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Fusion Rates of Instrumented Lumbar Spinal Arthrodesis according to Surgical Approach: A Systematic Review of Randomized Trials

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Background: Lumbar spine fusion rates can vary according to the surgical technique. Although many studies on spinal fusion have been conducted and reported, the heterogeneity of the study designs and data handling make it difficult to identify which approach yields the highest fusion rate. This paper reviews studies that compared the lumbosacral fusion rates achieved with different surgical techniques.

Methods: Relevant randomized trials comparing the fusion rates of different surgical approaches for instrumented lumbosacral spinal fusion surgery were identified through highly sensitive and targeted keyword search strategies. A methodological quality assessment was performed according to the checklist suggested by the Cochrane Collaboration Back Review Group. Qualitative analysis was performed.

Results: A literature search identified six randomized controlled trials (RCTs) comparing the fusion rates of different surgical approaches. One trial compared anterior lumbar interbody fusion (ALIF) plus adjunctive posterior transpedicular instrumentation with circumferential fusion and posterolateral fusion (PLF) with posterior lumbar interbody fusion (PLIF). Three studies compared PLF with circumferential fusion. One study compared three fusion approaches: PLF, PLIF and circumferential fusion.

Conclusions: One low quality RCT reported no difference in fusion rate between ALIF with posterior transpedicular instrumentation and circumferential fusion, and PLIF and circumferential fusion. There is moderate evidence suggesting no difference in fusion rate between PLF and PLIF. The evidence on the fusion rate of circumferential fusion compared to PLF from qualitative analysis was conflicting. However, no general conclusion could be made due to the scarcity of data, heterogeneity of the trials included, and some methodological defects of the six studies reviewed.

Keywords: *Systematic review, Spinal fusion, Surgical approach*

Surgical fusion is the mainstay in the treatment of degenerative disorders of the lumbar spine. Many spinal fusion techniques have been developed since the initial description of spinal fusion in the early 20th century. Traditional posterolateral intertransverse fusion (PLF) still remains a useful procedure with acceptable fusion rates for most degenerative conditions. Interbody fusion techniques using either anterior (anterior lumbar interbody fusion, ALIF) or posterior (posterior lumbar interbody fusion, PLIF) approaches have been developed to restore the structural integrity of degenerative or unstable discs. However, there is no solid evidence showing that the functional outcomes are better after anterior column support than other fusion models.[1,2] Harms introduced transforaminal interbody fusion (TLIF) to overcome the issue of dural manipulation and subsequent epidural fibrosis.[3] For solid fusion, PLF can be combined with interbody fusion to circumferentially stabilize the relevant segment, even though it is unclear

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whether this improves the fusion rates.[4-8]

The fusion rates in lumbar spine surgery can vary according to the technique. Although numerous studies on spinal fusion have been conducted, their outcomes are so inconsistent that it is difficult to determine which approach provides the highest fusion rate. Therefore, in this study, an attempt was made to identify all relevant randomized controlled trials (RCTs) comparing fusion techniques. In addition, a systematic review was performed to summarize and describe the contemporary best evidence.

METHODS

Literature Search

A computer assisted search of Medline (from 1966 to September 2008) was conducted to retrieve all the relevant randomized controlled trials. The highly sensitive search strategies suggested by others[9,10] were used, and the specific search terms included the following: spine fusion, spinal fusion, posterolateral lumbar fusion, posterior lumbar interbody fusion, transforaminal lumbar interbody fusion, anterior lumbar interbody fusion, circumferential fusion, spinal arthrodesis and spondylodesis. The relevant RCTs from the Cochrane Central Register of Controlled Trials (3rd quarter 2008) with similar terms were also identified. The search was limited to English language publications and complete articles from peer-reviewed journals. The references were screened from articles selected based on the abstract.

Selection

The titles and abstracts of the identified studies were reviewed, and possible studies were retrieved in the full text version. Only RCTs reporting the results of instrumented lumbar spinal fusion for degenerative conditions were included. Studies involving patients with spinal fractures, tumors, infections or scoliosis were excluded. Studies that compared lumbar fusion with artificial disc replacement, dynamic stabilization, electrical stimulation or any conservative treatment were excluded. Because the purpose of the study was to examine the fusion rates according to the surgical approach, only those studies that compared fusion rates of two or more surgical approaches were included. Accordingly, studies comparing different instrumentation with the same approach were also excluded. The trials must have reported the fusion rate as an outcome measure.

Methodological Quality Assessment

The studies that met all the above criteria were reviewed closely in terms of the methodological quality using the checklist suggested by the Cochrane Collaboration Back Review Group (BRG).[10] The criteria were assessed by two reviewers and scored as 'yes,' 'no,' or 'don't know.'

Data Extraction

The data was extracted using a data extraction form included in the Cochrane Handbook for Systematic Reviews for Interventions (Chapter 7, version 5.0.0). One reviewer extracted the data and a second reviewer confirmed them. The checklist contains the study characteristics of methods, participants, interventions, outcomes and results.

Data Analysis

For the outcome of fusion, the relative risk (RR) and 95% confidence interval (CI) were calculated. A chi-square analysis was performed for each study to determine the statistical significance. The results were considered significant at $p < 0.05$ and two-tailed values were used. Meta-analysis was not possible due to the heterogeneity of the outcome definitions and scarcity of valid data allowing for only qualitative analysis.[10]

RESULTS

Literature Search

The highly sensitive search for controlled trials and spinal fusion retrieved 5,064 references in Medline. The literature regarding 'cervical' or 'scoliosis' were excluded using the 'NOT' prefix. After screening the titles of the remaining 2,700 references, the abstracts of 312 potentially relevant articles were reviewed. Finally, six articles that satisfied all the inclusion/exclusion criteria were obtained. A search of the Cochrane Central Register of Controlled Trials identified 466 references in which all six studies were included. There was no additional study found in the Cochrane search and reference screening of the selected articles.

Study Characteristics

Table 1 summarizes the characteristics of the six studies included in this study. Three studies[5-7] included the three intervention groups, and two had non-relevant groups, such as noninstrumented fusion (Fritzell et al.[5]) or foraminotomy (Hallett et al.[6]). A total of 526 patients in the 6 studies were followed to the last follow-up period. There were 220 PLF patients, 215 circumferential fusion patients, 67 PLIF patients and 22 ALIF patients. All PLIF and ALIF patients underwent transpedicular instrumentation. Five studies compared circumferential fusion with other fusion approaches but the approaches combined with PLF were heterogeneous. The timing of the outcome assessment in-

Table 1. Summary of the Trials Included

	Schofferman et al.[8]	Fritzell et al.[5]	Christensen et al.[4]	Kim et al.[7]	Inamdar et al.[11]	Hallett et al.[6]
Year published	2001	2002	2002	2006	2006	2007
			Participants			
Total no.	53	222	148	184	22	48
Fusion level	1 or 2 or 3 levels	1 or 2 levels (L4-5, L5-S1)	1 or 2 levels	1 or 2 levels	1 level (L4-5 or L5-S1)	1 level (L3-4 or L4-5 or L5-S1)
Inclusion criteria	Structural problem amenable to fusion, failed conservative care, no psychological contraindications	Severe and therapy resistant CLBP, pain duration at least 2 years, back pain is severer than leg pain, no sign of nerve root compression	Severe CLBP and leg pain	Disabling back pain and/or leg pain with or without neurologic symptoms, neural canal stenosis on MRI	Neurogenic claudication, neurological deficits, severe persistent backache, high-grade slip with instability	Single level degenerative disc disease, foraminal stenosis with leg pain
Diagnosis	FBS, painful degenerated disc, SS, SL	NS	Isthmic SL grade 1-2, primary degeneration, secondary or accelerating degeneration after decompressive surgery	SS, isthmic SL, degenerative SL	Isthmic and degenerative SL	Same as above
Exclusion criteria	NS	Previous spine surgery except for successful removal of a herniated disc, SL, SS	Previous surgery, age < 20 or > 65, metabolic bone disease, comorbidity, psychosocial instability	Fracture, infection, tumor, revision, secondary gains	NS	Degenerative SL > grade 2, vertebral translocation > 1 cm, disc space narrowing > 50%, malignancy
Country	United States	Sweden	Denmark	Korea	India	Scotland
			Intervention			
Intervention groups	1. 360° fusion: ALIF + PLF with instrumentation 2. 270° fusion: ALIF with instrumentation	(1. PLF without instrumentation) 2. PLF with instrumentation 3. PLF + ALIF or PLIF	1. PLF 2. ALIF + PLF	1. PLF 2. PLIF 3. PLF + PLIF	1. PLIF 2. PLF	(1. Foraminotomy only) 2. PLF 3. PLF + TLIF
Instrumentation	TSRH transpedicular	VSP and internal fixation device	CDI or transarticular screws Brantigan cages for ALIF	TSRH pedicle screws Harms mesh cages for PLIF	Moss Miami pedicle screws	Moss Miami pedicle screws Titanium interbody cages for TLIF
Bone graft	ALIF : FRA with allograft chips PLF: autogenous ICBG	Autogenous ICBG (tricortical bone block for interbody fusion)	Autogenous ICBG	PLF: autogenous ICBG + local bone PLIF: local bone with cage	PLIF: autogenous tricortical ICBG PLF: spinous process with BG substitute	Autogenous ICBG

cluding the fusion status ranged from one and three years after surgery.

Only Hallett et al.'s study[6] included single level fusion, but various segments were fused (L3-4, L4-5, L5-S1). Two or three level fusions were mixed in the other studies. The diagnostic inclusion criteria in these studies were also heterogeneous. However, study groups in each study were generally similar in terms of the prognostic indicators. An autogenous iliac bone graft was harvested in most studies except for the ALIF group in Schofferman et al.'s study[8] in which a femoral ring allograft and decalcified allograft chips were used. For the other interbody fusions, two studies[5,11] employed autogenous tricortical bone blocks and three studies[4,6,7] used various cages (Table 1).

Table 1. Continued

	Schofferman et al.[8]	Fritzell et al.[5]	Christensen et al.[4]	Kim et al.[7]	Inamdar et al.[11]	Hallett et al.[6]
Year published	2001	2002	2002	2006	2006	2007
			Outcomes			
Time point	1 yr	2 yr	1 yr	6 mo, 1 yr, 2 yr, 3 yr	1 yr	2 yr
Definition	Refer to Table 2.					
			Results			
No. of participants allocated	1. 29 2. 24	2. 74 3. 75	1. 73 2. 75	NS	1. 11 2. 11	2. 16 3. 14
Age (range)	1. 43 (24-57) 2. 40 (25-54)	2. 43 (25-65) 3. 42 (28-59)	1. 45.5 (23-65) 2. 45.4 (20-63)	1. 58.6 (42-74) 2. 55.2 (38-79) 3. 53.4 (39-75)	1. 41.4 2. 44.7	2. 54 3. 59
Gender	1. M 14, F 12 2. M 13, F 9	2. M 60.8% 3. M 40.0%	1. M 27, F 46 2. M 31, F 42	1. M 15, F 47 2. M 17, F 40 3. M 13, F 35	NS	2. M 6, F 10 3. M 9, F 5
Missing participants	1. 3 (X-ray available for 22) 2. 2 (X-ray available for 18)	NS	1. 2 2. 3	17	1. 1 2. 1	2. 1 at 2 yr, 5 at 5 yr 3. 1 at 2 yr, 5 at 5 yr
Fusion rate	1. 77% (17/22) 2. 89% (16/18)	2. 87% (54/62) 3. 91% (58/64)	1. 80% (57/71) 2. PLF: 92% (67/72), ALIF: 82% (60/72)	1. 92% (57/62) 2. 95% (54/57) 3. 93% (46/48)	1. 100% 2. 100%	2 and 3. PLF 95% (26/28) 3. TLIF 46% (6/13)
RR	0.869	0.961 (2 vs. 3)	0.863 (PLF1 vs. PLF2) 0.963 (PLF1 vs. ALIF)	Not possible	1	Not possible
Confidence interval	0.657-1.150	0.849-1.088 (2 vs. 3)	0.757-0.984 (PLF1 vs. PLF2) 0.825-1.125 (PLF1 vs. ALIF)	Not possible	1	Not possible
p-value	0.336	0.529 (2 vs. 3)	0.024 (PLF1 vs. PLF2) 0.636 (PLF1 vs. ALIF)	0.667	1	Not possible
Remarks	Very low PLF rate			Fusion rates at last follow-up		

The numbers (1, 2, 3) indicate the corresponding groups in each study. Group 1 data in the Fritzell[5] and Hallett[6] studies were not included in the present analysis. CLBP: chronic low back pain, MRI: magnetic resonance imaging, FBS: failed back surgery, SS: spinal stenosis, SL: spondylolisthesis, NS: not specified, ALIF: anterior lumbar interbody fusion, PLF: posterolateral fusion, PLIF: posterior lumbar interbody fusion, TLIF: transforaminal interbody fusion, TSRH: Texas Scottish Rite Hospital, VSP: variable screw placement, CDI: Cotrel-Dubousset instrumentation, FRA: femoral ring allograft, ICBG: iliac crest bone graft, RR: relative risk.

All studies evaluated spinal fusion from simple radiographs with or without flexion-extension views. However, the definitions of fusion were quite heterogeneous. For PLF, three authors (Christensen et al.,[4] Kim et al.,[7] Hallett et al.[6]) defined fusion as a bony bridge between transverse processes on at least one side, whereas Fritzell[5] defined fusion as bridging trabeculae on both sides. The other two studies[8,11] did not specify the bilaterality of fusion. The definitions for interbody fusion were relatively similar. For circumferential fusion, either the criteria of interbody fusion or PLF was used in some studies, whereas the other studies reported the fusion rates of interbody fusion and PLF separately (Table 2).

Methodological Quality

According to the criteria list of BRG,[10] the trials were scored between 3 and 7 out of 11 possible points (Table 3). Only two studies had more than six points, and were referred to as 'high quality' studies.[12] Three studies (Fritzell et al.,[5] Christensen et al.,[4] Hallett et al.[6]) described an acceptable randomization process including sequence generation and allocation concealment.[13,14] In Schofferman et

Table 2. Definitions of Fusion

	PLF	Interbody fusion	Circumferential fusion
Schofferman et al.[8]	Mature bridging trabeculae with remodeling, no radiolucent lines, no motion on flexion/extension radiographs	No radiolucent lines, no motion, remodeling of FRA with trabeculation and density equal to the adjacent vertebra	Separately (ALIF or PLF)
Fritzell et al.[5]	Trabeculae on both sides with evidence of increasing density with cortication	Trabeculae on both sides	Interbody fusion was assumed to be sufficient
Christensen et al.[4]	Continuous intertransverse bony bridge on at least 1 side	Continuous trabecular bony structure	Separately (ALIF or PLF)
Kim et al.[7]	Lenke classification: results above B level were considered fusion	Bony bridge, < 5 degrees movement on flexion/extension views, absence of radiolucency around the cage and cage migration	Either the criteria of group 1 or 2
Inamdar et al.[11]	Grade 0: no visible gap Grade 1: amorphous noncontiguous bone Grade 2: amorphous contiguous bone Grade 3: trabecular bone	Same as PLF grade 0 and 1: pseudoarthrosis Grade 2 and 3: good union	
Hallett et al.[6]	Continuous bony bridge on at least 1 side	Solid bar of bone within or anterior to cages	Separately (TLIF or PLF)

PLF: posterior lumbar fusion, FRA: femoral ring allograft, ALIF: anterior lumbar interbody fusion, TLIF: transforaminal interbody fusion.

Table 3. Assessment of the Methodological Quality

Criteria[10]	Schofferman et al.[8]	Fritzell et al.[5]	Christensen et al.[4]	Kim et al.[7]	Inamdar et al.[11]	Hallett et al.[6]
Was the method of randomization adequate?	No	Yes	Yes	Don't know	Don't know	Yes
Was the treatment allocation concealed?	No	Yes	Yes	Don't know	Don't know	Yes
Were the groups similar at baseline regarding the most important prognostic indicators?	Yes	No	Yes	Yes	Don't know	Yes
Was the patient blinded to the intervention?	Don't know	No	Don't know	Yes	Don't know	Don't know
Was the care provider blinded to the intervention?	No	No	No	No	No	No
Was the outcome assessor blinded to the intervention?	Yes	Yes	Don't know	Don't know	Don't know	No
Were cointerventions avoided or similar?	No	Yes	No	No	Yes	Yes
Was the compliance acceptable in all groups?	Yes	Yes	Yes	Yes	Yes	Yes
Was the drop-out rate described and acceptable?	No	Yes	No	Yes	Yes	Yes
Was the timing of the outcome assessment in all groups similar?	Yes	Yes	Yes	No	Don't know	Yes
Did the analysis include an intention-to-treat analysis?	No	No	No	No	No	Unclear
Score	4	7	5	4	3	7

al.'s study,[8] the patients were randomized into either the fusion group according to their clinic patient number. In the other two studies,[7,11] the authors did not report the method of randomization explicitly. Only one trial (Hallett et al.[6] reported an analysis explicitly described as an intention to treat.[13,15]

Fusion Rates and Qualitative Analysis

Schofferman et al.[8] compared 360° and 270° fusion methods. They designated an ALIF plus transpedicular instrumentation with PLF as '360° fusion,' and an ALIF plus transpedicular instrumentation without PLF as '270° fusion.' The fusion rates for ALIF and PLF were reported separately. ALIF in the 360° group appeared solid in 77%

of patients, whereas ALIF in the 270° group was solid in 89%; this difference was not significant (p = 0.336) with a RR of 0.869 (95% CI, 0.657 to 1.150). In contrast, the fusion rate of PLF was quite low; 14% on both sides and 18% on one side in the 360° group. They concluded there were no significant clinical differences between the 360° and 270° fusion groups. However, the 270° fusions were associated with shorter operating times, less blood loss, reduced cost, and less utilization of health care resources.

In an RCT from the Swedish Lumbar Spine Study Group, Fritzell et al.[5] compared 3 surgical techniques: PLF without instrumentation, PLF with instrumentation and PLF with instrumentation and ALIF or PLIF (circumferential fusion). In the 360° group, interbody fusion that healed convincingly was assumed to be sufficient to be classified as solid fusion. The fusion rates for the PLF (with instrumentation) and 360° groups were 87% and 91%, respectively. There was no significant difference between the two approaches (p = 0.529; RR, 0.961; 95% CI, 0.849 to 1.088).

In the study reported by Christensen et al.,[4] circumferential fusion with a Brantigan cage (ALIF) was compared with PLF. Cotrel-Dubousset instrumentation (CDI) was used exclusively in the PLF group but either CDI or transarticular titanium screws were used in the circumferential group depending on whether decompression had been performed. They reported fusion rates of PLF and ALIF separately. In the PLF alone group, the fusion rate was 80%. In the circumferential group, the fusion rates of PLF and ALIF were 92% and 82%, respectively. The fusion rate of PLF in the circumferential group was significantly higher than that of the PLF group (p = 0.024; RR, 0.862; 95% CI, 0.757 to 0.984). Compared to the fusion rate of ALIF, the fusion rate of PLF group was similar to that of the circumferential group (p = 0.636; RR, 0.963; 95% CI, 0.825 to 1.125).

Kim et al.[7] compared the clinical outcomes of three fusion methods using the posterior approach: PLF, PLIF and circumferential fusion (PLF and PLIF). In the circumferential group, cases that satisfied either the criteria of PLF or PLIF were considered to be fusion. All three groups showed high union rates at the last follow-up; 92% for the PLF group, 95% for the PLIF group, and 93% for the circumferential group. There was no significant difference between union rates (p = 0.667).

Inamdar et al.[11] compared the PLF and PLIF in the treatment of spondylolisthesis. Only 11 patients were allocated to each group, and there was no incidence of pseudoarthrosis in either of the PLF and PLIF patients. They graded bony union from grade 0 to grade 3. In the PLIF group, 20% and 80% of patients showed evidence of grade 3 and 2 union, respectively. In the PLF group, 60% and 40% of patients showed evidence of grade 3 and 2 union, respectively.

Table 4. Levels of Evidence[10]

Strong	Consistent findings among multiple high quality RCTs
Moderate	Consistent findings among multiple low quality RCTs and/or CCTs and/or one high quality RCT
Limited	One low quality RCT and/or CCT
Conflicting	Inconsistent findings among multiple trials (RCTs and/or CCTs)
No evidence	No RCTs or CCTs

RCT: randomized controlled trial, CCT: controlled clinical trial.

A trial of Hallett et al.[6] included three groups: foraminotomy, foraminotomy with PLF, and foraminotomy with PLF and TLIF. Two circular titanium interbody cages were used in the TLIF fusion group. The fusion rate of PLF was much higher than TLIF because 95% of the patients undergoing PLF developed solid fusion, and solid interbody fusion was only apparent in 6 of the 13 patients assessed. However, statistical analysis was impossible because they did not report the results of PLF in the PLF and circumferential groups separately.

The above articles describe four different surgical approaches with varying fusion success rates. Qualitative analyses was performed using various levels of evidence (Table 4) suggested by the BRG[10] as follows:

1. There is limited evidence (1 trial; 40 patients) to indicate no difference in fusion rates between ALIF plus posterior transpedicular instrumentation and circumferential fusion (PLF and ALIF): Schofferman et al.[8]
2. There is limited evidence (1 trial; 110 patients) indicating that there is no difference in the fusion rates between PLIF and circumferential fusion (PLF and PLIF): Kim et al.[7]
3. There is moderate evidence (2 trials; 139 patients) suggesting no difference in fusion rates between PLF and PLIF: Kim et al.[7] and Inamdar et al.[11]
4. There is conflicting evidence (4 trials; 407 patients) regarding the fusion rate of circumferential fusion compared to PLF: Fritzell et al.,[5] Christensen et al.,[4] Kim et al.,[7] and Hallett et al.[6]

DISCUSSION

A range of surgical approaches can be used to achieve

lumbar spinal fusion. Numerous investigators have reported the biomechanical and biological rationale, advantages and disadvantages, fusion rates and clinical results of each approach. However, the outcomes of the studies are so inconsistent that there is no evidence of the superiority of one approach over another one in terms of the fusion rate. This may be due to the diversity of the patient populations, diagnostic criteria of fusion, bone graft source or postoperative bracing. Therefore, randomized trials and systematic reviews will be needed to enhance evidence-based practice.

The present study identified only six RCTs that compared the fusion rates of different surgical approaches for instrumented lumbar spine fusion. There were four combinations of comparison as described above, and the body of literature was too small to perform quantitative analysis. Although some conclusions were possible through qualitative analysis, the clinical heterogeneity was problematic. For circumferential fusion, different approaches were used with PLF. Furthermore, the indications for fusion surgery and the type of graft material inserted into the disc space were not consistent. More importantly, the definitions of the radiological outcomes varied according to the trial, particularly for PLF.

This analysis had some limitations. Publication bias was unavoidable because the study selection was restricted to published peer-reviewed articles.[14] Furthermore, this study included only English-language journals. However, there is some controversy as to whether the language restriction would give rise to bias due to an overestimation of the reported treatment effect.[6,17] Another problem is that EMBASE was not included in the search strategy, which is in contrast to the recommendations of BRG.[10] EMBASE has a better coverage of European journals[18] but it focuses primarily on pharmacological publications.[19,20]

The current study only included instrumented fusions. Instrumented fusion has been reported to have a higher fusion rate than noninstrumented fusion.[21,22] Therefore, a meta-analysis or systematic review to compare the noninstrumented fusion rates according to the surgical approach may provide different results to the present findings. However, the heterogeneity between studies might have been more serious if this study had combined both instrumented and noninstrumented fusion studies. In addition, ALIF or PLIF using 'stand-alone' cages has been reported to have biomechanically lower stiffness than instrumented fusion, and is not considered to be a standard for spinal fusion.[1,23]

Whether osseous fusion rate correlates with the clinical outcome remains a controversial issue.[24,25] The clinical results were not analyzed systematically because the purpose of this study was to compare the fusion rates of different surgical approaches. Three studies reported that the clinical results correlated well with the fusion rates (Schofferman et al.,[8] Christensen et al.,[4] Kim et al.[7]). However, Fritzell et al.[5] reported that radiographic fusion did not significantly correlate with the clinical outcome. Inamdar et al.[11] recommended PLF over PLIF because of the simplicity of the procedure, lower complication rate and good clinical and radiological outcomes, even though both groups had fusion rates of 100%. In the study reported by Hallett et al.,[6] PLF was solid in more than 90% of stabilized patients and TLIF was even less clearly demonstrated than PLF. However, there was no significant difference between the groups in terms of the functional results.

The RCTs included in this study have some methodological flaws. Only three trials[4-6] described the adequate randomization method and its concealment. The blinding of patients and the outcome assessors was poor, even though the surgeon could not be blinded in surgical trials.[14] Most trials did not follow intention-to-treat principles except for one study, which can lead to a loss of randomization and possible inflation of the type-I error, or a false rejection of the null hypothesis.[6,13] Finally, the diagnostic criteria varied substantially from study to study as described above. Some studies included revision surgery and spondylolisthesis cases, but others did not. The level of the fused segments also varied. Only two trials[5,6] had more than six points according to the criteria list of BRG.[10,12] However, the lower-quality studies were not excluded because the results can be biased.

Another fundamental problem is that the presence of spinal instrumentation can make an evaluation of the fusion mass difficult, particularly in plain radiographs.[26-29] The posterolateral and interbody fusion mass may be obscured by pedicle screws and radioopaque interbody cage devices, respectively. In addition, the use of metal implants reduces the value of flexion and extension views by failing to show motion in the presence of pseudoarthrosis. Unfortunately, all the studies in this review used plain radiographs with or without flexion-extension views to determine the fusion status. However, no reported diagnostic technique, including fine-cut CT scans, has shown a high level of accuracy in predicting spinal fusion.[30]

In conclusion, one low quality RCT showed no difference in fusion rates between ALIF plus posterior transpedicular instrumentation and circumferential fusion, and PLIF and circumferential fusion.[7,8] There was moderate evidence suggesting no difference in fusion rate between PLF and PLIF.[7,11] The evidence on the fusion rate

of circumferential fusion compared to PLF from qualitative analysis was contradictory.[4-7] However, a general statement could not be made because of the scarcity of data, heterogeneity of the trials included and some methodological defects.

The authors suggest that more RCTs in a homogeneous population be carried out to compare each single approach with circumferential fusion to determine whether a combined approach is necessary to improve the clinical results and fusion rate. A randomized comparison between single approaches, such as PLF vs. PLIF, ALIF vs. PLIF, or PLIF vs. TLIF, is also needed to provide an evidence-based rationale in the selection of appropriate fusion methods for spine surgeons.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest relevant to this article.

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