MINIMALLY INVASIVE LUMBAR ARTHRODESIS AND PERCUTANEOUS PEDICLE SCREWS: A SYSTEMATIC REVIEW

ARTRODESE LOMBAR MINIMAMENTE INVASIVA E PARAFUSOS PEDICULARES PERCUTÂNEOS: REVISÃO SISTEMÁTICA

ARTRODESIS LUMBAR MÍNIMAMENTE INVASIVA Y TORNILLOS PEDICULARES PERCUTÁNEOS: REVISIÓN SISTEMÁTICA

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ABSTRACT

A systematic review of the literature was performed in order to organize, evaluate, and select evidences available about the safety and efficacy of minimally invasive percutaneous arthrodesis with percutaneous pedicle screws in the treatment of patients with degenerative disc disease (and other spinal pathologies) as compared to conventional arthrodesis. PubMed, EMBASE and Cochrane Library databases were consulted to locate clinical trials and case reports/case series published in English between 2014 and 2019. After selection according to the inclusion/exclusion criteria, 21 of the 197 articles identified were chosen for a complete reading and used for the present review. Although the level of evidence of most of the studies included made the demonstration of efficacy and superiority among the surgical techniques reviewed difficult, the findings related to the minimally invasive procedure indicate a safe and reliable approach for the treatment of lumbar diseases. ***Level of evidence II; Systematic review of literature.***

Keywords: Arthrodesis; Case Reports; Clinical Trial; Pedicle Screws; Spine; Spinal Fusion.

RESUMO

A revisão sistemática da literatura foi realizada com o objetivo de organizar, avaliar e selecionar evidências a respeito da segurança e eficácia da artrodese percutânea minimamente invasiva com parafusos pediculares percutâneos no tratamento de pacientes com doença degenerativa de disco (e outras patologias da coluna), em comparação com a artrodese convencional. Foram consultadas as bases de dados PubMed, EMBASE e Biblioteca Cochrane para localizar ensaios clínicos e relatos/séries de casos publicados em inglês entre 2014 e 2019. Dentre 197 estudos identificados, depois de seleção usando critérios de inclusão/exclusão, 21 artigos foram escolhidos para leitura na íntegra e usados na presente revisão. Apesar do nível de evidência da maioria dos estudos incluídos dificultar a demonstração de eficácia e superioridade entre as técnicas cirúrgicas revisadas, os achados referentes ao procedimento minimamente invasivo apontam para uma abordagem segura e confiável para o tratamento de doenças lombares. ***Nível de evidência II; Revisão sistemática da literatura.***

Descritores: *Artrodese; Relatos de Casos; Ensaio Clínico; Parafusos Pediculares; Coluna Vertebral; Fusão Vertebral.*

RESUMEN

La revisión sistemática de la literatura fue realizada con el objetivo de organizar, evaluar y seleccionar evidencias al respecto de la seguridad y eficacia de la artrodesis percutánea mínimamente invasiva con tornillos pediculares en el tratamiento de pacientes con enfermedad degenerativa de disco (y otras patologías de la columna) en comparación con la artrodesis convencional. Fueron consultadas las bases de datos PubMed, EMBASE y Biblioteca Cochrane para localizar ensayos clínicos y relatos/series de casos publicados en inglés entre 2014 y 2019. Entre 197 estudios identificados, después de selección usando criterios de inclusión/exclusión, fueron escogidos 21 artículos para lectura integral y usados en la presente revisión. A pesar de que el nivel de evidencia de la mayoría de los estudios incluidos dificulte la demostración de eficacia y superioridad entre las técnicas quirúrgicas revisadas, los hallazgos referentes al procedimiento mínimamente invasivo apuntan hacia un abordaje seguro y confiable para el tratamiento de enfermedades lumbares. ***Nivel de evidencia II; Revisión sistemática de la literatura.***

Descriptores: *Artrodesis; Informes de Casos; Ensayo Clínico; Tornillos Pediculares; Columna Vertebral; Fusión Vertebral.*

INTRODUCTION

Arthrodesis (or fusion) is a commonly used technique for the treatment of degenerative lumbar diseases[1–3] and its use has grown substantially in recent decades,[4] however, the conventional approaches and instrumentations used in open procedures demand extensive tissue dissection, which is associated with traumas, blood loss, reoperation rates, and substantial costs.[5–7] With these issues in mind, minimally invasive fusion is proposed in pathological spinal conditions,[8] significantly reducing blood loss and tissue damage, and making the patient's faster recovery and better rehabilitation

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possible.[9–12] In minimally invasive lumbar arthrodesis surgeries, the placement of percutaneous pedicle screws provides fusion without extensive incisions, which reduces the probability of complications.[13] The objective of this systematic review was to investigate evidence related to the safety and efficacy of minimally invasive percutaneous arthrodesis with percutaneous pedicle screws in the treatment of patients with degenerative disc disease (and other pathological spinal conditions) as compared to conventional open arthrodesis.

METHODS

This systematic review was conducted in accordance with the PRISMA statement[14,15] and was registered in the PROSPERO database as number CRD42019133252. The inclusion criteria were articles related to patients with degenerative disc disease and arthrosis or facet joint degeneration, degenerative scoliosis/adult scoliosis, spinal instability, a history of previous lumbar spine surgery, spinal canal stenosis, spinal fractures of traumatic, neoplastic, osteoporotic, infectious, and/or rheumatological origins treated with minimally invasive percutaneous arthrodesis with percutaneous pedicle screws or conventional open arthrodesis, written in English, including clinical trials and case series/reports. Incomplete texts were excluded. The PubMed, Cochrane Library, and EMBASE databases were used to locate articles published from 2014 to April 2, 2019. The title and abstract of each article were analyzed to eliminate duplicate articles and the full text of potentially relevant articles was retrieved for analysis. Subsequently, the texts were examined by two independent reviewers, who applied the Oxford Centre for Evidence-Based Medicine (OCEBM) scale[16] to all of the articles in order to classify them according to level of evidence. The following items (when available) were collected from each article: author(s); year of publication; study design; number of participants; mean age, sex, and diagnosis of the participants; intervention; control group; instrumentation; graft/implant used; surgical time (minutes); blood loss (ml); complications/adverse events; reoperation/revision; duration of follow-up (months); outcome measurements; Visual Analog Scale or VAS (pain); Oswestry Disability Index or ODI; and conclusions.

RESULTS

The initial search of the PubMed, Cochrane Library, and EMBASE data bases using "intervertebral disc degeneration", "arthropathies", "spondylolysis", "scoliosis", "spinal stenosis"; "spinal fractures", "arthrodesis", "spinal fusion", "pedicular screws", and "minimally invasive surgical procedures", adapting the keywords to each of the databases and including synonyms, with filters for clinical trials or case reports/series, written in English, published between 2014 and 2019, identified 197 articles. After the elimination of duplicates, 162 articles remained. Two authors reviewed the titles and abstracts of the remaining works, selecting them according to the inclusion criteria. Only clinical trials and case reports/series related to minimally invasive percutaneous arthrodesis with percutaneous pedicle screws for the treatment of patients with degenerative disc disease (and other pathological spinal conditions) were included, resulting in 40 articles. Publications in languages other than English were also excluded in this step. The final step was to fully review each of the 40 eligible articles, comprising 2 prospective randomized controlled studies, 1 prospective non-randomized controlled study, and 18 case reports/series, resulting in a total of 21 articles for inclusion in the systematic review. (Figure 1)

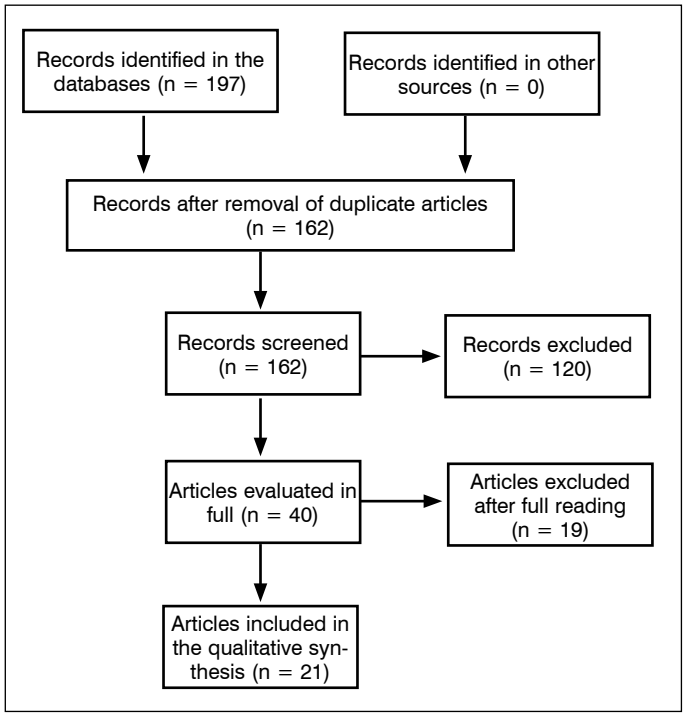

Figure 1. Schedule for articles published in databases.

A total of 230 participants/cases (129 who were submitted to minimally invasive procedures and101 to conventional open procedures) were included in this systematic review. Most of the results came from patients/participants diagnosed with stenosis (54.3%) or spondylolisthesis (14.8%). The results were expressed as mean values ± standard deviations. The data collected from the 3 clinical trials and the 18 case reports/series are summarized in Table 1.

Mean participant age: The 3 clinical trials had similar mean participant ages, as shown in Table 1. Considering all the selected case reports/series together, the mean age of the 30 participants was 52.2 ± 22.2 years.

Diagnosis: The most reported diagnosis was stenosis, found in the 3 clinical trials [18,24,28] and 3 case reports.[17,20,37] A total of 62 participants with stenosis were described in minimally invasive procedures and 63 in open procedures. The second most reported diagnosis was spondylolisthesis, present in 1 clinical trial[28] and in 4 case reports.[17,20,27,34] A total of 19 participants with this pathology were described in minimally invasive procedures, while 15 were described in open procedures. Other diagnoses are described in Table 1.

Intervention: Five different fusion procedures were reviewed: 215 cases of lumbar fusion, 1 case of thoracic fusion, 9 cases of thoracolumbar fusion, 2 cases of thoracolumbosacral fusion, and 3 cases of lumbosacral fusion. Among them, 129 were performed by minimally invasive approach, while open procedures were applied in 101 cases. Lumbar fusion was the main technique used for the treatment of spondylolisthesis[17,20,27,28,34] and stenosis.[17,18,20,24,28,37]

Control: Only the three clinical trials had control groups. Kim et al. (2018)[18] had a conventional open posterior lumbar interbody fusion group (Cop-PLIF) as the control for Robot-PLIF. Kim et al. (2015),[24] also with an interventional group that underwent Rom-PLIF, had a Cop-PLIF group for comparison. In turn, Wang et al.,[28] who had minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) as the intervention, described open transforaminal lumbar interbody fusion (TLIF) as the control procedure.

Instrumentation: The use of pedicle screws was reported in all the studies included. It is important to mention that 11 studies[17,19,21,22,28,30–32,34,35,37] refer to instrumentation with percutaneous pedicle screws and 12[18,20,23,24,26–29,33,36–38] refer to pedicle screws. Some of them specify other types of instrumentation used in conjunction with the screws: cage (6 studies),[20,21,28,35–37] rod (1 study),[32] and percutaneous s2Al screws (1 study).[33] Tender et al.[27] reported the use of cage and plate in one of their cases and the use of plate only in another of the cases reported, however, these instruments were used without pedicle screws (which are mentioned only during the revision surgery).

Graft/Implant: Fifteen studies report the use of grafts or implants in the surgical procedures. Among these, only 2 describe the use of implants.[23,34] The other 13 studies report the use of different types of grafts, as shown in Table 1.

Surgical time: Nine studies[18,24,26–28,32,33,35,38] reported surgical time.

Table 1. Summarization of the 21 articles selected for inclusion in the systematic review.

	Source	Level of evidence	# of participants and sex	Mean age (years)	Diagnosis	Intervention	Control Group	Instrumentation	Graft/Implant	Surgical Time (minutes)	Blood loss (ml)	Adverse events	Follow-up (months)
1	Chachan et al. (2019)[17]	4[c]	3 (F)	62	1: Spondylolisthesis and stenosis; 2: Disc herniation; 3: Spondylolisthesis and retrolisthesis with disc protrusion	Microscopic anterior neural lumbar decompression with OLIF	N/A	Percutaneous pedicle screws	Cellular allograft	NR	NR	No	1: 6; 2: 3; 3: 6
2	Kim et al. (2018)[18]	1[a]	37 (F) 41 (M)	40-80	Degenerative spinal disease with lumbar stenosis	Robot PLIF	Freehand PLIF	Pedicle screws	Subproducts of the local lamina and facet joint bone + DBM	Robot-PLIF: 220.1 ± 55.9*; Freehand-PLIF: 189.8 ± 45.1*	NR	Freehand-PLIF: violation by screw and irritation of the nerve root	12
3	Anand et al. (2017)[19]	4[c]	1 (F)	66	Adult spinal deformity	Minimally invasive circumferential protocol	N/A	Percutaneous pedicle screws	Local bone graft, RhBMP-2 and DBM	NR	NR	Abdominal discomfort	24
4	Coe et al. (2016)[20]	4[c]	1 (F)	75	Spondylolisthesis, spinal stenosis, and collapse of the disc space	TLIF	N/A	Cage and pedicle screws	Allograft	NR	100	No	3
5	Maruo et al. (2016)[21]	4[c]	1 (F)	61	Lumbar disc herniation	TLIF	N/A	PEEK cage and percutaneous pedicle screws	Autologous bone graft	NR	300	Hemothorax	0.46
6	Wang et al. (2016)[22]	4[c]	1 (F)	68	Lumbar tuberculosis	Antituberculosis drugs, minimally invasive debridement and XLIF	N/A	Percutaneous pedicle screws	Autologous bone graft	220	500	No	12
7	Dailey et al. (2015)[23]	4[c]	1 (F)	24	Idiopathic scoliosis	Minimally incisional posterior fusion	N/A	Pedicle screws	Implant	NR	NR	Pseudoarthrosis	6
8	Kim et al. (2015)[24]	1[a]	21 (F) 19 (M)	Rom-PLIF: 64.4 ± 11.9; Cop-PLIF: 64.7 ± 8.6	Degenerative listhesis, lytic listhesis, foraminal and central stenosis	Rom-PLIF	Cop-PLIF	Pedicle screws	NR	Rom-PLIF: 217.75 ± 33.9*; Cop-PLIF: 195 ± 46.9*	NR	NR	NR
9	Sarwahi et al. (2015)[25]	4[c]	2 (F)	12.2	Neuromuscular scoliosis	1 – Posterior spinal fusion; 2 – Spinal deformity correction surgery	N/A	Pedicle screws	Allograft and autograft mixed with vancomycin in powder form	1: 300; 2: 420	1: 600; 2: 800	NR	NR
10	Brodano et al. (2014)[26]	4[c]	1 (F)	18	Adolescent idiopathic scoliosis type 1AN (Lenke)	Corrective surgery by minimally invasive fusion	N/A	Posterior pedicle screws	Bone graft from facet joint osteotomy and homologous bank	180	550	NR	12
11	Tender (2014)[27]	4[c]	2 (M)	67	Spondylolisthesis	1: Lumbar fusion; 2: Autonomous lateral lumbar fusion	N/A	1: Cage and plate; 2: Cage	Allograft	1: 60; 2: 45	NR	1: Coronal fracture and collapse of cage in the vertebral body; 2: Coronal fracture and collapsed cage	1: > 18; 2: 12
12	Wang et al. (2014)[28]	2[b]	56 (F) 25 (M)	55,3	Lumbar canal stenosis, spondylolisthesis, or post-laminectomy instability	MIS-TLIF	Open TLIF	MIS-TLIF: PEEK cage and percutaneous pedicle screws; open TLIF: cage and pedicle screws	MIS-TLIF: Autologous bone graft; open TLIF: NR	MIS-TLIF: 127 ± 25**; open TLIF: 168 ± 37**	MIS-TLIF: 274 ± 99; open TLIF: 645 ± 163	MIS-TLIF: 2 cases of dural rupture. Both: one case of non-union	36,1
13	Ntourantonis et al. (2018)[29]	4[c]	1 (F)	76	Vertebral fracture from osteoporosis with invasion of the spinal canal	Less invasive corpectomy and 360^0 fusion	N/A	Pedicle screws	NR	NR	Yes	Postoperative bleeding	0.23
14	Fomekong et al. (2018)[30]	4[c]	1 (M)	60	Spondylodiscoarthrosis	TLIF	N/A	Percutaneous pedicle screws	NR	NR	NR	Ureteral perforation	5
15	Agarwal et al. (2016)[31]	4[d]	3 (F) 4 (M)	29	Thoracolumbar burst fracture	Fixation with percutaneous pedicle screws	N/A	Percutaneous pedicle screws	Graft of corticocancellous bone and DBM	NR	NR	Hemorrhage due to violation by the screw	25.7
16	Suratwala et al. (2016)[32]	4[c]	1 (F)	72	Kyphoscoliosis	DLIF	N/A	Percutaneous pedicle screws and rod fixation	NR	240	150	Acute renal infarction	12
17	Funao et al. (2016)[33]	4[c]	2 (M)	74	Lumbosacral spondylodiscitis	1: MIS; 2: MIS and anterior fusion	N/A	1: Pedicle screws + percutaneous S2AI screws; 2: percutaneous S2AI screws	1: NR; 2: iliac bone graft	1: 188; 2: 178	1: 26; 2: 171	NR	NR

	Source	Level of evidence	# of participants and sex	Mean age (years)	Diagnosis	Intervention	Control Group	Instrumentation	Graft/Implant	Surgical Time (minutes)	Blood loss (ml)	Adverse events	Follow-up (months)
18	Phan et al. (2015)[34]	4c	1 (M)	72	Isthmic spondylolisthesis	Autonomous ALIF	N/A	Percutaneous pedicle screws	ANCHOR-L Implant	NR	60	Fracture across the sacral promontory and listhesis	12
19	Wakita et al. (2015)[35]	4c	1 (M)	80	Severe kyphoscoliosis and gait disorder	OLIF	N/A	Cage and percutaneous pedicle screws	NR	300	378	Reduced muscle strength	3
20	Staub et al. (2015)[36]	4c	1 (M)	51	Achondroplastic dwarfism	Arthrodesis	N/A	Cage and pedicle screws	Lateral graft	NR	NR	No	0.69
21	Chin et al. (2015)[37]	4c	2 (F)	49.5	1: Herniated central nucleus pulposus with annular fissure and disc desiccation; Possible hemilaminectomy defect, herniated nucleus pulposus with severe stenosis, disc collapse, and terminal plate changes	1: Lumbar fusion with percutaneous pedicle screws; 2: Decompression and lumbar fusion with percutaneous pedicle screws (open procedure)	N/A	1: PEEK cage and percutaneous pedicle screws 2: Pedicles	NR	NR	NR	NR	1: NR; 2: 11

Only 2 clinical trials provided this information. Kim et al.,[18] reported a mean surgical time of 220.1 ± 55.9 minutes for the Robot-PLIF group and of 189.8 ± 45.1 minutes for the Freehand-PLIF group. In turn, Kim et al.,[24] reported 217.7 ± 33.9 minutes for the Rom-PLIF group, while the mean time for the Cop-PLIF group was 195 ± 46.9 minutes. The case reports/series had a mean surgical time of 241.6 ± 94.5 minutes for the minimally invasive procedures. One of the studies selected[27] reported mean surgical time for cage and plate procedures, but not for cases related to fusion with pedicle screws.

Blood loss: Eleven studies reported blood loss during the surgical procedures, only one of which was a clinical trial.[28] In this study the authors described mean blood loss of the minimally invasive procedures (274 ± 99 ml) and of the open procedures (645 ± 163 ml) ($p < 0.01$). Ntourantonis et al.,[29] reported blood loss during the surgical procedure in their case report, but did not provide volume information. The mean blood loss for the 9 case reports/series that did report this information was 330.5 ± 255.0 ml.

Complications/adverse events: Among the 21 studies selected, there was an overall complications rate of 57.1% (12 studies – 2 clinical trials and 10 case reports/series), as shown in Table 1. Four studies[17,20,22,36] reported the absence of complications, while five studies[24,26,33,37,38] did not report any information about complications or adverse events.

Reoperation or revision: Five studies[18,24,27,31,34] reported the need for reoperation or revision of the surgical procedure, although only one of these[27] described the procedure. Tender et al., reported 2 cases of patients with degenerative spondylolisthesis, who had undergone lateral lumbar fusion with cage and/or plate. Due to complications related to the surgical procedures, the patients were submitted to a second procedure: the placement of pedicle screws in L4-L5 and S1 and facet joint graft (case 1) and bilateral foraminotomy of L3-L4 followed by instrumented posterolateral fusion of L3-L4 (case 2). Wang et al.,[28] reported the absence of reoperation or revision surgery.

Outcome measurement: Of the 21 studies, only the 3 clinical trials published outcome measurements. Kim et al.,[18] in a study conducted to compare the robot-assisted posterior fusion surgical technique (Robot-PLIF) with conventional posterior fusion (Freehand-PLIF) in patients with degenerative spinal disease through clinical outcomes, used the Visual Analog Scale (or VAS), the Oswestry Disability Index (or ODI), and the SF-36 questionnaire, in addition to radiological evaluation of fusion status (by computed tomography) and flexion/extension and disc degeneration by X-ray, to measure outcomes. Kim et al.,[24] reported using cumulative sum control analysis for quality control monitoring of the accuracy of pedicular screw insertion and computed tomography of the accuracy of screw insertion for quality control monitoring of robot-assisted fixation.

Wang et al.,[28] whose study aimed to evaluate the safety and efficacy of minimally invasive transforaminal lumbar interbody fusion (TLIF) as an alternative technique for overweight or obese patients, used changes in surgical time, blood loss, time of exposure to X-rays, and perioperative complications to measure outcomes. Several of the remaining studies reported scores obtained from the VAS and ODI, however, because they are case reports, the scores are not described as outcome measurements.

Visual Analog Scale (VAS) and Oswestry Disability Index (ODI): Of the 21 studies selected, 6 had VAS information (2 clinical trials[18,28] and 4 case reports[17,22,27,30]) and 9 (2 clinical trials [18,28] and 7 case reports[17,20,22,27,30,34,36]) had ODI information. Both clinical trials reported a mean value for the participants. Kim et al.,[18] evaluated the VAS for back and leg pain in Robot-PLIF and Freehand-PLIF groups during the pre- and postoperative periods and observed no significant differences between the groups in either period. Wang et al.,[28] used the VAS to assess back pain in the minimally invasive and open procedure groups. No statistical difference between the groups was observed. Intergroup analyses were not shown. As for the case reports/series, none of them reported statistical analysis, although a decrease in scores was observed between the pre- and postoperative periods. As regards the ODI in the clinical trials, Kim et al.,[18] evaluated the Robot-PLIF and Freehand-PLIF group scores during pre- and postoperative periods without significant differences between the groups in either period. Wang et al.,[28] assessed the ODI in minimally invasive and open procedure groups. Once again, no statistically significant differences were observed between the groups and no intragroup analysis was shown. None of the case reports/series demonstrated statistical analysis, although a decrease in the scores had been observed between the pre- and postoperative periods.

Follow-up: The mean duration of follow-up, considering 18 studies (3 studies[24,33,38] did not report this information) was 10.1 ± 9.3 months. In the clinical trials the mean duration was 24.1 ± 17.0 months.[18,28] In the cases reports/series this duration was 8.6 ± 7.4 months. Tender et al.,[27] did not report the exact number of months of follow-up ("> 18 months") in one of their 2 cases.

Main conclusions: Table 2 summarizes the main conclusions of the studies included in the systematic review, according to the respective authors. Regarding their clinical trials, Kim et al. (2018)[18] and Kim et al.,[24] reported that minimally invasive techniques can be beneficial to patients. Wang et al.,[28] concluded that minimally invasive fusion is safe and reliable. The case reports/series presented quite specific and very diversified conclusions, making it impossible to group them.

DISCUSSION

The main objective of this systematic review was to gather evidence related to the safety and efficacy of minimally invasive arthrodesis/fusion with percutaneous pedicle screws in the treatment of

Table 2. Main conclusions of the 21 selected studies.

Source	Main conclusions
Kim et al. (2018)[a]	Need for more extensive follow-up, considering that the outcomes did not differ between the groups
Kim et al. (2015)[a]	Adequacy of the quality control for robot-assisted pedicle screw fixation
Wang et al. (2014)[a]	MIS-TLIF is a safe and reliable procedure for the treatment of obese and overweight patients as compared to the open procedure.
Chachan et al. (2019)[b]	Decompression combined with oblique lumbar fusion is feasible and safe.
Anand et al. (2017)[b]	A protocol with various minimally invasive techniques can be safe and effective for adult spinal deformity.
Coe et al. (2016)[b]	The use of a multiexpandible cage allows a less invasive approach with satisfactory short-term clinical results.
Maruo et al. (2016)[b]	First report of hemothorax following MIS-TLIF caused by rod with trocar tip. Attention to the insertion of the rod is necessary at the thoracolumbar levels.
Wang et al. (2016)[b]	Extreme lateral fusion with pedicle screw can be an effective treatment for lumbar tuberculosis in the elderly.
Dailey et al. (2015)[b]	Attention to the possibility of caudal migration after rod fracture.
Sarwahi et al. (2015)[b]	The minimally invasive approach seems to offer benefits to patients with neuromuscular scoliosis.
Brodano et al. (2014)[b]	The minimally invasive approach for the treatment of adolescent idiopathic scoliosis demonstrates deformity correction and advantages, but long-term data is needed.
Tender (2014)[b]	Attention to the caudal vertebral fracture as a potential complication following minimally invasive lumbar fusion.
Ntourantonis et al. (2018)[b]	Attention must be paid to signs of postoperative bleeding and hematomas.
Fomekong et al. (2018)[b]	Attention to ureteral injury, considering its serious consequences.
Suratwala et al. (2016)[b]	In patients with atherosclerosis, the lateral approach to the anterior lumbar spine may induce occlusion of the renal artery and renal infarction.
Funao et al. (2016)[b]	Improvement of the clinical outcomes and percutaneous rigid stabilization of the lumbosacral spine. More in-depth investigations are necessary.
Phan et al. (2015)[b]	Fusion is critical to achieving good functional results in isthmic spondylolisthesis with neurological symptoms.
Wakita et al. (2015)[b]	The use of minimally invasive OLIF demonstrated advantages for the treatment of degenerative kyphoscoliosis in a patient with Parkinson's disease.
Staub et al. (2015)[b]	Apparently safe approach for achondroplastic dwarfism.
Chin et al. (2015)[b]	Highly successful placement of pedicle screws
Agarwal et al. (2016)[c]	Fixation with percutaneous pedicle screws may provide lasting benefits, although more in-depth investigations are necessary.

MIS-TLIF: minimally invasive transforaminal lumbar interbody fusion surgery; OLIF: oblique lateral interbody fusion; [a]: clinical trial; [b]: case report; [c]: case series.

degenerative disc disease (and other pathological spinal conditions) when compared to conventional arthrodesis. A considerable number of studies related to this intervention were identified in the literature (21), although few of the studies reviewed dealt with randomized and controlled clinical trials (2) based on rigorously planned experimental design and, consequently, with more reliable results. Most of the studies included in this review (86%) were case reports and series, studies that present a low level of scientific evidence and are biased by their methodologies. Therefore, the main limitations of the present study are the lack of clinical trials and the small number of articles included with moderate or high levels of evidence.

The conclusions and parameters such as age and follow-up time, for example, are quite different among the case reports, making comparisons and assertive conclusions about the safety and efficacy of the minimally invasive techniques difficult. Among the 18 case reports/series presented in this systematic review, four[26,33,37,38] offered no information about complications or adverse events and only three[17,20,36] reported the absence of these situations. All these factors taken together allow only inferences about the safety and efficacy of the technique and of the instrumentation.

Clinical trials conducted to evaluate minimally invasive techniques suggest that these may be beneficial to patients, but the results presented were not significantly different from those obtained from open procedures or required longer follow-up periods, making it difficult to prove the superiority of one procedure over the other.

Despite the difficulty in demonstrating superiority, the findings regarding minimally invasive techniques indicate a safe and reliable procedure and attribute the inconclusive results to limitations related to study design, follow-up time, and number of participants. Of the three clinical trials selected, only two presented an experimental design that included a control group and a randomization technique.[18,24] The study by Kim et al.,[18] emphasized that a follow-up of more than two years would be necessary to obtain more accurate data. Additionally, the authors argue that many participants did not have access to computed tomography in the postoperative period (only 28 in the minimally invasive group and 25 in the conventional group), a fact that may have influenced the conclusions. Kim et al.,[24] in turn, suggested the differences in instrumentation (screw) used among the groups and the fact that operating time was not included in the performance quality measurement as possible limitations of the study. The third clinical trial selected,[28] although controlled, was not randomized. This study reports only three complications in the group treated with the minimally invasive procedure and one in the conventional procedure group, without the need for repair or surgical revision. The authors concluded, then, that the minimally invasive fusion technique is safe and reliable, but this conclusion was made based on a non-randomized, small, and specific (overweight and obese patients) population. It is worth mentioning, however, that almost all the studies showed that there were no serious adverse effects related to the use of a minimally invasive technique. These findings are corroborated by cohort and prospective studies not considered in this systematic review.

The scarcity of clinical trials with a high level of evidence, verified through the preparation of this systematic review, was also the subject of discussion of Park et al.,[39] in a meta-analysis that included nine prospective cohort studies published up until December 2017, involving the comparison between minimally invasive lumbar fusion and the conventional technique. The results found in this study show that minimally invasive lumbar fusion techniques are more effective than open techniques in the treatment of spondylolisthesis in terms of improving function and reducing rates of infection, blood loss, and hospitalization time. However, there was no significant difference in parameters such as pain improvement, fusion rates, complications, or need for subsequent surgeries. In contrast, the prospective study by Giorgi et al.,[40] which involved 66 participants and a two-year follow-up, reported satisfactory results obtained from the minimally invasive technique (fusion rate of 96.8% in radiographic analyses), with a low rate of postoperative complications (6.1%), demonstrating the need to conduct more robust studies to obtain significant and reliable results.

CONCLUSIONS

Although the level of evidence of most of the studies included makes it difficult to demonstrate efficacy and superiority among the surgical techniques reviewed, the findings around the minimally invasive procedure indicate a safe and reliable approach for the treatment of lumbar diseases. Many of the studies with lower levels of evidence present favorable results and add information to our understanding of the application of the technique and the instrumentation in rare and critical cases of lumbar disorders, while clinical trials, prospective studies and cohort studies may be more indicated and more reliable for the purpose of determining the best approach to choose for each patient in more generalized populations.

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