

Original Article

Stand-alone interspinous spacers versus decompressive surgery in lumbar spinal stenosis: a systematic review and meta-analysis

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Received February 14, 2016; Accepted May 5, 2016; Epub July 15, 2016; Published July 30, 2016

Abstract: Purpose: This study aimed to compare the efficacy and safety of stand-alone placement of interspinous spacers (IPS) with decompressive surgery (DS) for the treatment of lumbar spinal stenosis. Methods: Medline, Embase, and the Cochrane Central Register of Controlled Trials databases were searched until February 2016 to identify relevant randomized controlled trials (RCTs) and comparative cohort studies. The relative risk (RR) and 95% confidence intervals (CIs) were calculated for dichotomous variables. The weighted mean difference (WMD) and 95% CIs were calculated for continuous variables. A random effect model was used for heterogeneous data; otherwise, a fixed effect model was used. Results: Four RCTs and four comparative cohort studies with 834 patients in total met the eligibility criteria for this meta-analysis. Overall, there were no significant differences regarding leg pain score and ODI score between the IPS and DS groups. Pooled estimates showed that patients in the IPS group achieved worse low back pain score and higher rate of reoperation. However, IPS group had a significantly lower rate of complications, shorter hospital stay, and shorter operative time. Conclusions: Based on the current literature, we concluded that there were no significant differences regarding leg pain and ODI scores between the IPS and DS groups. Although having a lower rate of complications and shorter hospital stay and operative time, the IPS group resulted in inferiority of low back pain and a higher rate of reoperation. Careful preoperative consideration on indications, benefits and risks of employing this interspinous implant should be made.

Keywords: Stand-alone, interspinous spacers, decompressive surgery, lumbar spinal stenosis, systematic review, meta-analysis

Introduction

Lumbar spinal stenosis (LSS) is a degenerative and disabling condition in which changes in intervertebral disc, ligamentum flavum, and facet joints with aging cause narrowing of the spinal canal and neural foramina [1]. It has been reported to be the most common reason for spinal surgery in people over 65 years [2, 3]. Patients with LSS typically complain with claudication with dermatomal leg pain and impaired walking capacity. Low back pain can also occur as partly a result of this degenerative process. These symptoms of LSS are usually relieved on flexion and worsened on extension [4-6].

Various therapeutic modalities exist as to the treatment of LSS. LSS can be treated by conservative therapy, including anti-inflammatory

drugs, physiotherapy and epidural injection [7, 8]. However, surgical decompression should be considered if patient symptoms worsen [9]. Many studies have reported that surgical decompression is superior to conservative treatment in relieving symptoms of LSS [10-14]. However, open decompression may not offer satisfactory outcome because of the destructive nature of bony decompression [15, 16].

As an alternative to surgical decompression with or without fusion, interspinous spacers (IPS) have been designed to increase the interspinous distance with indirect decompression of the dural sac and nerve root [17-28]. Previous biomechanical studies have reported that the implantation of IPS could enhance segmental stability and decrease intradiscal pressure during extension [29-32]. However, few evidences

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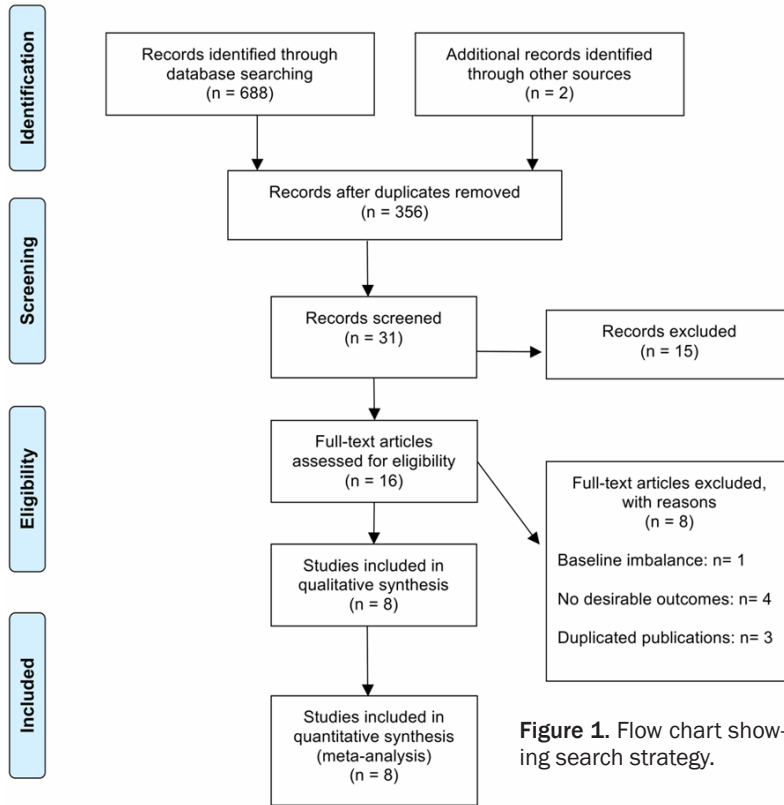


Figure 1. Flow chart showing search strategy.

board. The references lists of selected studies and relevant reviews were also reviewed to identify studies no identified in the original search. Two investigators independently reviewed all subjects, abstracts, and the full text of studies that were potentially eligible based on abstract review. The eligible studies were then selected based on the eligibility criteria. Inconsistencies between investigators' data were resolved through discussion until a consensus was reached.

Eligibility criteria

Randomized controlled trials (RCTs) and/or comparative cohort studies were considered eligible for inclusion if they met all of the following: (1) the study population consists of patients diagnosed with lumbar spinal stenosis; (2) the different interventions were stand-alone interspinous spacer (IPS) versus decompressive surgery (DS); (3) at least one desirable outcome should be reported. Studies were excluded if the patients had any of the following conditions: (1) spinal stenosis at more than 2 levels (2) previous surgery at affected levels (3) duration of follow-up less than 18 months.

Methodological quality assessment

The checklist by Furlan [34] was used to evaluate the methodological quality of RCTs. A Furlan score of ≥ 6 out of a possible 12 was considered to reflect high quality. Evaluation of the comparative cohort studies was carried out using the Newcastle-Ottawa quality assessment scale (NOS) [35]. This scale assigns a maximum of nine points to each study: four points for selection, two points for comparability, and three points for the assessment of exposure and non-response rate. Scores of 0-3, 4-6, and 7-9 were considered as low, moderate, and high quality, respectively.

existed as to whether stand-alone IPS implantation had superior outcomes compared to decompressive surgery.

The aim of this study was to review the current literature to get a better understanding of comparative effectiveness of stand-alone placement of IPS and bony decompression for the treatment of lumbar spinal stenosis.

Methods

Search strategy

The study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines [33]. Medline, Embase, the Cochrane Central Register of Controlled Trials databases were searched through February 2016 by using the following key terms: 'interspinous', 'X-Stop', 'Aperius', 'Coflex', 'DIAM', 'Wallis', 'Superion', 'lumbar spinal stenosis', 'lumbar stenosis', 'neurogenic claudication', and 'neurogenic intermittent claudication'. No linguistic restriction was imposed on the search as recommended by the Cochrane Back Review Group editorial

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Table 1. Characteristics of all included studies

Studies	Year	Study design	Device	No. of Patients (IPS, DS)	Mean age (years, IPS/DS)	Follow-up (months)	Outcomes
Beyer et al.	2013	P	Aperius	12, 33	64.25±9.6/71.12±9.2	24	Low back and leg pain, ODI, Complications
Kondrashov et al.	2007	R	X-Stop	18, 12	68.2±12.5/69.2±7.9	51	ODI, Hospital stay, Operative time
Lønne et al.	2015	RCT	X-Stop	40, 41	67±8.8/67±8.7	24	Low back and leg pain, ODI, Complications, Reoperation, Hospital stay
Lønne et al.	2015	RCT	X-Stop	40, 41	67±8.8/67±8.7	24	Operative time
Moojen et al.	2015	RCT	Coflex	80, 79	66/64	24	Low back and leg pain, Complications, Reoperation, Hospital stay, Operative time
Patil et al.	2014	R	NA	174, 174	73±10/73±10	18	Complications, Reoperation, Hospital stay
Postacchini et al.	2011	P	Aperius	36, 35	68/65	24	Reoperation
Strömqvist et al.	2013	RCT	X-Stop	50, 50	67/71	24	Low back and leg pain, Complications, Reoperation

P: prospective cohort studies, R: retrospective cohort studies, RCT: randomized controlled trial, IPS: interspinous spacer, DS: decompression surgery.

Table 3. Methodological quality assessment of the comparative cohort studies on the Newcastle-Ottawa scale

Studies	Bayer et al.	Kondrashov et al.	Patil et al.	Postacchini et al.
Selection	Representativeness of the Exposed Cohort	0	0	0
	Selection of the Non-Exposed Cohort	1	1	0
	Ascertainment of Exposure	1	1	1
	Demonstration That Outcome of Interest Was Not Present at Start of Study	1	1	1
Comparability	Study controls for age or gender	1	1	0
	Study controls for any additional factor	0	0	1
Outcome	Ascertainment of outcome	1	1	1
	Was Follow-Up Long Enough for Outcomes to Occur	1	1	1
	Adequacy of Follow Up of Cohorts	1	1	1
	Total score	7	7	7

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Table 2. Methodological quality assessment of the randomized controlled trials using Furlan's checklist

Studies	Moojen et al.	Lønne et al.	Lønne et al. 2	Strömqvist et al.
Adequate randomization	Yes	Yes	Yes	Yes
Allocation concealment	Yes	Unclear	Unclear	Yes
Blinding of patient	Yes	Unclear	Unclear	Unclear
Blinding of care provider	Unclear	Unclear	Unclear	Unclear
Blinding of outcome assessor	Unclear	Unclear	Unclear	Unclear
Drop-out rate was described	Yes	Yes	Yes	Yes
Intention-to-treat analysis	No	No	No	No
Free of selective outcome reporting	Yes	Yes	Yes	Yes
Baseline comparability	Yes	Yes	Yes	Yes
Co-interventions were avoided or similar	Yes	Yes	Yes	Yes
Acceptable compliance in all groups	Yes	Yes	Yes	Yes
Similar timing of outcome assessment	Yes	Yes	Yes	Yes
Total score	9	7	7	8

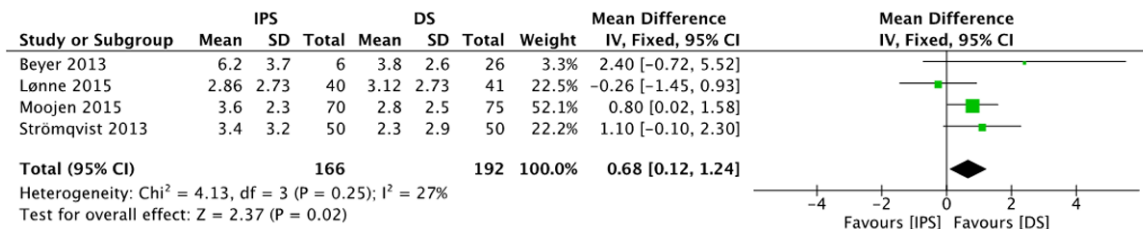


Figure 2. Forest plot for low back pain score.

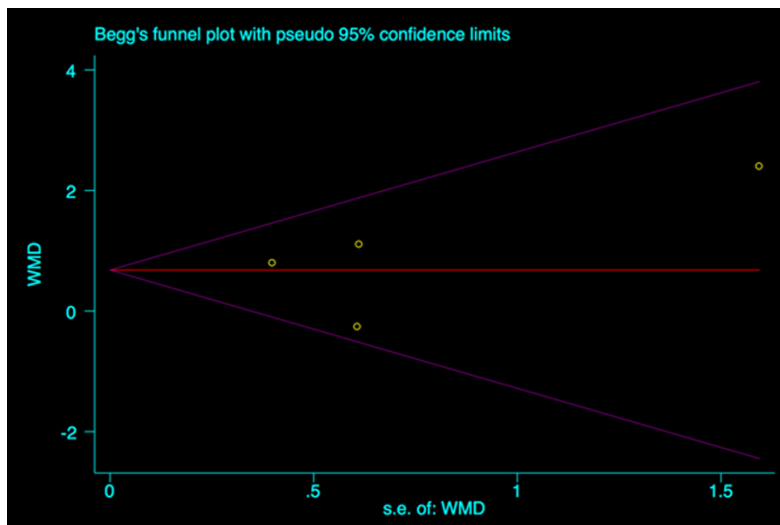


Figure 3. Begg's funnel plot for low back pain score.

Data extraction

The data were independently extracted by two reviewers and any discrepancies between the

reviewers were discussed and resolved by consensus. General characteristics data extracted included the name of first author, publication year, study design, device type, sample size, mean age and duration of follow-up. Outcomes for pooled analysis included low back pain score, leg pain score, ODI score, complications, reoperation, hospital stay, and operative time.

Data analysis

For dichotomous variables, the relative risk (RR) and 95% CIs were calculated.

For continuous variables, the weighted mean difference (WMD) and 95% CIs were calculated. The level of significance was set as $P < 0.05$. Standard errors, confidence intervals, P values

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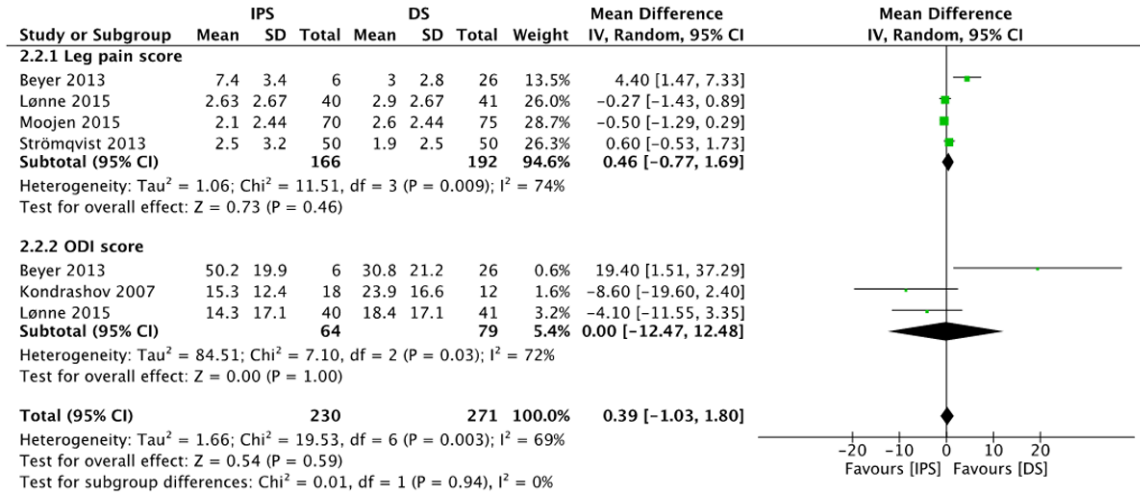


Figure 4. Forest plot for leg pain and ODI scores.

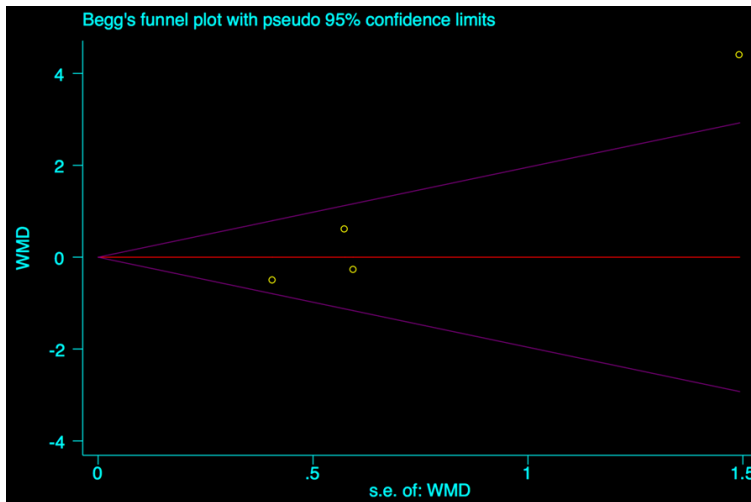


Figure 5. Begg's funnel plot for leg pain score.

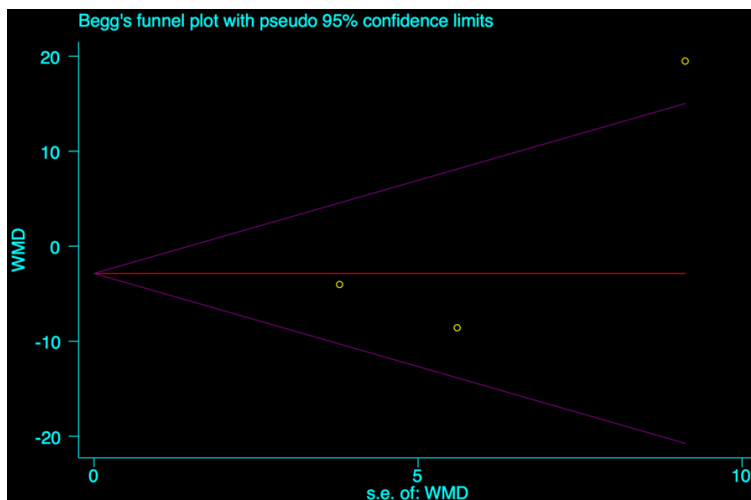


Figure 6. Begg's funnel plot for ODI score.

for difference in means, and interquartile ranges were transformed into standard deviation (SD), where necessary, according to the Cochrane Handbook for Systematic Reviews of Interventions. Statistical heterogeneity was evaluated using the chi-square test and Higgin's I² test. A P value of chi-square test < 0.10 or I² > 50% indicated statistical heterogeneity, promoting a random effects modeling estimate. Otherwise, a fixed effects model was used. Subgroup analysis of only RCTs was also performed. For the assessment of publication bias, Begg's tests were used and funnel plots were inspected [36]. These statistical analyses were conducted with the Review Manager 5.3 software (RevMan 5.3, The Cochrane Collaboration, Oxford, UK) and Stata/SE 12.0 (StataCorp LP, College Station, Texas, USA).

Results

Literature search

The details of the literature search and selection are summarized in **Figure 1**. A total of 688 articles were identified

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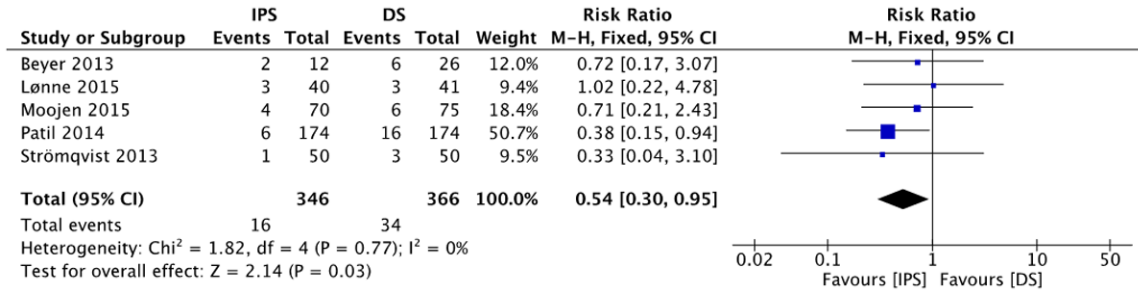


Figure 7. Forest plot for rate of complications.

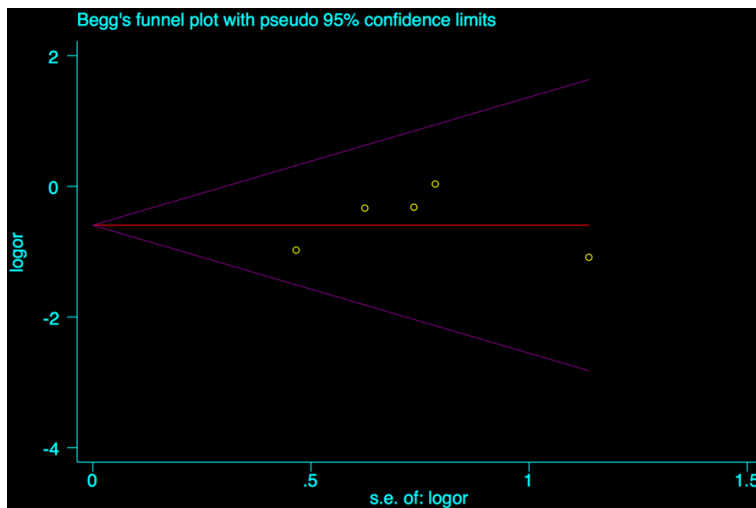


Figure 8. Begg's funnel plot for rate of complications.

through three electronic database searches. 2 additional studies were added by reviewing the references lists of relevant published reviews. After removal of duplicate and irrelevant articles by title and abstract review, 16 potential articles were retrieved for further full-text evaluation [20, 37-51]. Among them, 8 articles were excluded for not meeting the eligibility criteria [20, 37-43]. Finally, 8 studies involving 834 patients were included in this meta-analysis [44-51]. The basic characteristics of the included studies are shown in **Table 1**.

Methodological quality assessment

The methodological quality assessment of the RCTs and comparative cohort studies was shown in **Tables 2** and **3**. The Furlan scores for all RCTs [46-48, 51] were above 6 out of a possible 12, indicating 'high methodological quality'. For comparative cohort studies, three studies [44, 45, 49] received NOS scores of 7 out of

9, representing 'high methodological quality' while another one study [50] received NOS score of 6, representing 'moderate methodological quality'.

Meta-analysis outcomes

Clinical outcomes: Four studies [44, 46, 48, 51] reported the data of low back pain score at last follow-up. Pooled analysis showed that patients in the IPS group had a significantly higher low back pain score compared to that in the DS group (WMD = 0.68; 95% CI: 0.12, 1.24; $P = 0.02$; $I^2 = 27\%$, $P = 0.25$; **Figure 2**). Substantial asymmetry was

not identified in the funnel plot (Begg's test, $P = 0.308$; **Figure 3**). Four studies [44, 46, 48, 51] reported the data of leg pain score at last follow-up. Pooled estimate showed no significant difference between the two groups (WMD = 0.46; 95% CI: -0.77, 1.69; $P = 0.46$; $I^2 = 74\%$, $P = 0.009$; **Figure 4**). Substantial asymmetry was not identified in the funnel plot (Begg's test, $P = 0.308$; **Figure 5**). Data of ODI score at last follow-up was available in three studies [44-46]. Pooled analysis showed no significant difference between the two groups (WMD = 0.00; 95% CI: -12.47, 12.48; $P = 1.00$; $I^2 = 72\%$, $P = 0.03$; **Figure 4**). Substantial asymmetry was not identified in the funnel plot (Begg's test, $P = 1.00$; **Figure 6**).

Complications and reoperation

Five studies [44, 46, 48, 49, 51] reported the data of complications. Pooled analysis showed that the rate of complications in the IPS group

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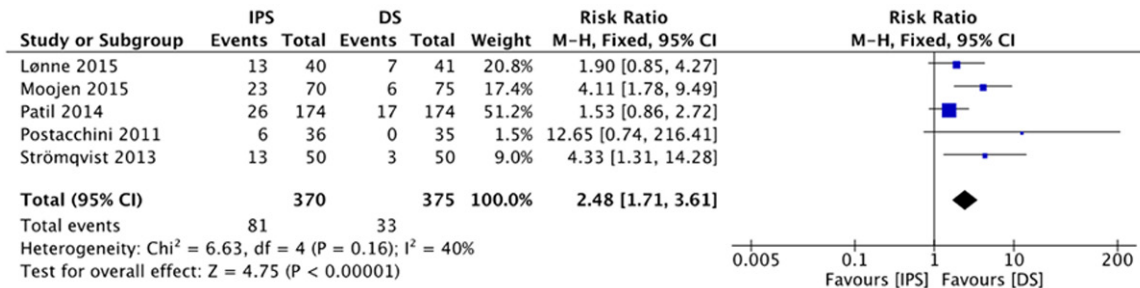


Figure 9. Forest plot for rate of reoperation.

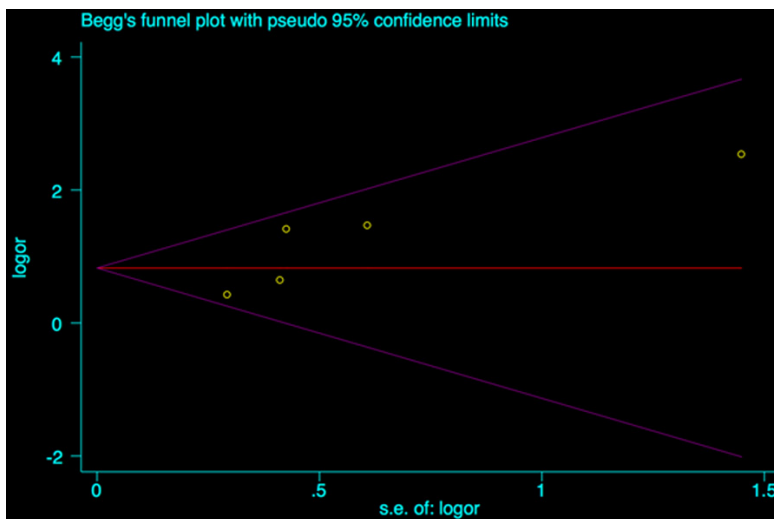


Figure 10. Begg's funnel plot for rate of reoperation.

was significantly lower than that in the DS group (RR = 0.54; 95% CI: 0.30, 0.95; P = 0.03; I² = 0%, P = 0.77; **Figure 7**). Substantial asymmetry was not identified in the funnel plot (Begg's test, P = 0.806; **Figure 8**). The data of reoperation was available in five studies [46, 48-51]. Pooled analysis showed that patients in the IPS group had a significantly higher rate of reoperation compared to that in the DS group (RR = 2.48; 95% CI: 1.71, 3.61; P < 0.00001; I² = 40%, P = 0.16; **Figure 9**). Substantial asymmetry was not identified in the funnel plot (Begg's test, P = 0.221; **Figure 10**). Subgroup analysis of the removal of the study with moderate methodological quality [50] showed the similar outcome (RR = 2.32; 95% CI: 1.59, 3.39; P < 0.0001; I² = 41%, P = 0.16).

Hospital stay and operative time

Four studies [45, 46, 48, 49] reported the data of hospital stay. Pooled analysis showed that

patients in the IPS group had a shorter hospital stay compared to that in the DS group (WMD = -1.49; 95% CI: -2.94, -0.04; P = 0.04; I² = 96%, P < 0.00001; **Figure 11**). Substantial asymmetry was not identified in the funnel plot (Begg's test, P = 0.308; **Figure 12**). Three studies [45, 47, 48] reported the data of operative time. Pooled analysis showed that operative time was significantly shorter in the IPS group compared to that in the DS group (WMD = -39.96; 95% CI: -71.51, -8.41; P = 0.01; I² = 92%, P <

0.00001; **Figure 11**). Substantial asymmetry was not identified in the funnel plot (Begg's test, P = 1.00; **Figure 13**).

Subgroup analysis

Subgroup analysis of only RCTs was also performed. The results were shown in **Table 4**.

Discussion

To our knowledge, this is the first meta-analysis comparing stand-alone placement of the interspinous spacers versus bony decompressive surgery for the treatment of lumbar spinal stenosis. This study concluded that there were no significant differences regarding leg pain and ODI scores at last follow-up between the IPS and DS groups. Although having a lower rate of complications and shorter hospital stay and operative time, the IPS group resulted in inferiority of low back pain and a higher rate of reoperation.

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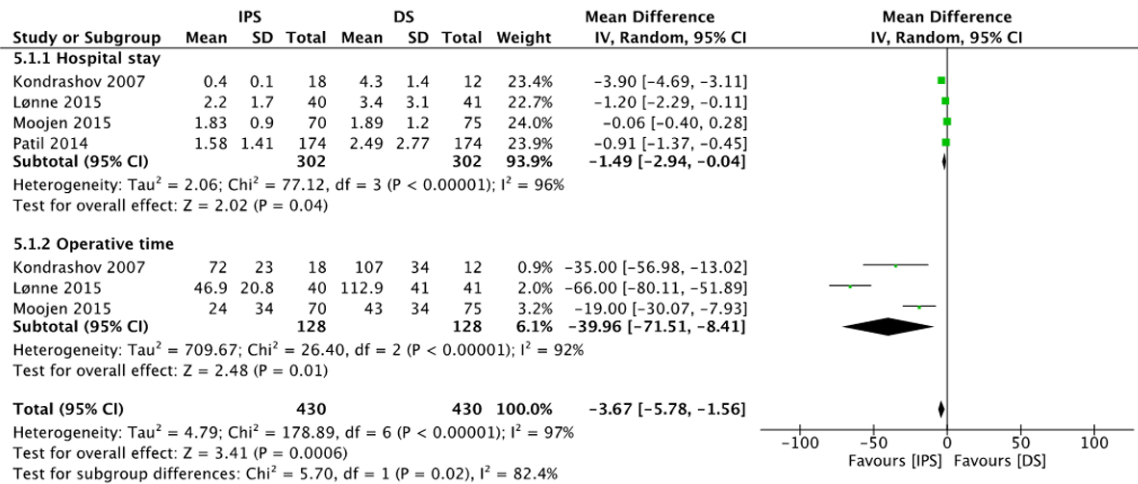


Figure 11. Forest plot for hospital stay and operative time.

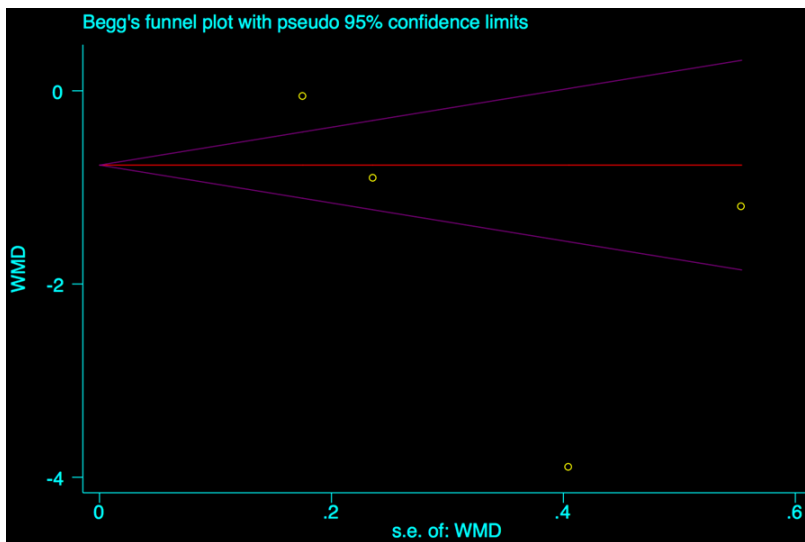


Figure 12. Begg's funnel plot for hospital stay.

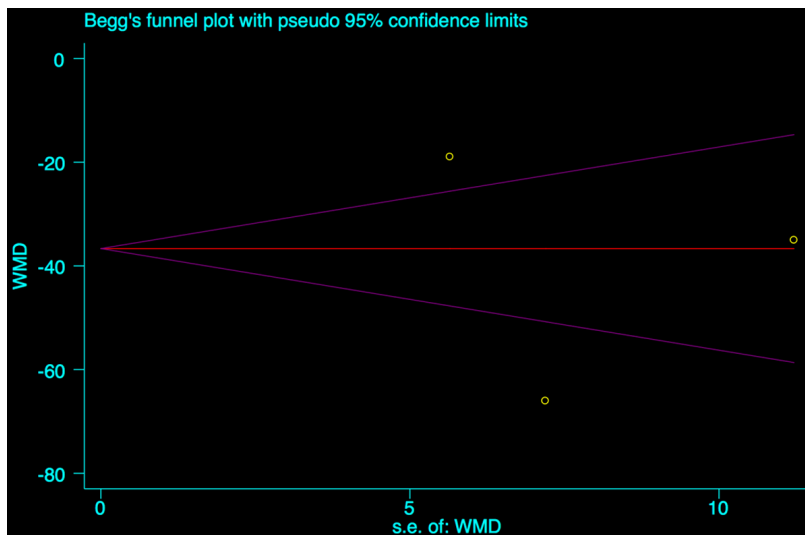


Figure 13. Begg's funnel plot for operative time.

The symptoms of LSS are typically relieved on flexion and worsened on extension [4-6]. This has been attributed to the widening of the spinal canal and foramen on flexion, resulting in direct neural decompression [4-6]. Interspinous spacers, as an alternative to decompressive surgery with or without fusion has been designed to limit extension and to be used to treat lumbar spinal stenosis [18-23]. The effects of the IPS were thought to be an overall increase in areas of spinal canal and neural foramina [24-28, 52] and mechanical reduction of lumbar extension [29-31]. Siddiqui et al showed that IPS increased the cross-sectional area of the dural sac and exit foramina without causing changes in posture [28]. Richards et al conducted a MRI measurement on spinal canal and neural foramina dimensions of cadaver lumbar spines

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Table 4. Subgroup analysis in RCTs

Outcomes	No. Studies	No. Patients	Statistical method	Effect estimate	P	X ²	I ² (%)
Low back pain score	3	326	Mean Difference (IV, Fixed, 95% CI)	0.62 (0.05, 1.20)	0.03	2.93	32%
Leg pain score	3	326	Mean Difference (IV, Fixed, 95% CI)	-0.17 (-0.73, 0.40)	0.57	2.49	20%
ODI score	1	81	Mean Difference (IV, Fixed, 95% CI)	-4.10 (-11.55, 3.35)	0.28	NS	NS
Complications	3	326	Risk Ratio (M-H, Fixed, 95% CI)	0.70 (0.29, 1.65)	0.41	0.66	0%
Reoperation	3	326	Risk Ratio (M-H, Fixed, 95% CI)	3.18 (1.89, 5.35)	< 0.0001	2.16	8%
Hospital stay	2	226	Mean Difference (IV, Random, 95% CI)	-0.51 (-1.60, 0.58)	0.36	3.85	74%
Operative time	2	226	Mean Difference (IV, Random, 95% CI)	-42.29 (-88.35, 3.77)	0.07	26.38	96%

during flexion and extension and also found that IPS could prevent narrowing of spinal canal and foramina in extension [27]. Several clinical studies have demonstrated the favorable outcomes of placement of IPS in the treatment of LSS in short-term [20, 22, 52, 53] and long-term follow-up [54,55].

This meta-analysis found that there were no differences regarding leg pain score and ODI score at last follow-up between the two groups. These findings were consistent with the results of studies by Hong et al and Wu et al [56, 57]. However, their results might be biased because they included other studies that compared IPS versus conservative therapy, IPS versus decompression and fusion/fixation or IPS with decompression versus decompression, rather than IPS versus decompressive surgery only. Moreover, this meta-analysis found that the placement of IPS achieved worse back pain score at last follow-up compared to that in the decompression group. Subgroup analysis of only RCTs also found the similar outcome. To our knowledge, the mechanism of low back pain relief remains unclear. The inferiority of low back pain relief might be partly due to the repetitive contact between the spacer and the bone potentially leading to bone resorption and spacer loosening and due to the effect of reduced anterior disc space at the implanted level [26]. Moreover, this finding was somehow not in agreement with previous biomechanical studies which reported IPS might relieve the discogenic low back pain by reducing the intradiscal pressure in extension [30, 32] and relieve the pain induced from pressure originating in the facets [58]. Nevertheless, these functional pooled outcomes should be interpreted cautiously because of the limited sample size included. Further RCTs with larger sample size are warranted to validate these outcomes.

This meta-analysis found that patients receiving stand-alone IPS had a fewer rate of complications than those undergoing decompressive surgery, but had a higher rate of reoperation. These findings were in agreement with the study by Deyo et al [38] in which they identified 99084 geriatric patients diagnosed with spinal stenosis undergoing surgery through Medicare inpatient claims data. However, their results would be underpowered by the nature of retrospective study and apparent imbalance of baseline characteristics between the IPS and decompression groups. Moreover, their outcomes were also limited by inability to identify patients with outpatient surgery and device-specific complications. Because of entering the spinal canal, decompressive surgery confers the risk of dura injury. Employing an interspinous spacer, on the other hand, is associated with spinous process fracture, implant dislocation [59, 60], and heterotopic ossification [61] although not involving accessing the spinal canal. Barbagallo et al suggested that there were anatomic features of the spinous process that could potentially be the underlying causes of complications [60].

This meta-analysis found that hospital stay and operative time were all shorter in IPS group compared to the DS group. In addition, blood loss was also found to be less in IPS group [46]. The interspinous spacers could be injected under local anesthesia with a shorter hospitalization but the implant is expensive [39-41, 47]. Constructing a cost-effectiveness model, Burnett et al. found that lumbar laminectomy appeared to be more cost-effective than IPS [62]. Lønne et al concluded that the significantly higher cost of X-stop was mainly due to implant cost and the significantly higher reoperation rate [47]. It should be acknowledged that the interspinous spacers does not replace

bony decompression in patients with severe stenosis and continuous claudication, but offers a less invasive alternative in selected patients with spinal stenosis [21, 23, 54].

Several limitations should be acknowledged in this meta-analysis. First, only eight studies with 834 patients in total were included in this meta-analysis. Moreover, not all included studies were RCTs, which might bring some biases. Second, the duration of follow-up was only 2 years in the majority of these studies. Further RCTs with larger sample size and long-term follow-up are required to validate these outcomes. Third, the high heterogeneity of the device type in these studies might confer an additional bias [19]. Despite these limitations, we still believe that the stand-alone placement of interspinous spacer achieved shorter hospital stay and operative time and lower rate of complications compared to decompressive surgery while it has higher rate of reoperation. Moreover, interspinous spacers seem to have inferiority on relieving low back pain compared to decompressive surgery. Therefore, careful preoperative consideration on indications, benefits and risks of employing this interspinous implant should be made.

Acknowledgements

The authors acknowledge the work is supported by China Scholarship Council fund: No. 201306370115 (YH).

Disclosure of conflict of interest

None.

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