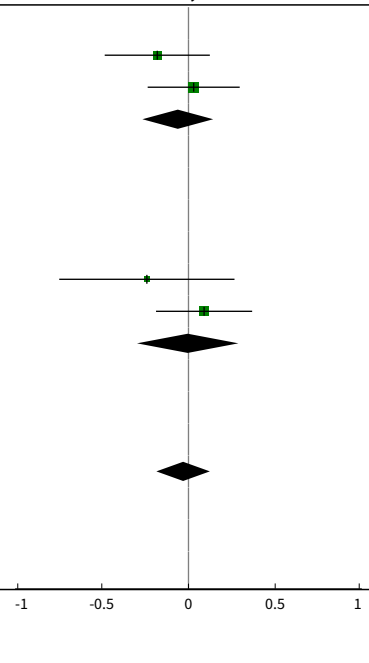
Analysis 2.2. Comparison 2 Decompression versus interspinous spacer, Outcome 2 Disability.

Study or subgroup	Decompression N	Decompression Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
2.2.1 Short-term (less than 12 months)							
Stromqvist 2013	48	42.5 (16.8)	48	46.8 (20.8)		14.35%	-4.25[-11.79,3.29]
Moojen 2013	78	45 (17.5)	74	42.5 (17.5)		21.49%	2.5[-3.07,8.07]
Lonne 2015	41	19.4 (16.6)	40	14.4 (17.1)		14.91%	5[-2.35,12.35]
Subtotal ***	**167**		**162**			**50.76%**	**1.3[-3.64,6.25]**
Heterogeneity: Tau²=7.32; Chi²=3.23, df=2(P=0.2); I²=38.02%							
Test for overall effect: Z=0.52(P=0.61)							
2.2.2 Long-term (12 months or more)							
Moojen 2013	79	45 (17.5)	73	42.5 (17.5)		21.48%	2.5[-3.07,8.07]
Stromqvist 2013	48	41.5 (18.5)	46	46.8 (20.8)		13.26%	-5.25[-13.21,2.71]
Lonne 2015	41	18.3 (16.6)	40	12.6 (17.7)		14.51%	5.7[-1.79,13.19]
Subtotal ***	**168**		**159**			**49.24%**	**1.25[-4.48,6.98]**
Heterogeneity: Tau²=13.15; Chi²=4.1, df=2(P=0.13); I²=51.16%							
Test for overall effect: Z=0.43(P=0.67)							
Total ***	**335**		**321**			**100%**	**1.34[-2.01,4.69]**
Heterogeneity: Tau²=5.51; Chi²=7.32, df=5(P=0.2); I²=31.72%							
Test for overall effect: Z=0.78(P=0.43)							
Test for subgroup differences: Chi²=0, df=1 (P=0.99), I²=0%							



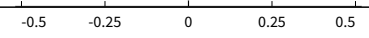
Analysis 2.3. Comparison 2 Decompression versus interspinous spacer, Outcome 3 Function.

Study or subgroup	Decompression N	Decompression Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
2.3.1 Short-term (less than 12 months)							
Stromqvist 2013	48	1.7 (0.8)	48	1.9 (0.8)		25.9%	-0.18[-0.48,0.12]
Lonne 2015	41	1.7 (0.6)	48	1.7 (0.6)		33.8%	0.03[-0.24,0.3]
Subtotal ***	**89**		**96**			**59.7%**	**-0.06[-0.27,0.14]**
Heterogeneity: Tau²=0; Chi²=1.04, df=1(P=0.31); I²=4.18%							
Test for overall effect: Z=0.59(P=0.55)							
2.3.2 Long-term (12 months or more)							
Stromqvist 2013	48	1.7 (1.6)	46	1.9 (0.8)		9.32%	-0.24[-0.75,0.27]
Lonne 2015	41	1.7 (0.6)	40	1.6 (0.6)		30.98%	0.09[-0.19,0.37]
Subtotal ***	**89**		**86**			**40.3%**	**-0[-0.3,0.29]**
Heterogeneity: Tau²=0.01; Chi²=1.26, df=1(P=0.26); I²=20.58%							
Test for overall effect: Z=0.03(P=0.98)							
Total ***	**178**		**182**			**100%**	**-0.03[-0.19,0.12]**
Heterogeneity: Tau²=0; Chi²=2.52, df=3(P=0.47); I²=0%							
Test for overall effect: Z=0.39(P=0.69)							
Test for subgroup differences: Chi²=0.1, df=1 (P=0.75), I²=0%							



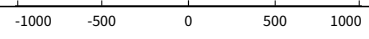
Analysis 2.4. Comparison 2 Decompression versus interspinous spacer, Outcome 4 Quality of life.

Study or subgroup	Decompression N	Decompression Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
2.4.1 Short-term (less than 12 months)							
Lonne 2015	41	0.6 (0.3)	40	0.7 (0.3)		50%	-0.12[-0.25,0.01]
Subtotal ***	**41**		**40**			**50%**	**-0.12[-0.25,0.01]**
Heterogeneity: Not applicable							
Test for overall effect: Z=1.85(P=0.06)							
2.4.2 Long-term (12 months or more)							
Lonne 2015	41	0.7 (0.3)	40	0.7 (0.3)		50%	-0.05[-0.18,0.07]
Subtotal ***	**41**		**40**			**50%**	**-0.05[-0.18,0.07]**
Heterogeneity: Not applicable							
Test for overall effect: Z=0.85(P=0.39)							
Total ***	**82**		**80**			**100%**	**-0.09[-0.18,0]**
Heterogeneity: Tau^2=0; Chi^2=0.49, df=1(P=0.48); I^2=0%							
Test for overall effect: Z=1.91(P=0.06)							
Test for subgroup differences: Chi^2=0.49, df=1 (P=0.48), I^2=0%							



Analysis 2.5. Comparison 2 Decompression versus interspinous spacer, Outcome 5 Costs.

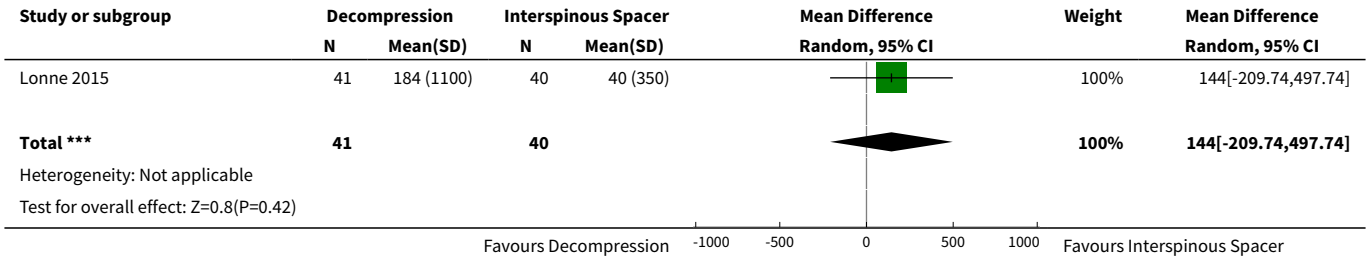
Study or subgroup	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Decompression N	Decompression Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Moojen 2013	80	10210 (8127.8)	79	7180 (8127.8)		12.29%	3030[503.26,5556.74]
Lonne 2015	40	8247 (2171.8)	41	5415 (2171.8)		87.71%	2832[1886.01,3777.99]
Total ***	**120**		**120**			**100%**	**2856.34[1970.4,3742.28]**
Heterogeneity: Tau^2=0; Chi^2=0.02, df=1(P=0.89); I^2=0%							
Test for overall effect: Z=6.32(P<0.0001)							



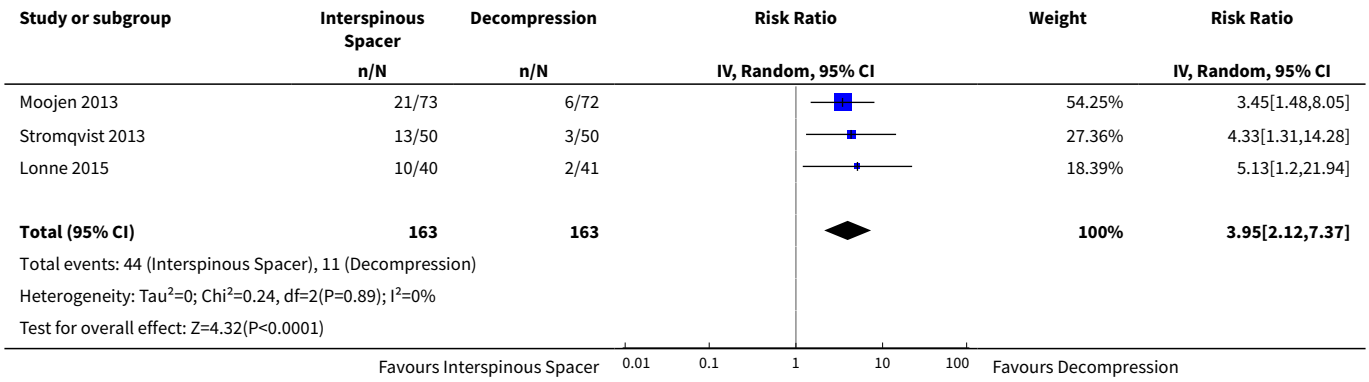
Analysis 2.6. Comparison 2 Decompression versus interspinous spacer, Outcome 6 Operation time.

Study or subgroup	Decompression N	Decompression Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Moojen 2013	79	43 (19)	80	24 (10)		35.05%	19[14.27,23.73]
Stromqvist 2013	50	98 (14.5)	50	62 (14.5)		34.74%	36[30.32,41.68]
Lonne 2015	41	112.9 (41)	40	46.9 (20.8)		30.22%	66[51.89,80.11]
Total ***	**170**		**170**			**100%**	**39.11[19.43,58.78]**
Heterogeneity: Tau^2=281.76; Chi^2=49.33, df=2(P<0.0001); I^2=95.95%							
Test for overall effect: Z=3.9(P<0.0001)							

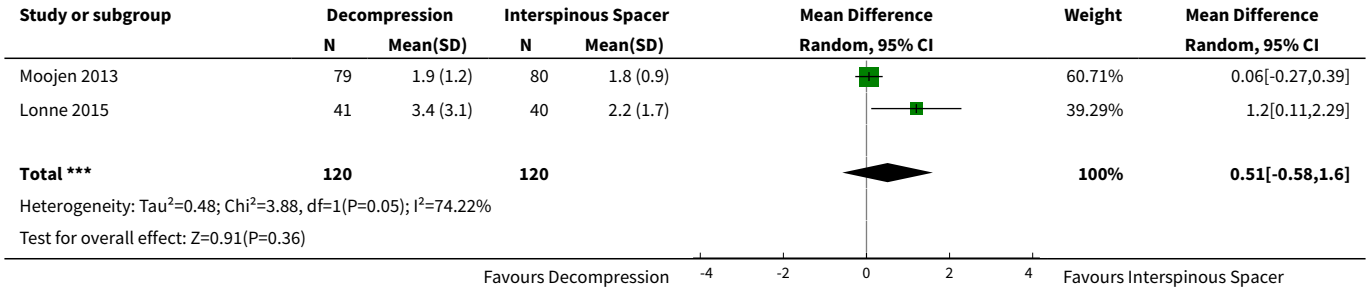
Analysis 2.7. Comparison 2 Decompression versus interspinous spacer, Outcome 7 Blood loss.



Analysis 2.8. Comparison 2 Decompression versus interspinous spacer, Outcome 8 Reoperations.



Analysis 2.9. Comparison 2 Decompression versus interspinous spacer, Outcome 9 Hospitalisation.



Comparison 3. Decompression plus fusion versus interspinous spacer

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	2	308	Mean Difference (IV, Random, 95% CI)	5.35 [-1.18, 11.88]
1.1 Long-term (12 months or more)	2	308	Mean Difference (IV, Random, 95% CI)	5.35 [-1.18, 11.88]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2 Disability	2	308	Mean Difference (IV, Random, 95% CI)	5.72 [1.28, 10.15]
2.1 Long-term (12 months or more)	2	308	Mean Difference (IV, Random, 95% CI)	5.72 [1.28, 10.15]
3 Quality of life	1	226	Mean Difference (IV, Random, 95% CI)	-3.10 [-6.30, 0.10]
3.1 Long-term (12 months or more)	1	226	Mean Difference (IV, Random, 95% CI)	-3.10 [-6.30, 0.10]
4 Operation time	2	381	Mean Difference (IV, Random, 95% CI)	78.91 [30.16, 127.65]
5 Blood loss	1	320	Mean Difference (IV, Random, 95% CI)	238.90 [182.66, 295.14]
6 Reoperations	1	322	Risk Ratio (IV, Random, 95% CI)	0.70 [0.32, 1.51]
7 Hospitalisation	2	382	Mean Difference (IV, Random, 95% CI)	1.58 [0.90, 2.27]

Analysis 3.1. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 1 Pain.

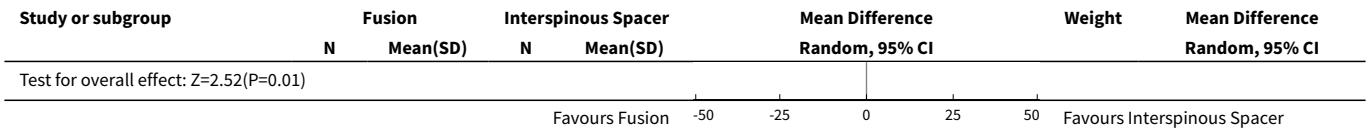
Study or subgroup	Fusion N	Fusion Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
3.1.1 Long-term (12 months or more)							
Azzazi 2010	30	35.5 (24.2)	30	25.5 (24.2)		28.45%	10[-2.25,22.25]
Davis 2013	86	24.1 (30.6)	162	20.6 (27.4)		71.55%	3.5[-4.22,11.22]
Subtotal ***	**116**		**192**			**100%**	**5.35[-1.18,11.88]**
Heterogeneity: Tau^2=0; Chi^2=0.77, df=1(P=0.38); I^2=0%							
Test for overall effect: Z=1.61(P=0.11)							
Total ***	**116**		**192**			**100%**	**5.35[-1.18,11.88]**
Heterogeneity: Tau^2=0; Chi^2=0.77, df=1(P=0.38); I^2=0%							
Test for overall effect: Z=1.61(P=0.11)							

Favours Fusion — Favours Interspinous Spacer

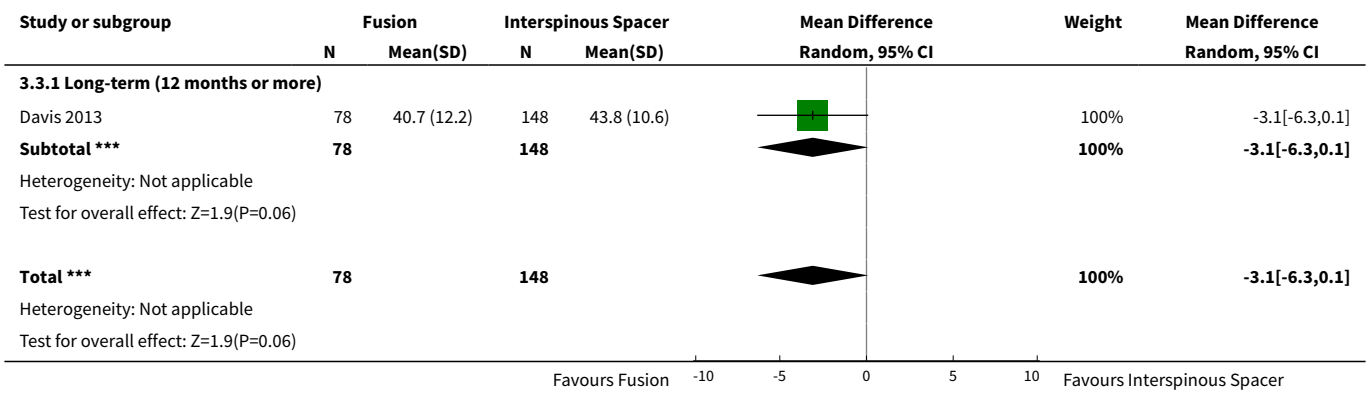
Analysis 3.2. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 2 Disability.

Study or subgroup	Fusion N	Fusion Mean(SD)	Interspinous Spacer N	Interspinous Spacer Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
3.2.1 Long-term (12 months or more)							
Azzazi 2010	30	34.5 (15.8)	30	26.5 (15.8)		30.81%	8[0,16]
Davis 2013	86	26.7 (21.3)	162	22 (18.6)		69.19%	4.7[-0.64,10.04]
Subtotal ***	**116**		**192**			**100%**	**5.72[1.28,10.15]**
Heterogeneity: Tau^2=0; Chi^2=0.45, df=1(P=0.5); I^2=0%							
Test for overall effect: Z=2.52(P=0.01)							
Total ***	**116**		**192**			**100%**	**5.72[1.28,10.15]**
Heterogeneity: Tau^2=0; Chi^2=0.45, df=1(P=0.5); I^2=0%							

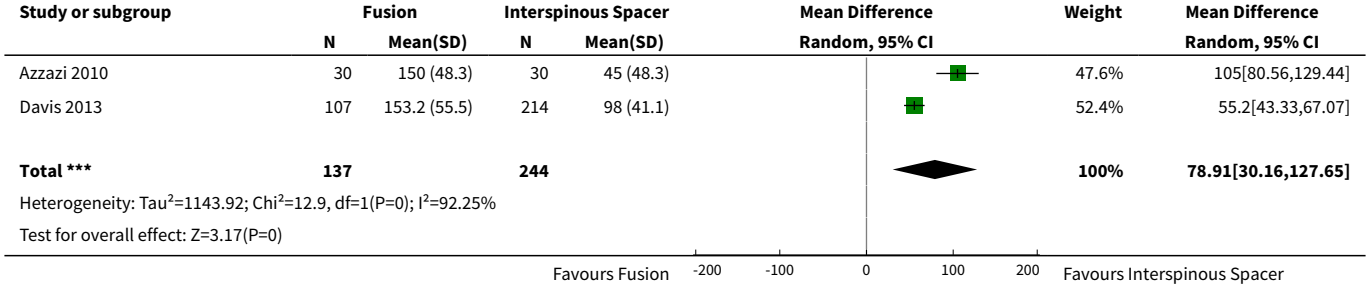
Favours Fusion — Favours Interspinous Spacer



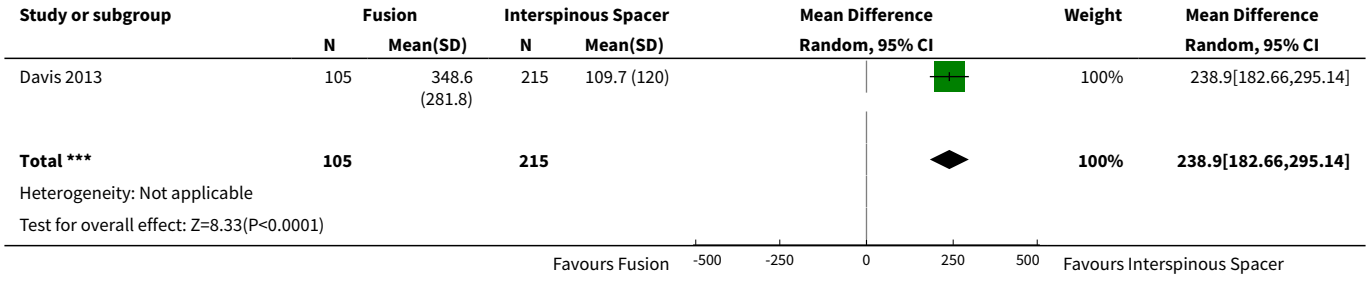
Analysis 3.3. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 3 Quality of life.



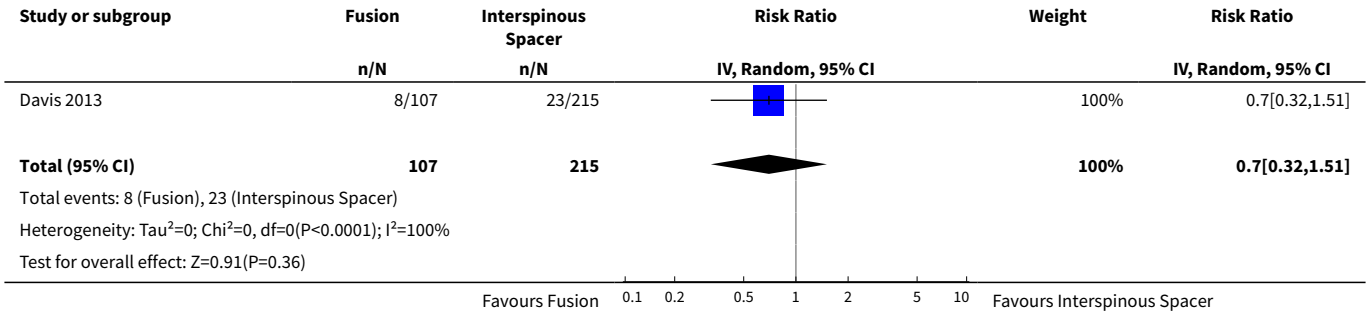
Analysis 3.4. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 4 Operation time.



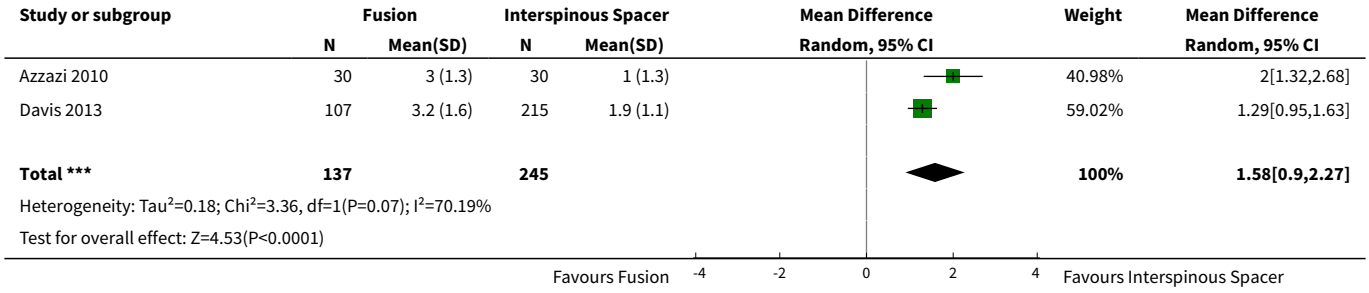
Analysis 3.5. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 5 Blood loss.



Analysis 3.6. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 6 Reoperations.



Analysis 3.7. Comparison 3 Decompression plus fusion versus interspinous spacer, Outcome 7 Hospitalisation.



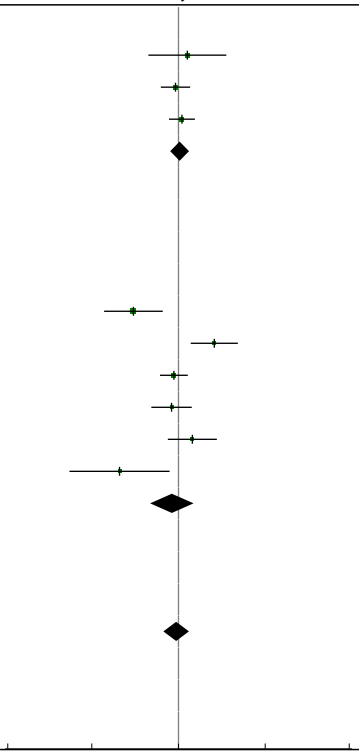
Comparison 4. Laminectomy versus laminotomy

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Pain	6	728	Mean Difference (IV, Random, 95% CI)	-0.67 [-4.36, 3.02]
1.1 Short-term (less than 12 months)	3	281	Mean Difference (IV, Random, 95% CI)	0.32 [-2.39, 3.04]
1.2 Long-term (12 months or more)	6	447	Mean Difference (IV, Random, 95% CI)	-1.92 [-8.19, 4.35]
2 Disability	6	722	Mean Difference (IV, Random, 95% CI)	1.05 [-0.81, 2.90]
2.1 Short-term (less than 12 months)	4	333	Mean Difference (IV, Random, 95% CI)	1.56 [-1.02, 4.13]
2.2 Long-term (12 months or more)	5	389	Mean Difference (IV, Random, 95% CI)	-0.43 [-4.37, 3.52]
3 Walking ability	3	414	Std. Mean Difference (IV, Random, 95% CI)	-0.05 [-0.25, 0.15]
3.1 Short-term (less than 12 months)	3	233	Std. Mean Difference (IV, Random, 95% CI)	-0.07 [-0.33, 0.20]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
3.2 Long-term (12 months or more)	2	181	Std. Mean Difference (IV, Random, 95% CI)	-0.02 [-0.33, 0.28]
4 Operation time	5	339	Mean Difference (IV, Random, 95% CI)	-6.25 [-13.76, 1.27]
5 Blood loss	5	381	Mean Difference (IV, Random, 95% CI)	38.80 [17.81, 59.80]
6 Reoperations	2	182	Risk Ratio (IV, Random, 95% CI)	2.61 [0.78, 8.78]
7 Hospitalisation	2	139	Mean Difference (IV, Random, 95% CI)	1.55 [0.61, 2.50]

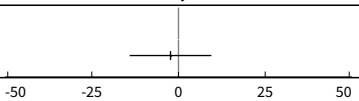
Analysis 4.1. Comparison 4 Laminectomy versus laminotomy, Outcome 1 Pain.

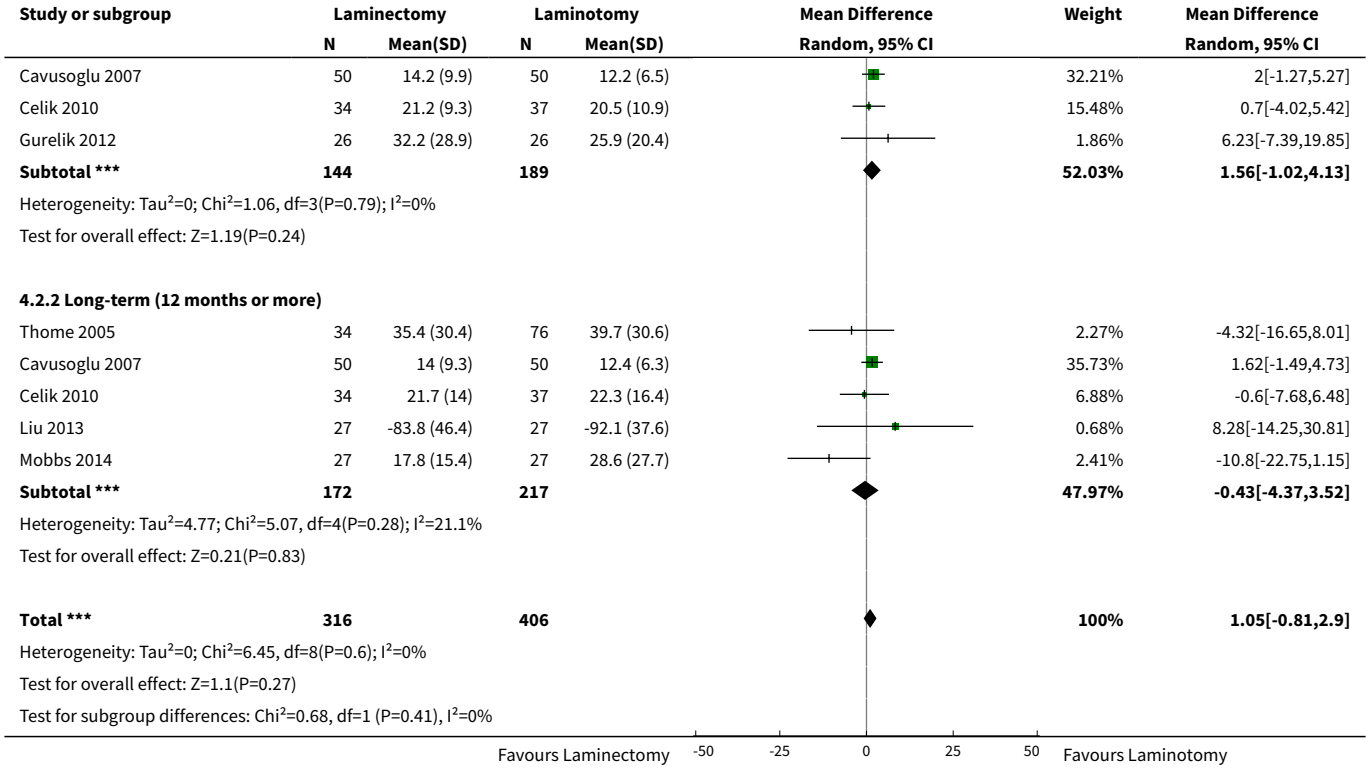
Study or subgroup	Laminectomy N	Laminectomy Mean(SD)	Laminotomy N	Laminotomy Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
4.1.1 Short-term (less than 12 months)							
Thome 2005	34	30.5 (27.3)	76	27.9 (28.9)		6.75%	2.56[-8.68,13.8]
Cavusoglu 2007	50	-62.6 (9.5)	50	-61.8 (11.9)		14.59%	-0.86[-5.09,3.37]
Celik 2010	34	26 (7)	37	25 (9)		15.23%	1[-2.73,4.73]
Subtotal ***	**118**		**163**			**36.57%**	**0.32[-2.39,3.04]**
Heterogeneity: Tau²=0; Chi²=0.58, df=2(P=0.75); I²=0%							
Test for overall effect: Z=0.23(P=0.82)							
4.1.2 Long-term (12 months or more)							
Postacchini 1993	32	-84 (15.3)	26	-71 (17.1)		9.26%	-13[-21.46,-4.54]
Thome 2005	34	40 (10)	76	29.7 (26.2)		11.2%	10.33[3.54,17.12]
Cavusoglu 2007	50	-69.6 (10.5)	50	-68.3 (9.9)		14.88%	-1.32[-5.33,2.69]
Celik 2010	34	23 (11)	37	25 (14)		12.44%	-2[-7.83,3.83]
Liu 2013	27	17 (15.6)	27	13 (10.4)		10.86%	4[-3.07,11.07]
Mobbs 2014	27	39 (29)	27	56 (25)		4.79%	-17[-31.44,-2.56]
Subtotal ***	**204**		**243**			**63.43%**	**-1.92[-8.19,4.35]**
Heterogeneity: Tau²=46.06; Chi²=25.14, df=5(P=0); I²=80.11%							
Test for overall effect: Z=0.6(P=0.55)							
Total ***	**322**		**406**			**100%**	**-0.67[-4.36,3.02]**
Heterogeneity: Tau²=19.63; Chi²=25.98, df=8(P=0); I²=69.21%							
Test for overall effect: Z=0.36(P=0.72)							
Test for subgroup differences: Chi²=0.41, df=1 (P=0.52), I²=0%							



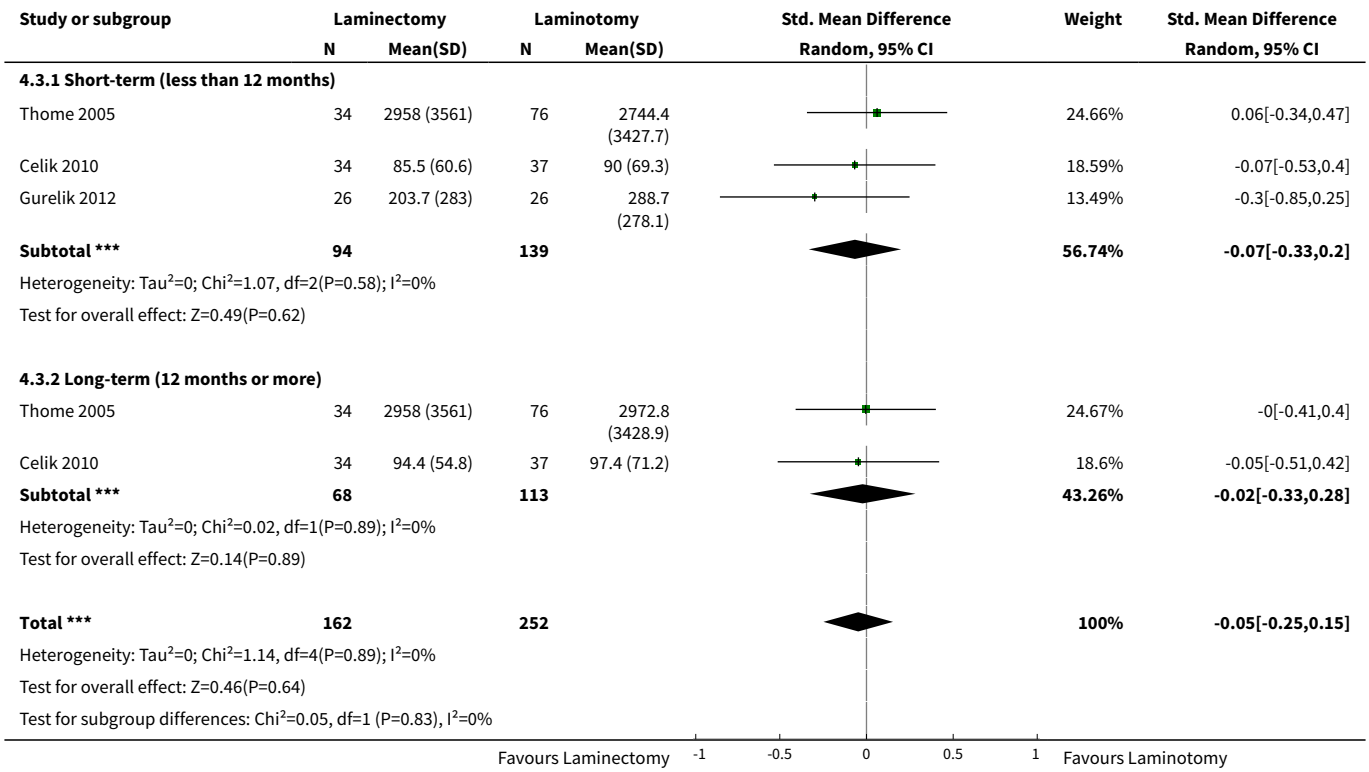
Analysis 4.2. Comparison 4 Laminectomy versus laminotomy, Outcome 2 Disability.

Study or subgroup	Laminectomy N	Laminectomy Mean(SD)	Laminotomy N	Laminotomy Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
4.2.1 Short-term (less than 12 months)							
Thome 2005	34	35.7 (28.2)	76	38 (31)		2.49%	-2.3[-14.07,9.47]



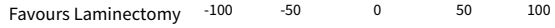


Analysis 4.3. Comparison 4 Laminectomy versus laminotomy, Outcome 3 Walking ability.



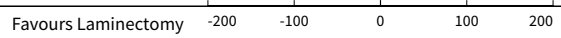
Analysis 4.4. Comparison 4 Laminectomy versus laminotomy, Outcome 4 Operation time.

Study or subgroup	Laminectomy N	Laminectomy Mean(SD)	Laminotomy N	Laminotomy Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Postacchini 1993	32	85.9 (41.9)	26	109.4 (50.2)		8.37%	-23.48[-47.63,0.67]
Thome 2005	38	73 (32)	79	83.4 (30)		23.65%	-10.42[-22.56,1.72]
Celik 2010	22	107 (70.4)	26	83 (61.2)		3.74%	24[-13.65,61.65]
Liu 2013	29	57 (64.6)	27	67 (109.1)		2.41%	-10[-57.41,37.41]
Usman 2013	30	65 (0.5)	30	69 (0.5)		61.83%	-4[-4.28,-3.72]
Total ***	**151**		**188**			**100%**	**-6.25[-13.76,1.27]**
Heterogeneity: Tau²=23.74; Chi²=5.76, df=4(P=0.22); I²=30.54%							
Test for overall effect: Z=1.63(P=0.1)							



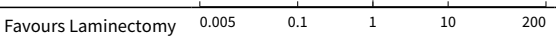
Analysis 4.5. Comparison 4 Laminectomy versus laminotomy, Outcome 5 Blood loss.

Study or subgroup	Laminectomy N	Laminectomy Mean(SD)	Laminotomy N	Laminotomy Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Postacchini 1993	32	188.8 (79.4)	26	174.6 (63.2)		19.11%	14.13[-22.55,50.82]
Thome 2005	38	227 (154)	79	194.3 (125.5)		10.69%	32.72[-23.52,88.96]
Celik 2010	34	227 (74)	37	178 (53)		23.56%	49[18.83,79.17]
Liu 2013	29	78 (54.9)	27	56 (57.2)		24.15%	22[-7.4,51.4]
Mobbs 2014	40	110 (79.4)	39	40 (63.2)		22.5%	70[38.4,101.6]
Total ***	**173**		**208**			**100%**	**38.8[17.81,59.8]**
Heterogeneity: Tau²=250.23; Chi²=7.21, df=4(P=0.13); I²=44.55%							
Test for overall effect: Z=3.62(P=0)							

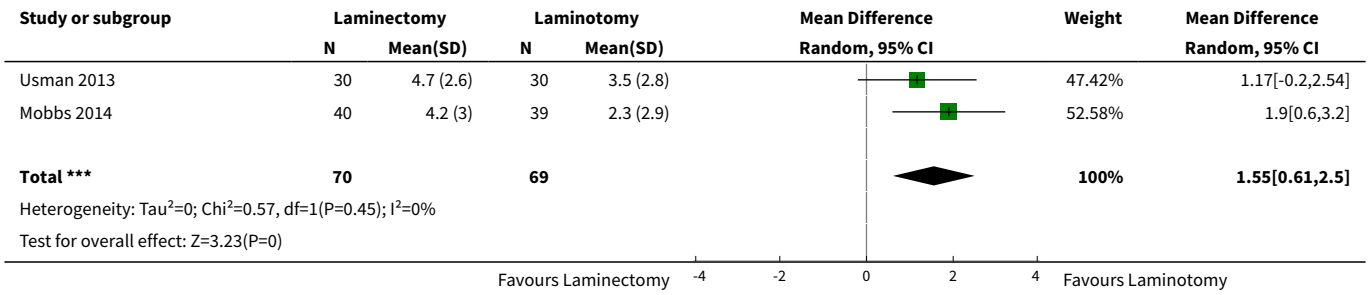


Analysis 4.6. Comparison 4 Laminectomy versus laminotomy, Outcome 6 Reoperations.

Study or subgroup	Laminectomy n/N	Laminotomy n/N	Risk Ratio IV, Random, 95% CI	Weight	Risk Ratio IV, Random, 95% CI
Thome 2005	4/34	4/77		83.67%	2.26[0.6,8.53]
Celik 2010	2/34	0/37		16.33%	5.43[0.27,109.19]
Total (95% CI)	**68**	**114**		**100%**	**2.61[0.78,8.78]**
Total events: 6 (Laminectomy), 4 (Laminotomy)					
Heterogeneity: Tau²=0; Chi²=0.27, df=1(P=0.6); I²=0%					
Test for overall effect: Z=1.55(P=0.12)					



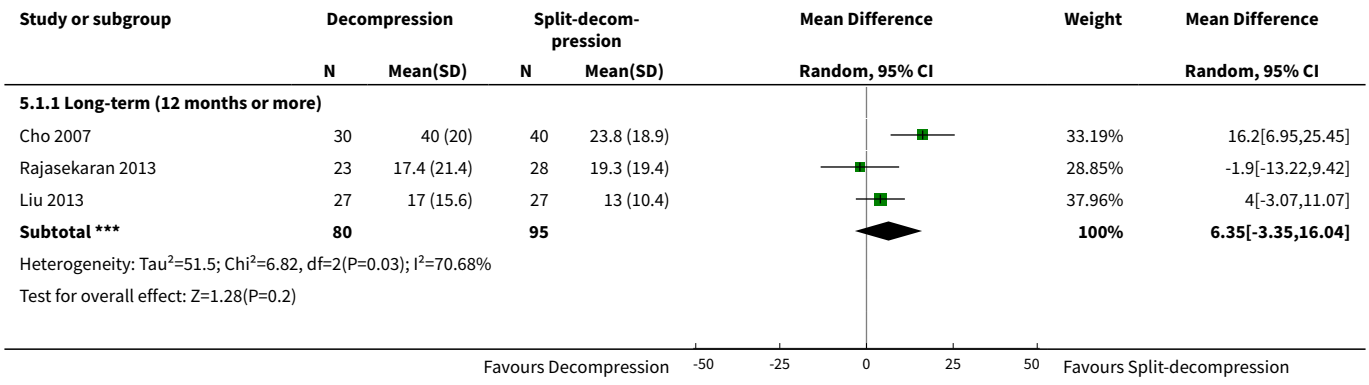
Analysis 4.7. Comparison 4 Laminectomy versus laminotomy, Outcome 7 Hospitalisation.

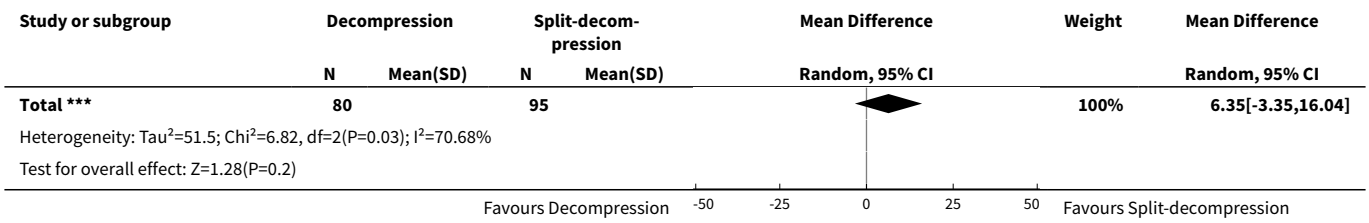


Comparison 5. Decompression versus split-decompression

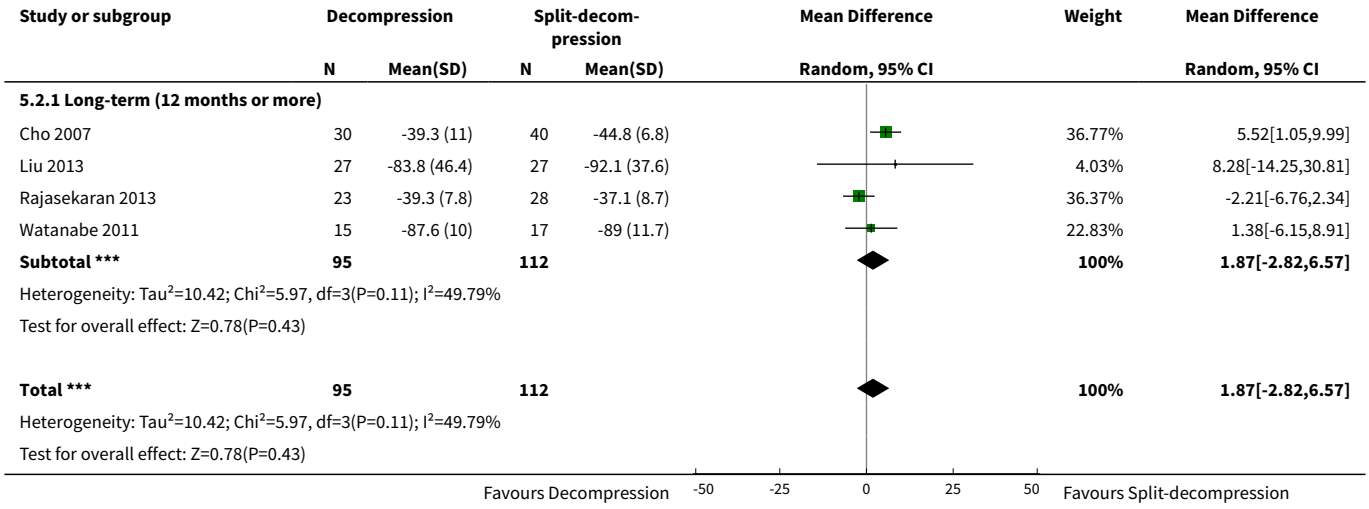
Outcome or sub-group title	No. of studies	No. of partici-pants	Statistical method	Effect size
1 Pain	3	175	Mean Difference (IV, Random, 95% CI)	6.35 [-3.35, 16.04]
1.1 Long-term (12 months or more)	3	175	Mean Difference (IV, Random, 95% CI)	6.35 [-3.35, 16.04]
2 Disability	4	207	Mean Difference (IV, Random, 95% CI)	1.87 [-2.82, 6.57]
2.1 Long-term (12 months or more)	4	207	Mean Difference (IV, Random, 95% CI)	1.87 [-2.82, 6.57]
3 Recovery	4	207	Mean Difference (IV, Random, 95% CI)	-5.18 [-19.81, 9.45]
4 Operation time	4	211	Mean Difference (IV, Random, 95% CI)	-10.57 [-34.39, 13.25]
5 Blood loss	4	211	Mean Difference (IV, Random, 95% CI)	-1.83 [-27.65, 23.98]
6 Reoperations	3	153	Risk Ratio (IV, Random, 95% CI)	1.22 [0.22, 6.85]
7 Hospitalisation	2	121	Mean Difference (IV, Random, 95% CI)	1.49 [-1.70, 4.67]

Analysis 5.1. Comparison 5 Decompression versus split-decompression, Outcome 1 Pain.

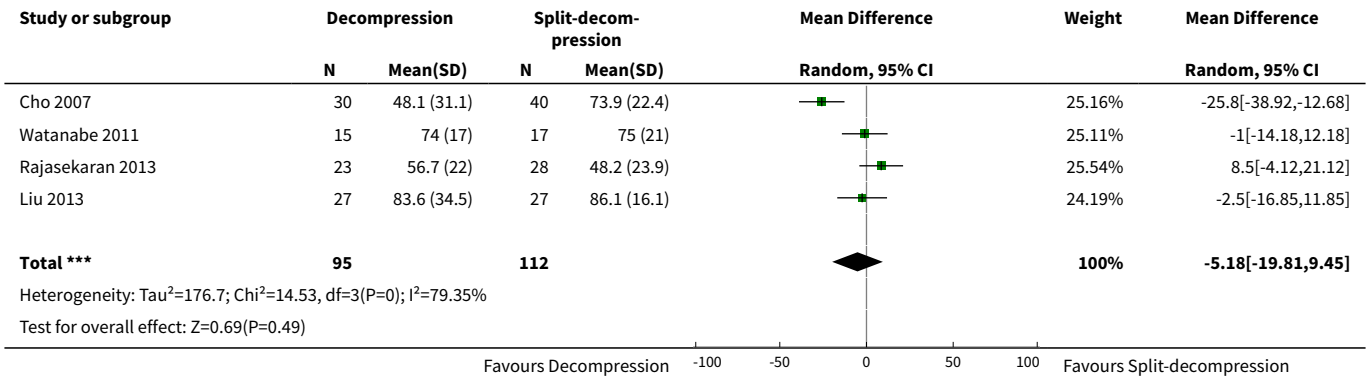




Analysis 5.2. Comparison 5 Decompression versus split-decompression, Outcome 2 Disability.



Analysis 5.3. Comparison 5 Decompression versus split-decompression, Outcome 3 Recovery.

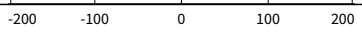


Analysis 5.4. Comparison 5 Decompression versus split-decompression, Outcome 4 Operation time.

Study or subgroup	Decompression N	Decompression Mean(SD)	Split-decompression N	Split-decompression Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Cho 2007	30	193 (68)	40	259 (122)		16.63%	-66[-110.96,-21.04]
Watanabe 2011	16	82 (36)	18	69 (29)		30.16%	13[-9.15,35.15]
Liu 2013	29	57 (64.6)	27	67 (109.1)		15.59%	-10[-57.41,37.41]
Rajasekaran 2013	23	57.1 (17.4)	28	62.3 (22.1)		37.62%	-5.2[-16.04,5.64]
Total ***	**98**		**113**			**100%**	**-10.57[-34.39,13.25]**

Heterogeneity: Tau²=361.9; Chi²=9.65, df=3(P=0.02); I²=68.91%

Test for overall effect: Z=0.87(P=0.38)



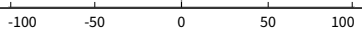
Favours Decompression — Favours Split-decompression

Analysis 5.5. Comparison 5 Decompression versus split-decompression, Outcome 5 Blood loss.

Study or subgroup	Decompression N	Decompression Mean(SD)	Split-decompression N	Split-decompression Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Cho 2007	30	132 (128)	40	154 (135)		12.91%	-22[-84.03,40.03]
Watanabe 2011	16	51.9 (45.3)	18	41.5 (70.8)		23.17%	10.4[-29.13,49.93]
Rajasekaran 2013	23	61.3 (38.9)	28	85.7 (56.1)		33.34%	-24.4[-50.57,1.77]
Liu 2013	29	78 (54.9)	27	56 (57.2)		30.59%	22[-7.4,51.4]
Total ***	**98**		**113**			**100%**	**-1.83[-27.65,23.98]**

Heterogeneity: Tau²=341.97; Chi²=6.15, df=3(P=0.1); I²=51.18%

Test for overall effect: Z=0.14(P=0.89)



Favours Decompression — Favours Split-decompression

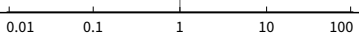
Analysis 5.6. Comparison 5 Decompression versus split-decompression, Outcome 6 Reoperations.

Study or subgroup	Decompression n/N	Split-decompression n/N	Risk Ratio IV, Random, 95% CI	Weight	Risk Ratio IV, Random, 95% CI
Cho 2007	1/30	1/40		39.82%	1.33[0.09,20.47]
Watanabe 2011	0/15	1/17		30.34%	0.38[0.02,8.57]
Rajasekaran 2013	1/23	0/28		29.85%	3.63[0.15,84.98]
Total (95% CI)	**68**	**85**		**100%**	**1.22[0.22,6.85]**

Total events: 2 (Decompression), 2 (Split-decompression)

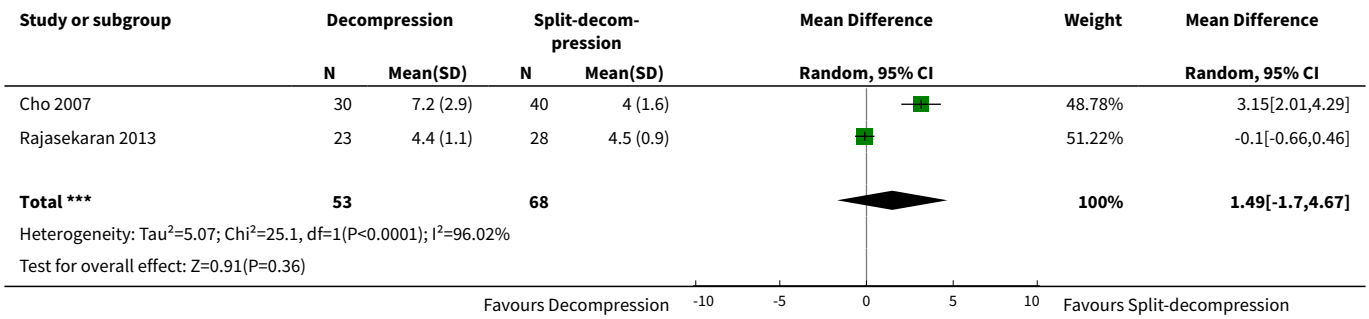
Heterogeneity: Tau²=0; Chi²=1.01, df=2(P=0.6); I²=0%

Test for overall effect: Z=0.23(P=0.82)



Favours Decompression — Favours Split-decompression

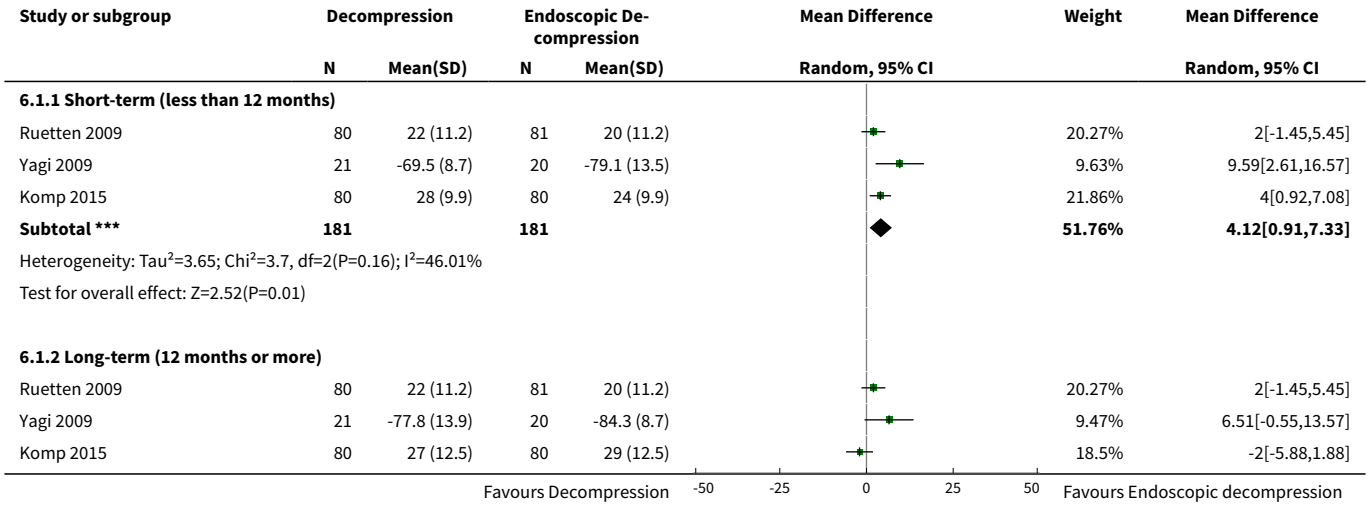
Analysis 5.7. Comparison 5 Decompression versus split-decompression, Outcome 7 Hospitalisation.

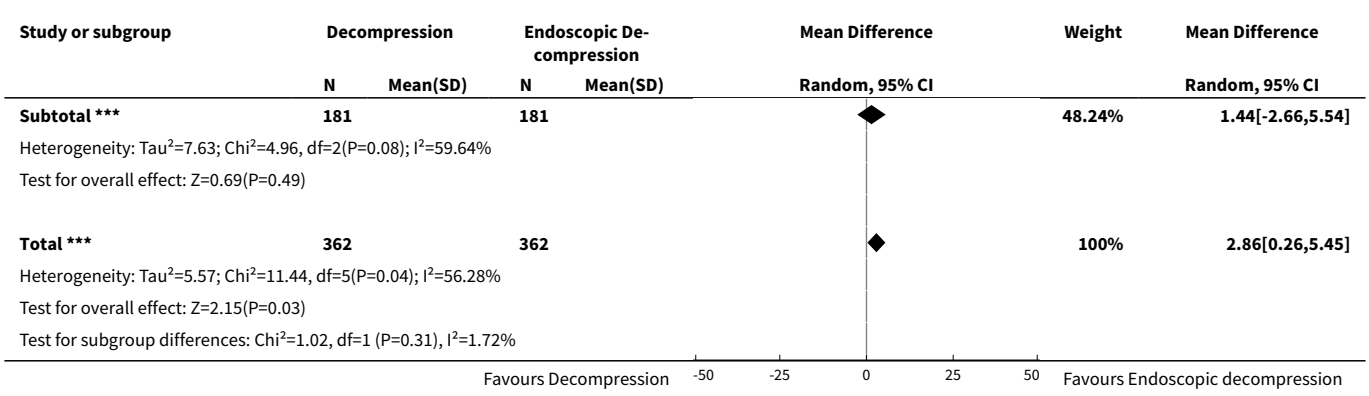


Comparison 6. Decompression versus endoscopic decompression

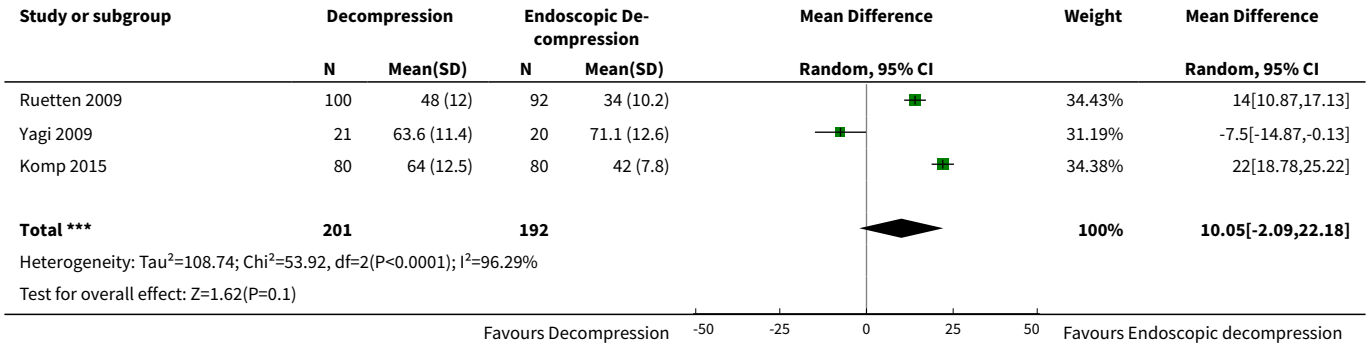
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Disability	3	724	Mean Difference (IV, Random, 95% CI)	2.86 [0.26, 5.45]
1.1 Short-term (less than 12 months)	3	362	Mean Difference (IV, Random, 95% CI)	4.12 [0.91, 7.33]
1.2 Long-term (12 months or more)	3	362	Mean Difference (IV, Random, 95% CI)	1.44 [-2.66, 5.54]
2 Operation time	3	393	Mean Difference (IV, Random, 95% CI)	10.05 [-2.09, 22.18]
3 Blood loss	1	41	Mean Difference (IV, Random, 95% CI)	34.0 [30.40, 37.60]
4 Reoperations	2	321	Risk Ratio (IV, Random, 95% CI)	0.81 [0.22, 2.97]
5 Hospitalisation	1	41	Mean Difference (IV, Random, 95% CI)	8.56 [6.78, 10.34]

Analysis 6.1. Comparison 6 Decompression versus endoscopic decompression, Outcome 1 Disability.

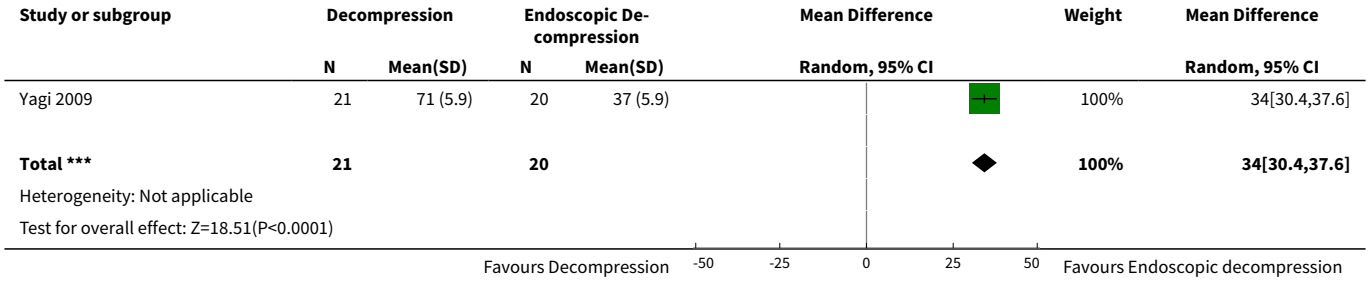




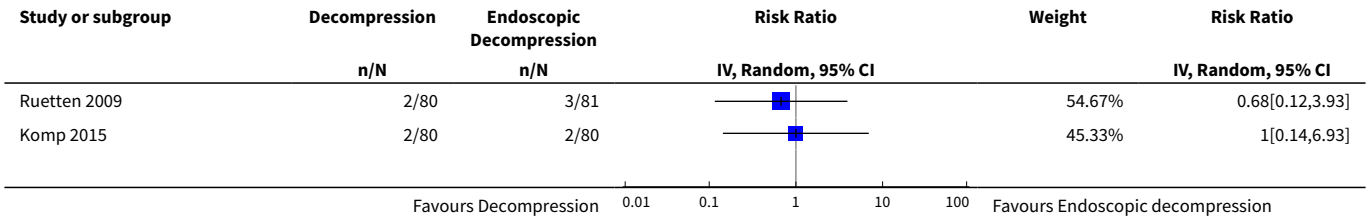
Analysis 6.2. Comparison 6 Decompression versus endoscopic decompression, Outcome 2 Operation time.

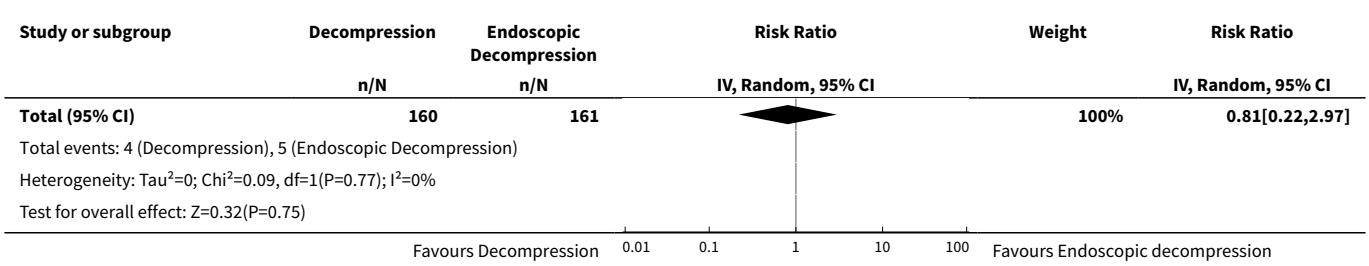


Analysis 6.3. Comparison 6 Decompression versus endoscopic decompression, Outcome 3 Blood loss.

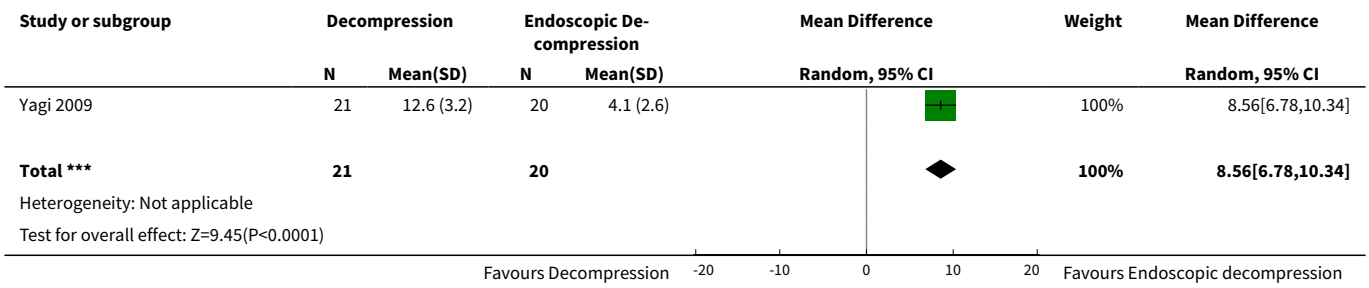


Analysis 6.4. Comparison 6 Decompression versus endoscopic decompression, Outcome 4 Reoperations.





Analysis 6.5. Comparison 6 Decompression versus endoscopic decompression, Outcome 5 Hospitalisation.



ADDITIONAL TABLES

Table 1. Sources of Risk of Bias

Bias Domain	Source of Bias	PossibleAnswers
Selection	(1) Was the method of randomization adequate?	Yes/No/Unsure
Selection	(2) Was the treatment allocation concealed?	Yes/No/Unsure
Performance	(3) Was the patient blinded to the intervention?	Yes/No/Unsure
Performance	(4) Was the care provider blinded to the intervention?	Yes/No/Unsure
Detection	(5) Was the outcome assessor blinded to the intervention?	Yes/No/Unsure
Attrition	(6) Was the drop-out rate described and acceptable?	Yes/No/Unsure
Attrition	(7) Were all randomized participants analysed in the group to which they were allocated?	Yes/No/Unsure
Reporting	(8) Are reports of the study free of suggestion of selective outcome reporting?	Yes/No/Unsure
Selection	(9) Were the groups similar at baseline regarding the most important prognostic indicators?	Yes/No/Unsure
Performance	(10) Were cointerventions avoided or similar?	Yes/No/Unsure
Performance	(11) Was the compliance acceptable in all groups?	Yes/No/Unsure

Table 1. Sources of Risk of Bias *(Continued)*

Detection	(12) Was the timing of the outcome assessment similar in all groups?	Yes/No/Unsure
Other	(13) Are other sources of potential bias unlikely?	Yes/No/Unsure

Furlan 2015

Table 2. Criteria for a Judgment of ''Yes'' for the Sources of Risk of Bias

1	A random (unpredictable) assignment sequence. Examples of adequate methods are coin toss (for studies with 2 groups), rolling a dice (for studies with 2 or more groups), drawing of balls of different colours, drawing of ballots with the study group labels from a dark bag, computer-generated random sequence, pre-ordered sealed envelopes, sequentially-ordered vials, telephone call to a central office, and preordered list of treatment assignments.Examples of inadequate methods are: alternation, birth date, social insurance/security number, date in which they are invited to participate in the study, and hospital registration number.
2	Assignment generated by an independent person not responsible for determining the eligibility of the patients. This person has no information about the persons included in the trial and has no influence on the assignment sequence or on the decision about eligibility of the patient.
3	Index and control groups are indistinguishable for the patients or if the success of blinding was tested among the patients and it was successful.
4	Index and control groups are indistinguishable for the care providers or if the success of blinding was tested among the care providers and it was successful.
5	Adequacy of blinding should be assessed for each primary outcome separately. This item should be scored ''yes'' if the success of blinding was tested among the outcome assessors and it was successful or: -for patient-reported outcomes in which the patient is the outcome assessor (e.g., pain, disability): the blinding procedure is adequate for outcome assessors if participant blinding is scored ''yes'' -for outcome criteria assessed during scheduled visit and that supposes a contact between participants and outcome assessors (e.g., clinical examination): the blinding procedure is adequate if patients are blinded, and the treatment or adverse effects of the treatment cannot be noticed during clinical examination -for outcome criteria that do not suppose a contact with participants (e.g., radiography, magnetic resonance imaging): the blinding procedure is adequate if the treatment or adverse effects of the treatment cannot be noticed when assessing the main outcome -for outcome criteria that are clinical or therapeutic events that will be determined by the interaction between patients and care providers (e.g., cointerventions, hospitalisation length, treatment failure), in which the care provider is the outcome assessor: the blinding procedure is adequate for outcome assessors if item ''4'' (caregivers) is scored ''yes''

Table 2. Criteria for a Judgment of ''Yes'' for the Sources of Risk of Bias *(Continued)*

	-for outcome criteria that are assessed from data of the medical forms: the blinding procedure is adequate if the treatment or adverse effects of the treatment cannot be noticed on the extracted data
6	The number of participants who were included in the study but did not complete the observation period or were not included in the analysis must be described and reasons given. If the percentage of withdrawals and drop-outs does not exceed 20% for short-term follow-up and 30% for long-term follow-up and does not lead to substantial bias a ''yes'' is scored. (N.B. these percentages are arbitrary, not supported by literature).
7	All randomized patients are reported/analysed in the group they were allocated to by randomization for the most important moments of effect measurement (minus missing values) irrespective of noncompliance and cointerventions.
8	All the results from all prespecified outcomes have been adequately reported in the published report of the trial. This information is either obtained by comparing the protocol and the report, or in the absence of the protocol, assessing that the published report includes enough information to make this judgment.
9	Groups have to be similar at baseline regarding demographic factors, duration and severity of complaints, percentage of patients with neurological symptoms, and value of main outcome measure(s).
10	If there were no cointerventions or they were similar between the index and control groups.
11	The reviewer determines if the compliance with the interventions is acceptable, based on the reported intensity, duration, number and frequency of sessions for both the index intervention and control intervention(s). For example, physiotherapy treatment is usually administered for several sessions; therefore it is necessary to assess how many sessions each patient attended. For single-session interventions (e.g., surgery), this item is irrelevant.
12	Timing of outcome assessment should be identical for all intervention groups and for all primary outcome measures.
13	Other types of biases. For example: -When the outcome measures were not valid. There should be evidence from a previous or present scientific study that the primary outcome can be considered valid in the context of the present. -Industry-sponsored trials. The conflict of interest (COI) statement should explicitly state that the researchers have had full possession of the trial process from planning to reporting without funders with potential COI having any possibility to interfere in the process. If, for example, the statistical analyses have been done by a funder with a potential COI, usually ''unsure'' is scored.

Furlan 2015

APPENDICES

Appendix 1. Search strategy

CENTRAL

Last searched 16 June 2016

1. spinal stenosis.mp. or Spinal Stenosis/

2. canal stenosis.mp.

3. lumbar stenosis.mp.

4. 1 or 2 or 3

5. neurosurgery/ or orthopedics/

6. decompression.mp. or Decompression, Surgical/

7. Spinal Fusion/

8. surgery.mp.

9. 5 or 6 or 7 or 8

10. 4 and 9

MEDLINE

Last searched 16 June 2016

1. Exp spinal stenosis/

2. "canal stenosis".mp.

3. (spin* adj3 stenosis).mp.

4. (lumbar adj3 stenosis).mp.

5. (lateral adj3 stenosis).mp.

6. (central adj3 stenosis).mp.

7. (foramin* adj3 stenosis).mp.

8. "neurogenic claudication".mp.

9. Exp radiculopathy/

10. Radiculopathy.mp.

11. "radicular pain".mp.

12. "lumbar radicular pain".mp.

13. Exp spondylolisthesis/

14. Spondylolisthesis.mp.

15. (lumb* adj5 spondyl*).mp.

16. Exp spondylosis/

17. Spondylosis.mp

18. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17

19. Exp general surgery/

20. Surgery.mp.

21. Exp decompression, surgical/

22. "decompres* surgery".mp.

23. Decompression.mp

24. (spin* adj3 decompress*).mp.

25. Exp laminectomy/

26. Laminectom*.mp.

27. Laminotom*.mp.

28. Laminoplasty.mp.

29. Exp spinal fusion/

30. (spin* adj3 fusion).mp.

31. (pedicle adj3 screw).mp.

32. "lumbar fusion".mp.

33. "vertebrae fusion".mp.

34. "vertebral fixation".mp.

35. "spinal fixation".mp.

36. Spondylodesis.mp

37. Spondylosyndesis.mp

38. Arthrodesis.mp. Or exp arthrodesis/

39. (posterolateral adj3 fusion).mp

40. (interbody adj3 fusion).mp

41. (anterior adj3 fusion).mp

42. (posterior adj3 fusion).mp

43. (transforaminal adj3 fusion).mp

44. (transpsoas adj3 fusion).mp

45. (facet adj3 fusion).mp

46. (bone adj3 graft).mp

47. (fixation adj3 spin*).mp

48. (pedicle adj3 fusion).mp

49. Graft.mp

50. (cage adj3 fusion).mp

51. (screw adj3 fusion).mp

52. Foraminotomy.mp. Or exp foraminotomy/

53. Foraminectomy.mp

54. Exp surgical procedures, minimally invasive/

55. "minim* invasive".mp.

56. 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55

57. 18 and 56

58. Exp randomized controlled trial/

59. Randomized controlled trial.pt.

60. "randomized controlled trial".mp.

61. (random* adj3 trial).ab,ti.

62. Exp controlled clinical trial/

63. "controlled clinical trial".mp.

64. Randomized.ab,ti.

65. Placebo.ab,ti.

66. Randomly.ab,ti.

67. Random*.ab,ti.

68. Trial.ab,ti.

69. Exp clinical trial/

70. "clinical trial".pt.

71. "clinical trial".mp.

72. "clinical study".ab,ti.

73. 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72

74. 57 and 73

75. Limit 74 to humans

EMBASE

Last searched 16 June 2016

1. 'vertebral canal stenosis'/exp OR 'vertebral canal stenosis'

2. 'spine NEAR/3 stenosis'

3. 'lumbar NEAR/3 stenosis'

4. 'lateral NEAR/3 stenosis'

5. 'central stenosis'

6. 'foraminal stenosis'

7. 'neurogenic claudication'

8. 'radiculopathy'/exp OR radiculopathy

9. 'radicular pain'/exp OR 'radicular pain'

10. 'lumbar radicular pain'

11. 'spondylolisthesis'/exp OR spondylolisthesis

12. 'spondylosis'/exp OR spondylosis

13. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12

14. 'surgery'/exp OR surgery

15. 'decompression surgery'/exp OR 'decompression surgery'

16. 'decompression spinal cord'/exp OR 'decompression spinal cord'

17. 'decompression'/exp OR decompression

18. 'laminectomy'/exp OR laminectomy

19. laminotomy

20. 'laminoplasty'/exp OR laminoplasty

21. 'spine fusion'/exp OR 'spine fusion'

22. 'spinal fusion'/exp OR 'spinal fusion'

23. 'lumbar NEAR/3 fusion'

24. 'vertebrae fusion'

25. 'vertebral fixation'

26. 'spondylodesis'/exp OR spondylodesis

27. 'spinal fixation'

28. 'spinal fixation device'/exp OR 'spinal fixation device'

29. 'spondylosyndesis'/exp OR spondylosyndesis

30. posterolateral NEAR/3 fusion

31. interbody NEAR/3 fusion

32. anterior NEAR/3 fusion

33. posterior NEAR/3 fusion

34. transforaminal NEAR/3 fusion

35. 'transpsoas fusion'

36. facet NEAR/3 fusion

37. 'arthrodesis'/exp OR arthrodesis

38. bone NEAR/5 graft

39. fixation NEAR/5 spin*

40. pedicle NEAR/5 fusion

41. cage NEAR/5 fusion

42. screw NEAR/5 fusion

43. pedicle NEAR/5 screw

44. 'foraminotomy'/exp OR foraminotomy

45. foraminectomy

46. 'minimally invasive procedures'/exp OR 'minimally invasive procedures'

47. 'minim$ invasive'

48. 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 43 OR 44 OR 45 OR 46 OR 47

49. 13 AND 48

50. 'randomized controlled trial'/exp OR 'randomized controlled trial'

51. 'controlled clinical trial'/exp OR 'controlled clinical trial'

52. 'clinical trial'/exp OR 'clinical trial'

53. randomized:ab

54. placebo:ab

55. randomly:ab

56. trial:ab

57. 'clinical study':ab

58. 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34

59. 26 AND 35

60. 59 AND 'human'/de

CINAHL

Last searched 16 June 2016

57. 19 AND 56

56. 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 43 OR 44 OR 45 OR 46 OR 47 OR 48 OR 49 OR 50 OR 51 OR 52 OR 53 OR 54 OR 55

55. (MH "Minimally Invasive Procedures") OR "Minimally Invasive"

54. "Foraminectomy"

53. "Foraminotomy"

52. "Screw fusion"

51. "Cage fusion"

50. "Pedicle fusion"

49. (MH "Grafts+") OR "Bone graft"

48. (MH "Arthrodesis+")

47. "Facet fusion"

46. "Transpsoas fusion"

45. "Transforaminal fusion"

44. "Posterior fusion"

43. "Anterior fusion"

42. "Anterior near/5 fusion"

41. "Interbody fusion"

40. "Posterolateral fusion"

39. "Spondylosyndesis"

38. "Spinal fixation" OR (MH "Orthopedic Fixation Devices+")

37. "Spondylodesis"

36. "vertebral fixation"

35. "vertebrae fusion"

34. "lumbar fusion"

33. (MH "Orthopedic Fixation Devices+") OR "pedicle screw"

32. "spin* fusion"

31. (MH "Arthrodesis+") OR "arthrodesis"

30. (MH "Spinal Fusion") OR "Spinal Fusion"

29. "Laminoplasty"

28. "Laminotom*"

27. "Laminectom*"

26. (MH "Laminectomy") OR "Laminectomy"

25. "lumbar decompress*"

24. "spin* decompress*"

23. "Decompres* surgery"

22. (MH "Decompression, Surgical+") OR "Decompression"

21. "surgery"

20. (MH "Surgery, Operative+")

19. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18

18. (MH "Spondylolysis+") OR "spondilolisys"

17. "Spondylosis"

16. (MH "Spondylosis+")

15. "lumb* spondyl*"

14. (MH "Spondylolisthesis") OR "Spondylolisthesis"

13. "lumbar radicular pain"

12. "radicular pain"

11. (MH "Radiculopathy") OR "Radiculopathy"

10. "neurogenic claudication"

9. (MH "Intermittent Claudication")

8. "foramin* stenosis"

7. "central stenosis"

6. "lateral stenosis"

5. "lumbar stenosis"

4. "Canal stenosis"

3. "spin* stenosis"

2. "spinal stenosis"

1. (MH "Spinal Stenosis")

AMED

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1. Exp Spinal stenosis/

2. Canal stenosis.mp.

3. (spin* adj3 stenosis).mp.

4. (lumbar adj3 stenosis).mp.

5. (lateral adj3 stenosis).mp.

6. (central adj3 stenosis).mp.

7. (foramin* adj3 stenosis).mp.

8. "neurogenic claudication".mp.

9. Radiculopathy.mp.

10. "radicular pain".mp.

11. "lumbar radicular pain".mp.

12. Exp Spondylolisthesis/

13. Spondylolisthesis.mp.

14. (lumb* adj5 spondyl*).mp.

15. Spondylosis.mp.

16. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15

17. Exp surgery/

18. Surgery.mp.

19. Surgery operative.mp.

20. Decompression.mp.

21. "Decompres* surgery".mp.

22. (spin* adj3 decompress*).mp.

23. Exp Laminectomy/

24. Laminectom*.mp.

25. Laminotomy.mp.

26. Laminoplasty.mp.

27. Exp arthrodesis/

28. (spin* adj3 fusion).mp.

29. (pedicle adj3 screw).mp.

30. "lumbar fusion".mp.

31. "vertebrae fusion".mp.

32. "Vertebral fixation".mp.

33. "Spinal fixation".mp.

34. Spondylodesis.mp.

35. Spondylosyndesis.mp.

36. Exp Arthrodesis/ or Arthrodesis.mp.

37. (Posterolateral adj3 fusion).mp.

38. (Interbody adj3 fusion).mp.

39. (Anterior adj3 fusion).mp.

40. (Posterior adj3 fusion).mp.

41. (Transforaminal adj3 fusion).mp.

42. (Transpsoas adj3 fusion).mp.

43. (Facet adj3 fusion).mp.

44. (Bone adj3 graft).mp.

45. (Fixation adj3 spin*).mp.

46. (Pedicle adj3 fusion).mp.

47. Graft.mp.

48. (Cage adj3 fusion).mp.

49. (Screw adj3 fusion).mp.

50. Foraminotomy.mp.

51. "Minim* invasive".mp.

52. 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51

53. 16 and 52

Web of Science

Last searched 16 June 2016

54. 53 and 43

53. 52 or 51 or 50 or 49 or 48 or 47 or 46 or 45 or 44

52. "clinical study"

51. "clinical trial"

50. Trial)

49. Random*

48. Placebo

47. Randomized

46. "controlled clinical trial"

45. "randomized clinical trial"

44. "randomized controlled trial"

43. 42 and 14

42.41 or 40 or 39 or 38 or 37 or 36 or 35 or 34 or 33 or 32 or 31 or 30 or 29 or 28 or 27 or 26 or 25 or 24 or 23 or 22 or 21 or 20 or 19 or 18 or 17 or 16 or 15

41. "minimally invasive"

40. Foraminectomy

39. Foraminotomy

38. "pedicle screw"

37. "cage fusion”

36. Arthrodesis

35. "facet fusion"

34. "transpsoas fusion"

33. "transforaminal fusion"

32. "posterior fusion"

31. "anterior fusion"

30. "interbody fusion"

29. "posterolateral fusion"

28. Spondylosyndesis

27. "spinal fixation"

26. Spondylodesis

25. "vertebral fixation"

24. "vertebrae fusion"

23. Arthrodesis

22. "lumbar fusion"

21. "spin* fusion"

20. Laminoplasty

19. Laminotom*

18. Laminectomy

17. Decompressive

16. Decompression

15. Surgery

14. 13 or 12 or 11 or 10 or 9 or 8 or 7 or 6 or 5 or 4 or 3 or 2 or 1

13. Spondylolysis

12. Spondylosis

11. "spondylolisthesis"

10. "lumbar radicular pain"

9." radicular pain"

8. "radiculopathy"

7. "neurogenic claudication"

6. "foramin* stenosis"

5. "central stenosis"

4. "lateral stenosis"

3. "lumbar stenosis"

2. "canal stenosis"

1. "spin* stenosis"

LILACS

Last searched 16 June 2016

("spine stenosis" OR "spinal stenosis" OR "canal stenosis" OR "lumbar stenosis" OR "central stenosis" OR "lateral stenosis" OR "foraminal stenosis" OR "spondylolisthesis" OR spondylosis OR "neurogenic claudication" OR radiculopathy OR "radicular pain") AND (surgery OR decompression OR decompressive OR laminectomy OR laminotomy OR laminoplasty OR "spinal fusion" OR "spine fusion" OR arthrodesis OR "lumbar fusion" OR "vertebrae fusion" OR "vertebral fixation" OR spondylodesis OR "spinal fixation" OR spondylosyndesis OR "posterolateral fusion" OR "interbody fusion" OR "anterior fusion" OR "posterior fusion" OR "transforaminal fusion" OR "transpsoas fusion" OR "facet fusion" OR "bone graft" OR "pedicle fusion" OR "cage fusion" OR "screw fusion" OR "pedicle screw" OR screw OR rod OR foraminotomy OR foraminectomy OR "surgical procedure" OR "minimally invasive")

ClinicalTrials.gov, WHO ICTRP and ANZCTR

Last searched 16 June 2016

ClinicalTrials.gov: Search: (surgery OR decompression) AND Condition: spinal stenosis

WHO ICTRP: Title: (surgery OR decompression) AND Condition: spinal stenosis

ANZCTR: Search terms: (surgery OR decompression) AND Health condition(s) or problem(s) studied: spinal stenosis

Appendix 2. The GRADE approach to evidence synthesis

The quality of evidence will be categorised as follows:

- High (⊕⊕⊕⊕): further research is very unlikely to change the confidence in the estimate of effect.
- Moderate (⊕⊕⊕⊖): further research is likely to have an important impact in the confidence in the estimate of effect.
- Low (⊕⊕⊖⊖): further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
- Very Low (⊕⊖⊖⊖): any estimate of effect is very uncertain.

The evidence available to answer each sub-question will be graded on the domains in the following manner:

1. Risk of bias

Limitations in the study design and implementation may bias the estimates of the treatment effect. Our confidence in the estimate of the effect and in the following recommendation decreases if studies suffer from major limitations. We will examine all studies on five types of biases:

a) Selection (random sequence generation, allocation concealment, group similarities at baseline)

b) Performance (blinding of participants, blinding of healthcare providers)

c) Attrition (dropouts and intention-to-treat analysis)

d) Measurement (blinding of the outcome assessors and timing of outcome assessment)

e) Reporting bias (selective reporting)

The quality of evidence will be downgraded as follows:

- by one level: when most of the evidence comes from individual studies either with a crucial limitation for one criterion, or with some limitations for multiple criteria
- by two levels: when most of the evidence comes from individual studies with crucial limitations for multiple criteria

2. Inconsistency

Inconsistency refers to an unexplained heterogeneity of results. Widely differing estimates of the treatment effect (i.e. heterogeneity or variability in results) across studies suggest true differences in underlying treatment effect. Inconsistency may arise from differences in: populations (e.g. drugs may have larger relative effects in sicker populations), interventions (e.g. larger effects with higher drug doses), or outcomes (e.g. diminishing treatment effect with time).

The quality of evidence will be downgraded as follows:

- by one level: when the heterogeneity or variability in results is large.
- by two levels: when the heterogeneity or variability in results is large AND there was inconsistency arising from populations, interventions, or outcomes.

3. Indirectness

Indirect population, intervention, comparator, or outcome: the question being addressed in this systematic review is different from the available evidence regarding the population, intervention, comparator, or an outcome in the included randomised trial.

The quality of evidence will be downgraded as follows:

- by one level: when there is indirectness in only one area
- by two levels: when there is indirectness in two or more areas

4. Imprecision

Results are imprecise when studies include relatively few participants and few events and thus have wide confidence intervals around the estimate of the effect. In such a case we judge the quality of the evidence to be lower than it otherwise would be because of uncertainty in the results. Each outcome is considered separately.

For dichotomous outcomes

We will consider imprecision for either of the following two reasons:

1. There is only one study (unless the study provide data from more than 300 participants). When there is more than one study, the total number of events is less than 300 (a threshold rule-of-thumb value) (Guyatt 2011).

2. 95% confidence interval around the pooled or best estimate of effect includes both 1) no effect and 2) appreciable benefit or appreciable harm. The threshold for 'appreciable benefit' or 'appreciable harm' is a relative risk reduction (RRR) or relative risk increase (RRI) greater than 25%.

The quality of the evidence will be downgraded as follows:

- by one level: when there is imprecision due to (1) or (2)
- by two levels: when there is imprecision due to (1) and (2)

For continuous outcomes

We will consider imprecision for either of the following two reasons:

1. There is only one study (unless the study provide data from more than 400 participants). When there is more than one study, total population size is less than 400 (a threshold rule-of-thumb value; using the usual α and β , and an effect size of 0.2 standard deviations, representing a small effect).

2. 95% confidence interval includes no effect and the upper or lower confidence limit crosses an effect size (standardised mean difference) of 0.5 in either direction.

The quality of the evidence will be downgraded as follows:

- by one level: when there is imprecision due to (1) or (2)
- by two levels: when there is imprecision due to (1) and (2)

5. Publication bias

Publication bias is a systematic underestimate or an overestimate of the underlying beneficial or harmful effect due to the selective publication of studies.

The quality of evidence will be downgraded as follows:

- by one level: when the funnel plot suggests publication bias

CONTRIBUTIONS OF AUTHORS

GCM drafted the manuscript. GCM, MBP, MR and RIY selected eligible studies from the systematic search and performed data extraction. GCM, MBP and RIY performed the 'Risk of bias' assessments. MLF, CGM, PHF and IAH are responsible for the concept and design of the review. BWK and MvT contributed with critical revision of the review for important intellectual content. All review authors participated in reading and approving the final manuscript.

DECLARATIONS OF INTEREST

The review authors declare that they have no competing interests and received no external funding to perform this systematic review. GCM and MBP are supported by an international postgraduate research scholarship/postgraduate award from the Australian Department of Education and Training. CGM is supported by a principal research fellowship from the National Health and Medical Research Council. MLF is supported by a Sydney Medical Foundation Fellowship from the Sydney Medical School, The University of Sydney. BWK is co-author of one of the included trials (Moojen 2013), but was not involved in the quality assessment or data extraction of this trial. The remaining authors have noting to declare.

SOURCES OF SUPPORT

Internal sources

- None, Other.

External sources

- None, Other.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

This is an update of a review published in PLoS One (Machado 2015). The study protocol was previously registered on PROSPERO (registration number CRD42013005901). We followed the new recommendations of the Cochrane Back and Neck Group in this review (Furlan 2015), which was not stated in the protocol or previous version of this review as it was not yet published. There were no substantial changes from the protocol or the previous version of this review.

INDEX TERMS

Medical Subject Headings (MeSH)

*Lumbar Vertebrae; Back Pain [surgery]; Blood Loss, Surgical [statistics & numerical data]; Decompression, Surgical [*methods]; Leg; Operative Time; Pain Management; Randomized Controlled Trials as Topic; Reoperation [statistics & numerical data]; Spinal Stenosis [*surgery]; Treatment Outcome

MeSH check words

Humans