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REVIEW

Reoperation of decompression alone or decompression plus fusion surgeries for degenerative lumbar diseases: a systematic review

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Abstract

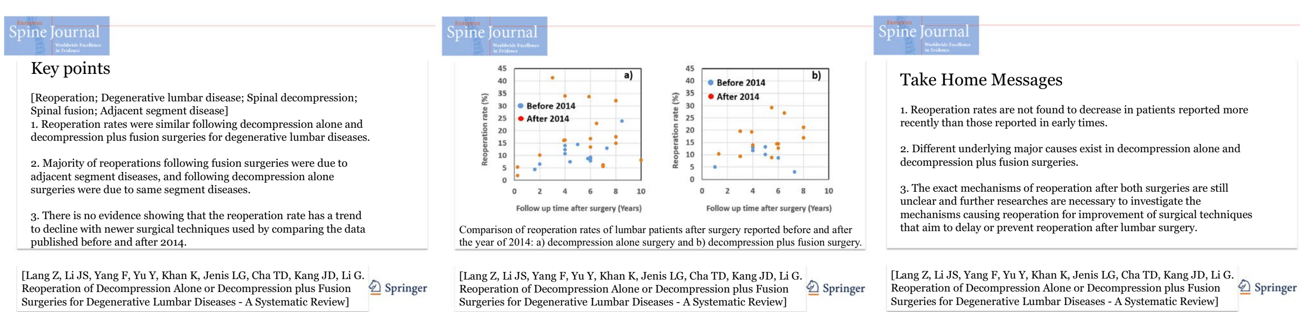
Purpose The objective of this paper was to compare the reoperation rates, timing and causes between decompression alone and decompression plus fusion surgeries for degenerative lumbar diseases through a systematic review of the published data.

Methods A search of the literature was conducted on PubMed/MEDLINE, EMBASE and the Cochrane Collaboration Library. Reports that included reoperations after decompression alone and/or decompression plus fusion surgeries were selected using designed eligibility criteria. Comparative analysis of reoperation rates, timing and causes between the two surgeries was conducted.

Results Thirty-two retrospective and three prospective studies were selected from 6401 papers of the literature search. The analysis of data reported in these studies revealed that both surgeries resulted in similar reoperation rates after the primary surgery. However, majority of reoperations following the fusion surgeries were due to adjacent-segment diseases, and following the decompression alone surgeries were due to the same-segment diseases. Reoperation rates were not found to decrease in patients operated more recently than those operated in early times.

Conclusions Reoperation rates were similar following decompression alone or plus fusion surgeries for degenerative lumbar diseases. However, different underlying major causes exist between the two surgeries. There is no evidence showing that the reoperation rate has a trend to decline with newer surgical techniques used. The exact mechanisms of reoperation after both surgeries are still unclear. Further researches are necessary to investigate the mechanisms of reoperation for improvement of surgical techniques that aim to delay or prevent reoperation after lumbar surgery.

Graphical abstract These slides can be retrieved under Electronic Supplementary Material.



Keywords Reoperation · Degenerative lumbar diseases · Spinal decompression · Spinal fusion · Adjacent-segment diseases

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Extended author information available on the last page of the article

Introduction

Low back pain is the most common cause of disability for adults, and its lifetime prevalence was estimated from 59 to 84% [1]. Degenerative lumbar spine disease (lumbar spondylolisthesis, stenosis, disc herniation or disc diseases) is the most common aetiology of low back pain and can have profound effects on functionality and quality of patient life [2–4]. When conservative treatment fails, symptoms of lumbar spine diseases are relieved by appropriate lumbar decompression procedures, such as laminectomy and discectomy [5, 6]. However, decompression may compromise the structure of lumbar segments and lead to further degeneration, abnormal motion, or deformity [7]. Lumbar fusion, which intends to relieve back pain attributed to movement at degenerated joints and increase the foramen space, is considered as a stabilizing treatment that may reduce the need for additional surgery [8]. Lumbar fusion surgeries have grown dramatically in the past decades [9, 10]. The number reached 245,000 in 2011 in US alone, while lumbar discectomies occurred in approximately 197,000 inpatients in 2011 [11].

However, it is controversial on the clinical advantages of the decompression alone and decompression plus fusion surgeries in treatment of lumbar degenerative patients [12–15]. Recent studies reported either similar [16] or slightly different [17] clinical outcomes between the two surgeries. Series of complications have been reported after lumbar surgeries using either techniques that resulted in reoperation of the patients [18, 19]. Reoperation is generally an undesirable outcome, implying persistent symptoms, progression of the underlying diseases, or complications related to the initial operation. The results of reoperation for lumbar degenerative diseases are generally worse than the results of the primary surgery [20, 21]. Patients with one reoperation after lumbar procedures are at considerable risks of further lumbar surgeries [22]. Therefore, reducing or preventing reoperation rate is a primary objective of contemporary spinal surgeries.

Most existing studies of lumbar patients focused on comparisons of clinical outcomes using different surgical techniques, with less focuses on the issue of reoperation [23–26]. Few studies have reported the timing and causes of reoperation of decompression alone and decompression plus fusion surgeries [27–29]. A systematic knowledge is lacking on the aetiology behind the reoperation after the primary surgery. This information is necessary for further improvement in the surgeries for treatment of lumbar patients. Therefore, the aim of this study was to conduct a systematic review of the literature that compared the reoperation rates, timing and causes between decompression alone and decompression plus fusion surgeries. Our null hypothesis was that there is no difference in reoperation rates between these two procedures when used to treat lumbar disease patients.

Methods

A literature search of the following databases (PubMed/MEDLINE, EMBASE and Cochrane Collaboration Library) was performed. Key search terms included “decompression,” “laminectomy,” “discectomy,” “laminotomy,” “laminoplasty,” “fusion,” “fixation,” “instrumentation,” “implantation,” “revision,” “reoperation,” “lumbosacral,” and “lumbar” in different combinations. Inclusion criteria were studies reporting the reoperation rates with underlying causes or risk factors for lumbar decompression alone or plus fusion surgeries. Excluded were non-English articles; in vitro, animal, or cadaveric studies; systematic reviews and meta-analyses; case reports; letters and comments; and studies on paediatric population; studies on trauma, infection, tumour, inflammatory diseases, and deformity; studies involving dynamic stabilization devices or lumbar disc replacement devices; studies with less than twenty patients.

An initial search yielded 6401 articles (Fig. 1). All duplicate publications were excluded. Additional 4147 articles were removed based on the exclusion criteria by analysing their titles. The remaining 550 articles were further filtered by reading their abstracts. In this process, 515 articles were further excluded: 4 for having less than 20 patients; 148 for researching on cervical or thoracic or sacral spine; 363 for not analysing causes or risk factors for reoperation. The remaining 35 publications met all criteria and were included in this systematic review.

Decompression alone surgery

There are 28 studies discussing the reoperation rates and underlying causes following lumbar decompression alone surgery that are included in this systematic review (Table 1).

Reoperation rate

The reoperation rate is highly variable among different reports. It depends on the length of follow-up time and type of decompression surgeries. In general, the reoperation rate following decompression alone surgery ranges from 1.6 to 41.3% in follow-up times from 3 months to 17.7 years [17, 29–36] (Table 1). Table 2 groups the reported reoperation rates based on follow-up time. Among these studies, the reoperation rates range from 1.6 to 10.8% within 1 year, 6.5–41.3% within 3 years, 3.6–34.0% within 5 years, 4.4–33.8% within 10 years after the primary surgery.

Kim et al. [37] showed that there were different reoperation rates for different decompression surgeries. In an over 5-year follow-up, the reoperation rates were 18.6, 13.8 and 12.4% for laminectomy, open discectomy and endoscopic

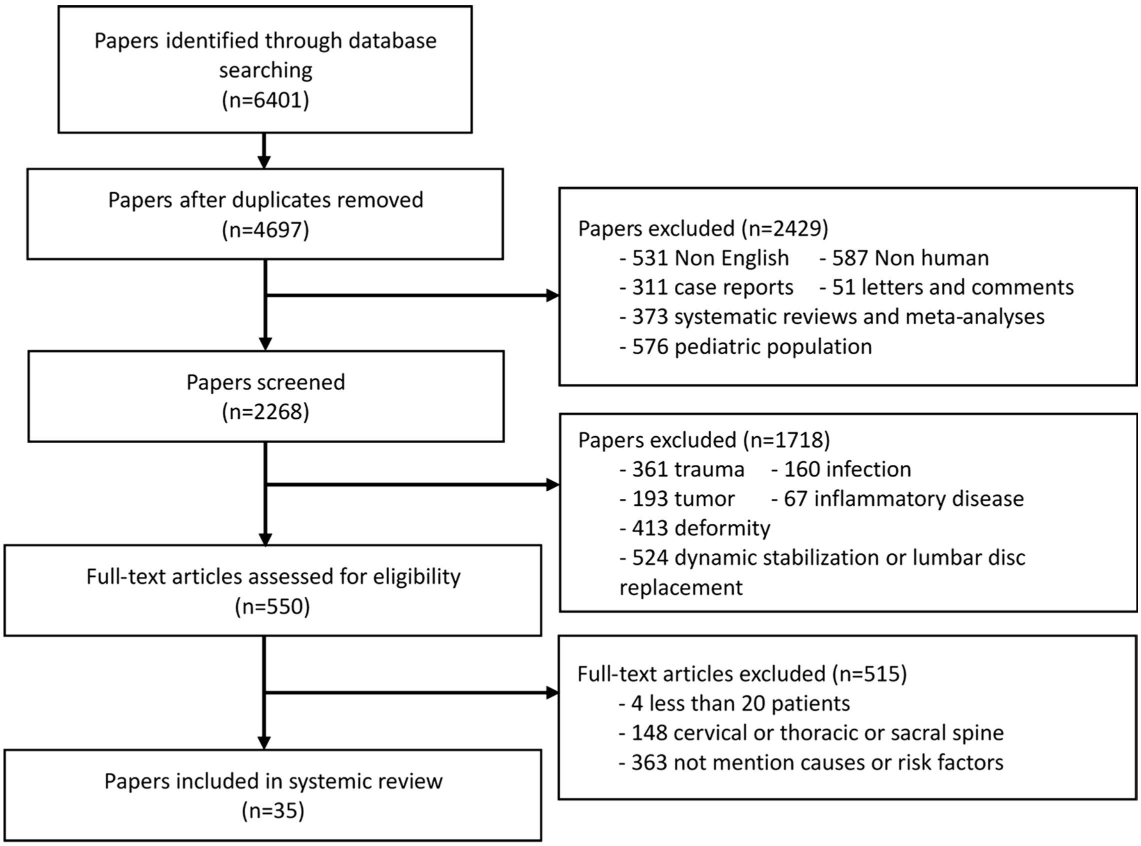

Fig. 1 Flow chart of literature search process for this systematic review

discectomy, respectively. However, even for the same type of decompression, the reoperation rate could be different among different studies. Lad et al. [28] reported that the reoperation rate in the patients who underwent a laminectomy alone was 5.7% at 1 year, 10.2% at 2 years and 14.5% at 5 years. However, Ghogawala et al. [38] reported that the reoperation rate reached 29.4% in less than 3 years after the surgery.

The underlying aetiology of reoperation

Same-segment diseases (SSD, including disc herniation, recurrent stenosis, and others) are the major cause of reoperation after decompression alone surgery, accounting for 52.1–100% of the reoperation patients [30, 36, 39, 40]. Leven et al. [41] found that 62% of the reoperations were attributed to the recurrent disc herniation at the same level as in the primary surgery after a standard open discectomy. Similar observations were reported in many other studies [30, 31, 34–36, 39, 40, 42]. Recently, Ghogawala et al. [17] reported that reoperations were all at the index levels because of SSD. Besides of the SSD, other causes of reoperation included irrigation and debridement of surgical-site infection, haematoma evacuation, epidural fibrosis, cerebrospinal fluid leakage and so on [31, 34, 35]. In general, SSD accounts for majority of the causes in revision surgeries after decompression alone procedures.

Fusion surgery

There are 19 papers discussing the reoperation rates and underlying causes following fusion surgery that were included in this systematic review (Table 3).

Reoperation rate

The reoperation rate of fusion surgery is highly affected by the length of follow-up time. From 1 to 11 years of follow-up, the reoperation rates ranged from 0 to 29.3% (Table 3) [16, 17, 28, 29, 43–51]. If the patients are grouped by follow-up times, the reoperation rate ranges from 0.0 to 7.0% within 1 year, 7.4–19.6% within 3 years, 7.8–19.3% within 5 years, 3.0–29.3% within 10 years after primary surgery (Table 4). The highest reoperation rate after fusion surgery was reported as 37.5% in a 15-year follow-up [52].

Table 1 Characteristics of reoperation after decompression alone surgery

Studies	Diagnosis	Participants	Reoperation rates and causes
Vaughan et al. [43]	LDH	85 cases; mean age, 40.8 years; follow-up, 7.3 years	13% (7/52); causes incl. recurrence at index level (5 patients, PTs), recurrence at different levels (2 PTs.); level of major cause, index level
Hirabayashi et al. [40]	LDH	214 cases; mean age, 34.6 years; follow-up, 4.4 years	7.5% (16/214); causes incl. recurrent disc herniation (9 PTs.), bony stenotic lateral recess at index level (2 PTs.), nerve injury at initial operation (1 PT.), herniation at different levels (2 PTs.), wrong level at initial operation (1 PT.), fusion at index level due to instability (1 PT.); level of major cause, index level
Vik et al. [60]	LDH	163 cases; mean age, 48 years; follow-up, 8.5 years	23.9% (39/163); causes incl. peridural scar (16 PTs.), herniation at index level (14 PTs.), herniation at different levels (5 PTs.), spinal instability (2 PTs.), other (2 PTs.); level of major cause, N/A
Erbayraktar et al. [34]	LDH	570 cases; mean age, 44 years; follow-up, 2 years	6.5% (37/570); causes incl. recurrent disc herniation (9 PTs.), epidural fibrosis (8 PTs.), de novo disc herniation (5 PTs.); level of major cause, index level
Morgan-Hough et al. [33]	LDH	531 cases; mean age, 39.4 years; follow-up, ≥ 1 years	7.9% (42/531); causes incl. N/A; level of major cause, N/A
Kayaoglu et al. [103]	LDH	715 cases; mean age, (40–50) years; follow-up, (1–6) years	11.9% (85/715); causes incl. epidural fibrosis (31 PTs.), small recurrence and epidural fibrosis (24 PTs.), true recurrent herniation (17 PTs.), new herniation at another level (9 PTs.), spinal stenosis (2 PTs.), adhesive arachnoiditis (1 PT.), pseudomeningocele (1 PT.); level of major cause, N/A
Martin et al. [59]	LDD	24,882 cases in 1990–1993 cohort; mean age, 50.1 years; follow-up, 4 years	12.4% (2793/22,537) in 1990–1993 cohort, 14.0% (2860/20,388) in 1997–2000 cohort; causes incl. N/A; level of major cause, N/A
		25,209 cases in 1997–2000 cohort; mean age, 54 years; follow-up, 4 years	
Martin et al. [46]	LDD	24,882 cases; mean age, 50 years; follow-up, 11 years	18.8% (4237/22,537); causes incl. N/A; level of major cause, N/A
Deyo et al. [27]	LSCS	31,543 cases; mean age, 76 years; follow-up, ≥ 4 years	11.3% (2603/23,055); causes incl. N/A; level of major cause, N/A
Shabat et al. [61]	LSCS	357 cases; mean age, 72 years; follow-up, 5.8 years	8.7% (31/357); causes incl. N/A; level of major cause, N/A
Kim et al. [37]	LDH	1465 cases in laminectomy; mean age, 48.2 years; follow-up, 6 years	8.8% (115/1306) in laminectomy, 9.3% (1130/12,173) in open discectomy, 7.8% (221/2848) in endoscopic discectomy; causes incl. N/A; level of major cause, N/A
		12,816 cases in open discectomy; mean age, 42.6 years; follow-up, 6 years	
		3001 cases in endoscopic discectomy; mean age, 38.1 years; follow-up, 6 years	
Cheng et al. [35]	LDH	5280 cases; mean age, 47.7 years; follow-up, N/A	4.4% (232/5280); causes incl. real recurrent herniations (127 PTs.), new herniations (52 PTs.), contralateral herniations (30 PTs.), scar or adhesive arachnoiditis (8 PTs.), infection (7 PTs.), haematoma (6 PTs.), cerebrospinal fluid leakage (2 PTs.); level of major cause, index level
Lad et al. [28]	LS	1468 cases; mean age, 67 years; follow-up, ≥ 2 years	15.7% (115/734); causes incl. repeat laminectomy (71 PTs.); level of major cause, N/A
Sato et al. [29]	Grade 1 DS	163 cases; mean age, 65.8 years; follow-up, 5.9 years	34% (25/74); causes incl. SSD (18 PTs.), ASDis (5 PTs.), SSI (2 PTs.); level of major cause, index level

Table 1 (continued)

Studies	Diagnosis	Participants	Reoperation rates and causes
Leven et al. [41]	LDH	810 cases; mean age, 40.7 years; follow-up, 8 years	15% (119/810); causes incl. recurrent disc herniation (74 PTs.), a complication or other factor (30 PTs.), a new condition (13 PTs.); level of major cause, index level
Bydon et al. [62]	LDD	500 cases; mean age, N/A; follow-up, 3.9 years	16.2% (81/500); causes incl. disc degeneration and/or stenosis at index or distal level (53 PTs.), new or worsening spondylolisthesis (14 PTs.), spinal cysts (3 PTs.), scoliosis (1 PT.); level of major cause, N/A
Hong et al. [36]	LDH	952 cases; mean age, 40.8 years; follow-up, N/A	6.1% (58/952); causes incl. recurrent disc herniation or epidural scar (32 PTs.), lumbar instability with/without disc herniation (17 PTs.), lumbar stenosis (4 PTs.), spondylolisthesis (3 PTs.), other (2 PTs.); level of major cause, index level
Aizawa et al. [30]	LSCS	5835 cases; mean age, 66 years; follow-up, 17.7 years	8.6%; causes incl. revision at the same level (112 PTs.), revision at other levels (103 PTs.); level of major cause, index level
Kim et al. [51]	LDD	25,031 cases in control; mean age, 46.2 years; follow-up, 6 years	13.4% (3353/25,031) in control, 16.9% (861/5095) in diabetes; causes incl. N/A; level of major cause, N/A
		5095 cases in diabetes; mean age, 57.2 years; follow-up, 6 years	
Kukreja et al. [32]	N/A	92 cases; mean age, 48.1 years; follow-up, 3 years	41.3% (38/92); causes incl. N/A; level of major cause, N/A
Bohl et al. [63]	LDH	226 cases; mean age, 40.6 years; follow-up, 2 years	10.2% (23/226); causes incl. N/A; level of major cause, N/A
Gerling et al. [64]	LSCS	417 cases; mean age, 63.9 years; follow-up, 8 years	17.6% (63/357); causes incl. N/A; level of major cause, N/A
Hwang et al. [39]	LSCS	43 cases; mean age, 69 years; follow-up, 4 years	16.3% (7/43); causes incl. disc herniation at index level (5 PTs.), foraminal stenosis at index level (1 PT.), spondylolisthesis at index level (1 PT.); level of major cause, index level
Forsth et al. [16]	LSCS	247 cases; mean age, 66.9 years; follow-up, 6.5 years	23% (28/120); causes incl. restenosis (18 PTs.), ASDis (5 PTs.), SSI (3 PTs.), LBP (2 PTs.); level of major cause, index level
Ghogawala et al. [17]	Grade 1 DS	66 cases; mean age, 67 years; follow-up, 4 years	34%; causes incl. post-instability at index level (N/A); level of major cause, index level
Klassen et al. [31]	LDH	278 cases in control; mean age, 44 years; follow-up, 0.25 years	5.4% (15/278) in control group, 1.9% (5/272) in ACD group; causes incl. discectomy (8 PTs.), discectomy with ACD implant (2 PTs.), haematoma evacuation (3 PTs.), wound revision (2 PTs.), discectomy (3 PTs.), decompression with subsequent fusion (1 PT.), implant removal (1 PT.); level of major cause, index level
		272 cases in ACD; mean age, 43 years; follow-up, 0.25 years	
Virk et al. [65]	LDH	2613 cases in HORTHO database; mean age, N/A; follow-up, 7 years	5.6% (147/2613) in HORTHO database, 6.2% (305/4907) in SAF5 database; causes incl. N/A; level of major cause, N/A
		4907 cases in SAF5 database; mean age, N/A; follow-up, 7 years	
Gerling et al. [44]	DS	406 cases; mean age, 64.6 years; follow-up, 8 years	32.1% (9/28); causes incl. N/A; level of major cause, N/A

All studies are retrospective except Forsth et al. [16] and Ghogawala et al. [17]

LDH lumbar disc herniation, *LDD* lumbar degenerative disease, *LSCS* lumbar spinal canal stenosis, *LS* lumbar spondylolisthesis, *DS* degenerative spondylolisthesis, *SSI* surgical-site infection, *LBP* low back pain, *ASDis* adjacent-segment disease, *SSD* same-segment disease, *ACD* annular closure device

Table 2 Reoperation rates in different follow-up times after decompression alone surgery

Studies	Year	Patient number	Reoperation rates			
			Within 1 year (%)	Within 3 years (%)	Within 5 years (%)	Within 10 years (%)
Vaughan et al. [43]	1988	52				13.0
Hirabayashi et al. [40]	1993	214			7.5	
Vik et al. [60]	2001	163		16.6		23.9
Erbayraktar et al. [34]	2002	570		6.5		
Martin et al. [59]	2007	22537	5.3		12.4	
		20388	6.0		14.0	
Deyo et al. [27]	2011	23055	4.3	9.2	10.7	
Shabat et al. [61]	2011	357				8.7
Kim et al. [37]	2013	1465	10.7			8.8
		12816	4.9			9.3
		3001	5.1			7.8
Cheng et al. [35]	2013	5280	2.1		3.6	4.4
Lad et al. [28]	2013	734	5.7	10.2	14.5	17.0
Sato et al. [29]	2015	74	10.8	24.3	29.7	33.8
Leven et al. [41]	2015	810	6.0	9.0	11.0	15.0
Bydon et al. [62]	2015	500			16.2	
Hong et al. [36]	2015	952	1.6			8.2
Kim et al. [51]	2015	25031	7.0	9.8	12.9	13.4
		5095	8.4	12.6	16.3	16.9
Kukreja et al. [32]	2015	92		41.3		
Bohl et al. [63]	2016	226		10.2		
Gerling et al. [64]	2016	357				17.6
Hwang et al. [39]	2016	43	7.0	16.3		
Forsth et al. [16]	2016	120				23.0
Ghogawala et al. [17]	2016	35	5.7		34.0	
Klassen et al. [31]	2017	278	5.4			
		272	1.9			
Virk et al. [65]	2017	2613				5.6
		4907				6.2
Gerling et al. [44]	2017	28				32.1

The underlying aetiology of reoperation

Symptomatic adjacent-segment degeneration or referred as adjacent-segment diseases (ASDis) [48] in the literature has been reported as a major cause of reoperation after fusion surgery in recent years, with the proportion ranging from 46.9 to 100% of total underlying causes [17, 49, 50]. For example, Irmola et al. [49] and Macki et al. [50] found that the most common pathology leading to reoperation following instrumented lumbar spine fusion was ASDis. Ghogawala et al. [17] recently reported that the reoperations were all at the adjacent levels after fusion surgery. Similar observation was reported at the 15-year follow-up study [52]. Other causes contributing to reoperation included irrigation and debridement for the treatment of surgical-site infection or haematoma, redecompression, screw or rod breakage for implant removal, implant revision for correcting screw position [49, 53, 54].

Comparison of decompression alone and decompression plus fusion surgeries

Among the selected studies in this review, there are 12 papers that directly compared the reoperation rates of decompression alone and decompression plus fusion surgeries (Table 5). Ten of these studies are retrospective and two are prospective. (The prospective study by Irmola et al. [49] only recruited patients with fusion surgery.)

Majority of the studies reported that patients with degenerative lumbar diseases treated with decompression alone tended to have reoperation early [27, 46, 55–57],

Table 3 Characteristics of reoperation after fusion surgery

Studies	Diagnosis	Participants	Reoperation rates and causes
Vaughan et al. [43]	LDH	85 cases; mean age, 40.8 years; follow-up, 7.3 years	3% (1/33); causes incl. pseudoarthrosis (1 patient, PT); level of major cause, index level
Glassman et al. [72]	N/A	235 cases; mean age, N/A; follow-up, N/A	11.5% (27/235); causes incl. N/A; level of major cause, N/A
Greiner-Perth et al. [53]	LDH	1680 cases; mean age, 53 years; follow-up, 5 years	13.2% (221/1680); causes incl. pseudoarthrosis (76 PTs.), ASDis (48 PTs.), foraminal or central persisting stenosis (27 PTs.), delayed wound healing (26 PTs.), implant failure (20 PTs.), screw misplacement (17 PTs.), postoperative bleeding (4 PTs.), iatrogenic spondylitis (2 PTs.); level of major cause, index level
Martin et al. [59]	LDD	24,882 cases in 1990–1993 cohort; mean age, 50.1 years; follow-up, 4 years	13% (304/2345) in 1990–1993 cohort, 13.8% (663/4821) in 1997–2000 cohort; causes incl. device complications (233 PTs.), pseudoarthrosis (111 PTs.); level of major cause, N/A
		25,209 cases in 1997–2000 cohort; mean age, 54 years; follow-up, 4 years	
Martin et al. [46]	LDD	24,882 cases; mean age, 51.3 years; follow-up, 11 years	20.1% (471/2345); causes incl. N/A; level of major cause, N/A
Deyo et al. [27]	LSCS	31,543 cases; mean age, 76 years; follow-up, ≥ 4 years	12.7% (1078/8488); causes incl. N/A; level of major cause, N/A
Lad et al. [28]	LS	1468 cases; mean age, 67 years; follow-up, ≥ 2 years	11.9% (87/734); causes incl. arthrodesis revisions (58 PTs.); level of major cause, index level
Martin et al. [45]	LDD	6091 cases; mean age, 56.4 years; follow-up, 1 years	5% (238/4805); causes incl. N/A; level of major cause, N/A
Kim et al. [37]	LDH	715 cases; mean age, 50.1 years; follow-up, 6 years	8.7% (60/689); causes incl. N/A; level of major cause, N/A
Nemani et al. [54]	LSCS	117 cases; mean age, 63.6 years; follow-up, 1.3 years	10.3% (12/117); causes incl. persistent stenosis (8 PTs.), ASDis (2 PTs.), pseudoarthrosis (1 PT.), sagittal decompensation (1 PT.); level of major cause, index level
Kim et al. [51]	LDD	3619 cases in control; mean age, 56.1 years; follow-up, 6 years	12.7% (461/3619) in control, 14.5% (170/1173) in diabetes; causes incl. N/A; level of major cause, N/A
		1173 cases in diabetes; mean age, 61.7 years; follow-up, 6 years	
Macki et al. [50]	LS	103 cases; mean age, 57.6 years; follow-up, ≥ 2 years	20.4% (21/103); causes incl. ASDis (23 PTs.), pseudoarthrosis/instrumentation failure (5 PTs.), persistent or worsening spondylolisthesis (3 PTs.); level of major cause, adjacent level
Sato et al. [29]	Grade 1 DS	163 cases; mean age, 65.8 years; follow-up, 5.9 years	15% (13/89); causes incl. ASDis (10 PTs.), SSI (1 PT.), haematoma (1 PT.), foreign body removal (1 PT.); level of major cause, adjacent level
Gerling et al. [64]	LSCS	417 cases; mean age, 63.9 years; follow-up, 8 years	17% (8/47); causes incl. N/A; level of major cause, N/A
Forsth et al. [16]	LSCS	247 cases; mean age, 66.9 years; follow-up, 6.5 years	27% (31/113); ASDis (22 PTs.), SSI (6 PTs.), pseudoarthrosis (3 PTs.); level of major cause, adjacent level
Ghogawala et al. [17]	Grade 1 DS	66 cases; mean age, 67 years; follow-up, 4 years	14% (4/28); causes incl. ASDis (N/A); level of major cause, adjacent level
Gerling et al. [44]	DS	406 cases; mean age, 64.6 years; follow-up, 8 years	21.2% (80/378); causes incl. N/A; level of major cause, N/A
Irmola et al. [49]	LDD	433 cases; mean age, 62 years; follow-up, 3.9 years	19.3% (84/433); causes incl. ASDis (38 PTs.), instrumentation failure (32 PTs.), acute complications (11 PTs.); level of major cause, adjacent level
Levin et al. [47]	N/A	240 cases; mean age, N/A; follow-up, ≥ 3 years	19.6% (22/112) in FJV, 9.4% (12/128) in control; causes incl. N/A; level of major cause, N/A

All studies are retrospective except Forsth et al. [16], Ghogawala et al. [17] and Irmola et al. [49]

LDH lumbar disc herniation, *LDD* lumbar degenerative disease, *LSCS* lumbar spinal canal stenosis, *LS* lumbar spondylolisthesis, *DS* degenerative spondylolisthesis, *SSI* surgical-site infection, *ASDis* adjacent-segment disease, *FJV* facet joint violation

but reoperation rates are similar at longer follow-up time between the two surgeries [16, 28, 44]. Lad et al. [28] revealed a significantly higher reoperation rate in patients who underwent a laminectomy alone than those who had a decompression plus fusion at 1-year follow-up (5.7 vs. 3.3%; $p=0.023$); however, at over 5-year follow-up, there were no significant differences between the two groups (17.0 vs. 13.2%; $p=0.347$). The prospective study recently published in the New England Journal of Medicine also stated that the percentage of patients who underwent

Table 4 Reoperation rates in different follow-up times after fusion surgery

Studies	Year	Patient number	Reoperation rates			
			Within 1 year (%)	Within 3 years (%)	Within 5 years (%)	Within 10 years (%)
Vaughan et al. [43]	1988	33				3.0
Greiner-Perth et al. [53]	2004	1680			13.2	
Martin et al. [59]	2007	2345	3.5		13.0	
		4821	4.7		13.8	
Deyo et al. [27]	2011	8488	3.7	9.6	11.7	
Lad et al. [28]	2013	734	3.3	7.4	10.1	13.2
Martin et al. [45]	2013	4805	5.0			
Kim et al. [37]	2013	715	3.4			8.7
Nemani et al. [54]	2014	117		10.3		
Kim et al. [51]	2015	3619	6.4	9.4	12.4	12.7
		1173	7.0	10.7	14.0	14.5
Macki et al. [50]	2015	58				29.3
		45				8.9
Sato et al. [29]	2015	89	2.2	7.8	7.8	14.4
Gerling et al. [64]	2016	417				17.0
Forsth et al. [16]	2016	113				27.0
Ghogawala et al. [17]	2016	31	0.0		14.0	
Gerling et al. [44]	2017	378				21.2
Irmola et al. [49]	2018	433		12.5	19.3	
Levin et al. [47]	2018	112		19.6		
		128		9.4		

Table 5 Comparison of reoperation rate and aetiology between two surgeries

Studies	Year	Patient number	Follow-up (years)	Decompression alone		Fusion	
				Rate of reoperation	Major cause of reoperation	Rate of reoperation	Major cause of reoperation
Vaughan et al. [43]	1988	85	7.3	13% (7/52)	Recurrence	3% (1/33)	Pseudoarthrosis
Martin et al. [59]	2007	24882 (1990–1993 cohort)	4	12.4% (2793/22,537)	N/A	13% (304/2345)	N/A
		25209 (1997–2000 cohort)	4	14.0% (2860/20,388)		13.8% (663/4821)	
Martin et al. [46]	2007	24882	11	18.8%	N/A	20.1%	N/A
Deyo et al. [27]	2011	31543	≥ 1	11.3% (2603/23,055)	N/A	12.7% (1078/8488)	N/A
Lad et al. [28]	2013	1468	≥ 2	15.7% (115/734)	Repeat laminectomy	11.9% (87/734)	Arthrodesis revisions
Kim et al. [37]	2013	17997	≥ 5	9.0% (1466/16,327)	N/A	8.7% (60/689)	N/A
Kim et al. [51]	2015	28650	6	13.4% (3353/25,031)	N/A	12.7% (461/3619)	N/A
		6268	6	16.9% (861/5095)		14.5% (170/1173)	
Sato et al. [29]	2015	163	5.9	33.8% (25/74)	SSD	14.6% (13/89)	ASDis
Forsth et al. [16]	2016	247	6.5	23% (28/120)	Restenosis	27% (31/113)	ASDis
Ghogawala et al. [17]	2016	66	4	34%	Instability	14%	ASDis
Gerling et al. [64]	2016	417	8	17.6% (63/357)	N/A	17% (8/47)	N/A
Gerling et al. [44]	2017	406	8	32.1% (9/28)	N/A	21.2% (80/378)	N/A

ASDis adjacent-segment disease, *SSD* same-segment disease additional operation within a mean follow-up period of 6.5 years was similar between the two surgeries [16].

In a study of patients with grade 1 degenerative spondylolisthesis at an average of 5.9-year follow-up, 10 out of 13 reoperations were due to ASDis in fusion group and 18 out of 25 reoperations were due to SSD in the decompression alone group [29]. In another study of patients with degenerative diseases of lumbar spine, half of the reoperations following a fusion surgery (17/34) were due to ASDis, and 41 out of 72 reoperations after a decompression surgery were at the index levels [58]. In a randomized, controlled trial for grade 1 degenerative spondylolisthesis patients at 4-year follow-up, Ghogawala et al. [17] found that all the reoperations performed in the decompression alone group were at the index levels due to subsequent clinical instability, and in contrast, all the reoperations performed in the fusion group were at the adjacent lumbar level (either disc herniation or clinical instability). In another prospective study for lumbar spinal stenosis at an average follow-up of 6.5 years, Forsth et al. [16] found that 31 patients received reoperations after lumbar fusion with 22 due to ASDis and 3 due to pseudoarthrosis; 28 patients received reoperations after decompression alone surgery with 18 due to restenosis at the index levels and 5 due to ASDis.

In general, these studies reported that the operation rates and clinical outcomes were similar among the patients operated using the two surgeries. ASDis is found to be the major cause of reoperation following the fusion surgeries, while SSD is the major cause of reoperation for decompression alone surgeries.

Reoperation rate with time

A review of the literature indicated that early reported studies showed lower reoperation rate than more recently reported studies [16, 17, 27–29, 31, 32, 34–37, 39–41, 43–51, 53, 54, 59–65]. Figure 2 groups the studies reported before 2014 and after 2014 to show the trend of reoperation with follow-up time, i.e., earlier than 2014 and between 2014 and 2017. For treatment of lumbar stenosis patients with the similar age and follow-up period, the reoperation reported by Shabat et al. [61] is 8.7%, which is lower than 23% reported by Forsth et al. [16]. The same phenomenon can also be observed in fusion studies. For treatment of lumbar spondylolisthesis patients with the similar age and follow-up period, Lad et al. [28] reported a 13.2% reoperation rate in 2013, while Gerling et al. [44] reported a 21.2% reoperation rate in 2017. Analysis of these studies implies that the reoperation rate has not been reduced in patients reported in recent years compared to patients reported in earlier years.

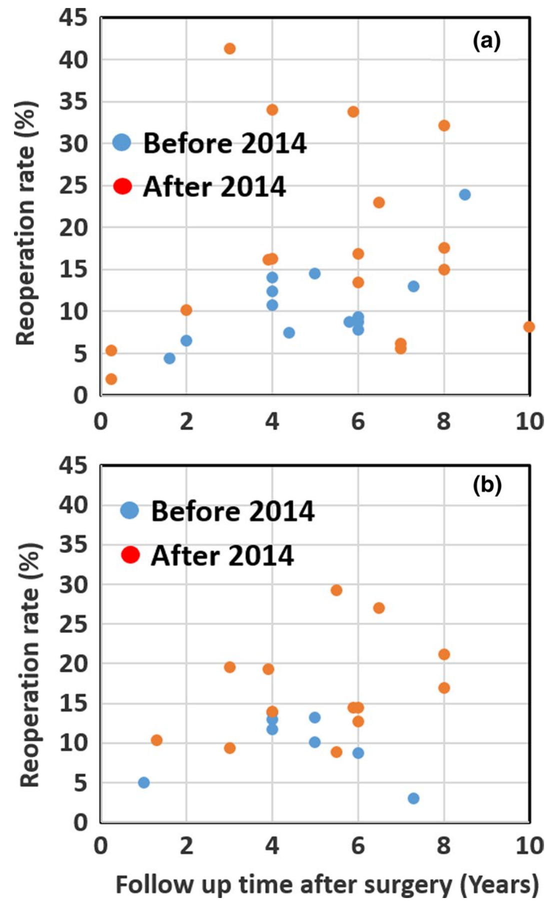

Fig. 2 Comparison of reoperation rates of lumbar patients after surgery reported before and after the year of 2014: **a** decompression alone surgery and **b** decompression plus fusion surgery

Discussion

This paper presented a systematic review of published studies on reoperation rates after lumbar surgeries. Specifically, we compare two popular surgical treatments, decompression alone and decompression plus fusion surgeries. Our review indicated that, on average, both surgeries resulted in similar reoperation rates after the primary surgery. However, majority of the reoperations following fusion surgeries are due to ASDis, and following decompression alone surgeries are due to SSD. Reoperation rates were not found to decrease in patients reported more recently than those reported in early times. These findings were largely consistent with our hypothesis that there is no difference between these two procedures in reoperation rate when used to treat lumbar disease patients.

Reoperation after primary surgery could heavily burden healthcare resources. Data from 2002 to 2004 showed that, within 2 years of reoperation, total direct cost of revision surgery was $10,272 for a repeated discectomy [66]. Another study analysed an institutional database from 1997 to 2007 and found that total direct cost of revision discectomy was $39,836 with a 1-year follow-up [67]. The cost for reoperation after fusion is even higher. Sherman et al. [66] reported that within 2 years of reoperation, total direct cost of revision fusion surgery was $27,740. Parker and Adogwa et al. [68] showed that overall mean two-year cost after a revision lumbar fusion was $32,915. Other studies showed that the mean total 2-year costs of revision fusion for pseudoarthrosis, same-level recurrent lumbar stenosis and adjacent-segment disease were $41,631, $49,431 and $47,846, respectively [69–71]. Therefore, improvement of surgical techniques to impede reoperation after lumbar surgery is critically important for reducing the healthcare expenditure.

Numerous studies have pursued to identify risk factors for reoperation following decompression alone or plus fusion surgeries with the aim to improve patient outcomes. Majority of the discussion on risk factors for both surgeries are related to patient age, gender, symptoms, coexisting degeneration and type of operation [27–29, 31, 32, 35–37, 39–41, 44, 47, 50, 53, 61, 62, 65, 72, 73]. However, due to different experimental set-up and patient population, inconsistent results have been reported on these risk factors. For example, age has been noted as a risk factor for reoperation but some reported younger ages and others reported older ages as being associated with reoperation [28, 37, 40, 41, 44, 65, 73]. Patients with instrumented arthrodesis have been found to have higher reoperation rates than those without instrumentation at 5-year or longer follow-ups [28]. Facet joint violation (FJV) has been suggested to alter load-bearing capability and to be an independent predictor of undergoing reoperation postoperatively [47]. Besides of the unchangeable inherent factors, smoking cessation [62], losing weight [29, 63], improving comorbidities (especially diabetes) [37, 51] and choosing appropriate operation types and surgical techniques [33, 40] have been reported to be helpful for reducing chances of reoperation after decompression alone surgeries.

For fusion surgery, clarifying the mechanisms of ASDis in order to modify the fusion surgeries has been consistently pursued [74–78]. The aetiology of ASDis has been thought to be multifactorial, stemming from existing spondylosis at adjacent levels [79–81], predisposed risk to degenerative changes [82–85] and altered biomechanical forces near a fusion site [78, 86, 87]. However, scientific data on the exact mechanisms of ASDis after fusion are lacking. Previous studies have mainly focused on the changes in the range of motion (ROM) of adjacent segments, but with inconsistent data reported due to different experiment designs [88, 89]. In addition, the ROMs measured under designed experimental conditions do not represent the intrinsic loading conditions of the spine people experience during activities of daily life [77, 90, 91]. The assumption that preservation of ROM at index level might diminish the incidence of ASDis resulted in the development and application of motion-preserving devices, such as total disc replacement (TDR) and other dynamic devices [92–94]. These devices are designed to prevent high stresses applied to the adjacent segment and to avoid the acceleration of structural and mechanical failure in the discs. However, there are insufficient data to support the reduction in ASDis with the use of motion-preserving devices [95–98]. Radcliff et al. [96] reported no statistically significant differences in reoperation rates at adjacent levels between TDR and fusion patients. No difference in the incidence of ASDis was also reported comparing dynamic devices with fusion surgeries [97, 98]. These results imply that the biomechanical mechanisms of ASDis are complicated and more investigations are warranted.

Recently, changes of disc height in the adjacent level after fusion were assumed as a possible mechanism of ASDis [99]. For example, Kaito et al. [99, 100] reported that increased disc height in the index level after fusion is associated with the development of adjacent-segment degeneration. Since contemporary fusion surgery is aimed to restore normal disc height [101], it could increase the index disc height and consequently increase the pressure at the adjacent segments, resulting in a decrease in the adjacent-segment disc height after fusion. This could lead to higher stresses inside the adjacent discs that could accelerate the disc degeneration. A prospective, longitudinal patient follow-up study is necessary to investigate the disc height changes of both index and adjacent segments that could help reveal the biomechanical mechanisms of ASDis.

It is interesting to find out that the more recently operated patients tend to have higher reoperation rates than patients operated earlier by comparing the data published before and after 2014, despite the advances in surgical techniques, instrumentation and uses of bone growth stimulators as evidenced by the findings that spinal fusion has been greatly improved recently [16, 17, 102]. There is no clear explanation for this observation. A possible reason could be because the threshold for patient reoperation is lower now than before. This observation might also suggest that surgical technique improvements and newer implantation devices do not result in reduced reoperation rate. As the mechanisms associated with the development of ASDis are still not well understood as discussed in this paper, it could be challenging to develop new surgical technologies that can effectively prevent the development of ASDis that leads to reoperation. It is critically important to determine the exact mechanisms that cause ASDis in order to develop new surgical technologies that aimed to delay or prevent reoperation after spinal surgeries.

It should be noted that there are limitations in this systematic review. There is a large variation in experimental conditions among different studies. These include different spine diseases, patient number, patient age, surgical techniques, length of follow-up time, etc. It is difficult to make a consistent comparison of the published data. Therefore, we selected studies for this systematic review using designed inclusion criteria. Further, we discussed the trend of reoperation rate changes with follow-up time. However, there are more studies reporting patient follow-up between 4 and 6 years and less patient reports in shorter or longer follow-up times. Despite these limitations, this systematic review does provide readers on the knowledge of current literature on decompression alone and decompression plus fusion surgeries in treatment of lumbar patients. A prospective, longitudinal study using same patient cohort is necessary for investigation of mechanisms of reoperation after lumbar surgeries.

In conclusion, this review found that the reoperation rates were similar following decompression alone or plus fusion surgeries for treatment of degenerative lumbar diseases. The major cause of reoperation following fusion surgery is ASDis, and the major cause of reoperation following decompression alone surgery is SSD. There is no evidence showing that the reoperation rate has a trend to decline with newer surgical techniques used. The exact mechanisms of reoperation after both surgeries are still unclear. Further researches are warranted to clarify the biological and biomechanical factors that could lead to postoperative reoperations after spine surgeries.

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Compliance with ethical standards

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