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Review

Preservation of the Posterior Interspinous Ligamentary Complex in Posterior and Transforaminal Lumbar Interbody Fusion

Renato Gondar [1,2], Christopher Marvin Jesse [1,*], Ralph T. Schär [1], Jens Fichtner [1,3], Christian Fung [1,4], Andreas Raabe [1] and Christian T. Ulrich [1,5]

1 Department of Neurosurgery, Inselspital, Bern University Hospital, University of Bern, 3010 Bern, Switzerland; neuroetdos.gondar@hin.ch (R.G.)
2 Department of Neurosurgery, Geneva University Hospitals, University of Geneva, 1205 Geneva, Switzerland
3 Cantonal Medical Service, Department of Health of the Canton of Bern, 3027 Bern, Switzerland
4 Department of Neurosurgery, Freiburg University Hospital, University of Freiburg, 79085 Freiburg, Germany
5 Neurosurgery, Lindenhof Hospital, 3001 Bern, Switzerland
* Correspondence: christophermarvin.jesse@insel.ch; Tel.: +41-31-632-24-09; Fax: +41-31-632-0432

Abstract: Posterior and transforaminal lumbar interbody fusion (PLIF and TLIF) allow some variation between surgeons, particularly regarding the extent of resection of the posterior interspinous ligamentary complex (PILC) with uncertain implications for outcome. The aim of this study was to assess the importance of preserving the PILC when performing PLIF or TLIF. Systematic review of clinical outcomes (adjacent segment degeneration (ASDG), fusion rate, reoperation rate, and visual analog scale (VAS) scores for back and leg pain) after PLIF/TLIF matched for integrity of PILC, Oswestry Disability Index (ODI) score, and radiological parameters. A total of 191 patients from 2 studies (1 prospective randomized control trial (RCT) and 1 retrospective observational cohort study) were identified. 102 (53.4%) had fusion (PLIF/TLIF) with preserved PILC. All 120 patients in the RCT underwent a L4–L5 single-level fusion, while the 71 patients in the retrospective cohort underwent surgery between T11 and S1. In the retrospective cohort study, significant differences between groups in mean number of fixed levels (4.8 ± 1.0 vs. 4.2 ± 0.5), decompressed levels (2.4 ± 0.7 vs. 3.0 ± 0.7), and interbody fusions (1.2 ± 0.9 vs. 2.0 ± 1.0) were reported. In each of the studies, all groups reported an improved ODI score at 3 months after surgery and at last follow-up. In each of the studies, the incidence of radiographic ASDG was significantly higher for the PILC resection group in both studies (9.0% vs. 43.0%, $p < 0.01$ and 23.0% vs. 49.0%, $p = 0.042$). Lumbar lordosis (which decreased after PILC resection in the RCT, $p < 0.05$) also differed between groups. Taken as a whole, these results suggest that preservation of the PILC during PLIF/TLIF surgery prevents future ASDG and loss of lumbar lordosis as well as the potential clinical consequences of these changes. Further prospective studies are needed.

Keywords: PLIF; TLIF; adjacent segment disease; outcomes; posterior tension band; posterior complex

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1. Introduction

Briggs and Milligan [1], and later Cloward [2] in 1954, pioneered posterior lumbar interbody fusion (PLIF). Harms and Jeszenszky [3] were the first to describe the transforaminal lumbar interbody fusion (TLIF) technique in 1998. These spinal fusion techniques are now the most popular surgical approaches for conditions requiring lumbar fusion [4,5].

One advantage of TLIF compared to PLIF is that the former can be accomplished without exposing more than the ipsilateral foramen. By removing the entire facet joint, it minimizes retraction on the thecal sac, thereby decreasing the risk of accidental durotomy and neurological injury. Even so, the extent of invasiveness varies between a minimally invasive approach (MIS-TLIF) [6] with a unilateral facetectomy and preservation of the midline ligaments as well as contralateral support, and an open approach (O-TLIF) [6]. O-TLIF can be performed either through a laminectomy (implying spinosectomy and posterior tension band disruption) or selective laminotomy and facetectomy, which allows preservation of midline and contralateral support despite bilateral muscle dissection. Nevertheless, total bilateral laminectomies are still broadly described for O-TLIFs, which can be justified as an attempt to decrease surgery time as well to better decompress bilaterally the dural sac or may even be essential in cases of spondylolytic spondylolisthesis.

There is a large body of literature comparing TLIF with PLIF and MIS-TLIF with O-TLIF techniques [5,6], but little specific information is available comparing preservation of the posterior ligamentary complex (PILC) (comprising the spinous process, the interspinous ligament, and the supraspinous ligament) following each of these techniques (Figures 1 and 2).

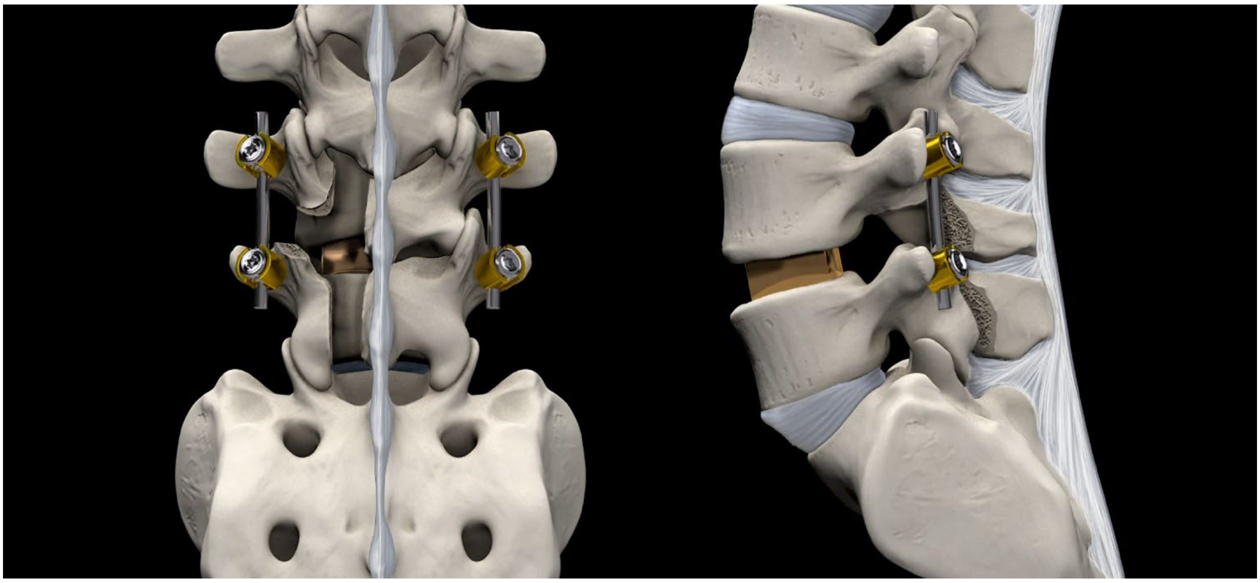

Figure 1. Schematic representation of a L4–L5 left-sided TLIF procedure with placement of four pedicular screws and two titanium rods, selective arthrotomy and hemilaminectomy of L4 and L5 and preservation of the PILC disruption.

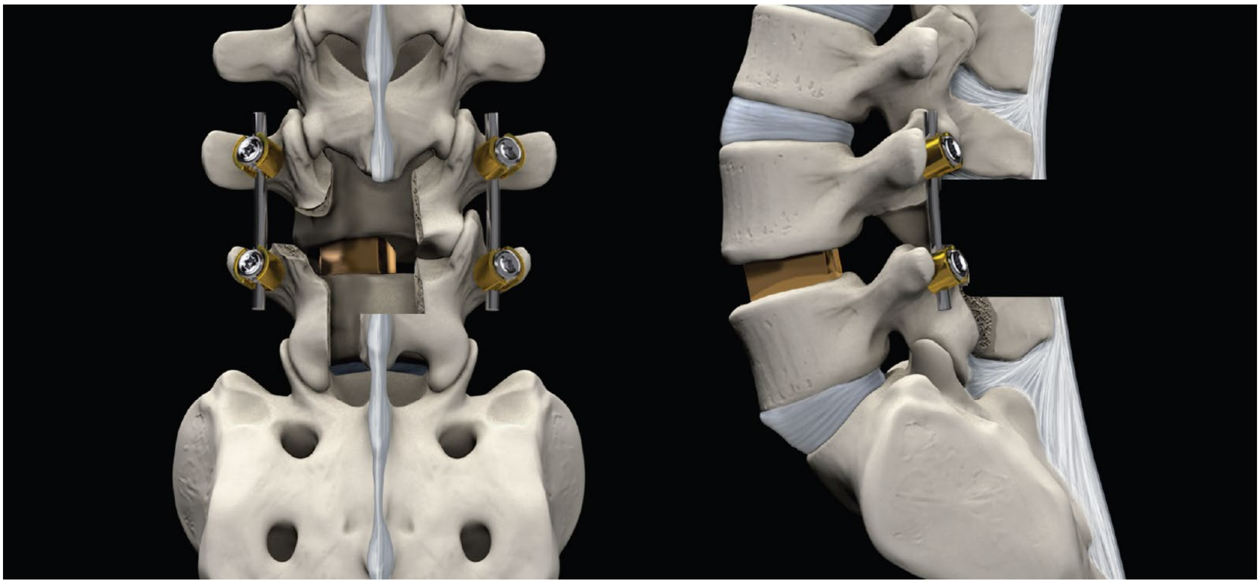

Figure 2. Schematic drawing of a L4–L5 left-sided TLIF with placement of four pedicular screws and two rods, almost complete laminectomy of L4 and partially L5, ablation of the spinous processes and PILC disruption.

Adjacent segment degeneration (ASDG), which is defined as radiological asymptomatic changes following arthrodesis, is reported to occur in up to 57% of patients [7–11]. Adjacent segment disease (ASD) is the symptomatic manifestation of ASDG and presents a risk between 1.9% and 30.3% after previous fusion [7–10]. Both have known risk factors such as many-level fusions, previous ASDG, facet joint sagittalization, laminar inclination, abnormal sagittal alignment, and older age [7–12]. Theoretically, the disruption of the PILC (Figure 2) could lead to a threefold increase in the risk of ASD (Lai et al.) [7]. Laminectomy of the level adjacent to the spinal fusion may increase the need for revision surgery about 2.4 times (Sears et al.) [13]. If the PILC is important for lumbar spine stability, as seen in traumatic cases, and this stability or alignment correlates to ASDG [9,10], this suggests a further correlation between PILC preservation and ASDG. Furthermore, biomechanical evidence, mostly from the cervical spine, shows that the interspinous ligament, the supraspinous ligament, and the surrounding muscles act as a tension band in an intact spine [14–18], especially during flexion (Figures 1 and 2).

We conducted a systematic review on the effect of preservation of PILC during PLIF and TLIF procedures, on clinical and radiological outcomes.

2. Methods

2.1. Search Strategy and Study Selection

This study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA-P) 2015 guidelines [19]. The review was not registered in Prospero because of the following: registration is not mandatory for review studies, even though it can be a good way of avoiding duplicates; Prospero receives funding from the United Kingdom (UK) National Institute for Health Research (NIHR), thus raising two other concerns: prioritization of registrations from the UK and a risk of discontinuation if those public funds need to be redirected.

We performed an extensive search using the keywords ('lumbar interbody fusion' OR 'TLIF' OR 'PLIF') AND ('posterior complex' OR 'tension band' OR 'adjacent segment' OR 'technique' OR 'outcome') on 15 August 2021. The following databases were searched: Embase, Cochrane Library, Medline, Google Scholar, and Web of Science, resulting in a list of 5293 references.

After reading the title and the abstract, the references list was scanned to identify additional potentially relevant studies. Two reviewers (RG and MJ) independently screened the titles and abstracts of all the publications identified, and full-text copies of all relevant articles were obtained. In the case of disagreement on the relevance of an article to the study, a third author (CU) arbitrated until consensus was reached among all authors.

The inclusion criteria were: (1) a randomized controlled trial (RCT) or retrospective comparative study design (cohort or case control) that compared PLIF and TLIF with and without posterior complex resection in the treatment of lumbar disease; (2) provision of at least one of the following outcome measurements: ASDG, ASD, fusion rate, pseudarthrosis, complications, operation time, sagittal balance parameters, Oswestry disability index (ODI), and visual analog scale (VAS) or numeric rating scale; (3) studies written in English, French, German, or Portuguese. Articles that did not meet the inclusion criteria were excluded. Editorials, letters, review articles, case reports, finite element, and animal experimental studies were also excluded.

2.2. Risk of Bias and Quality of Study

Following our PRISMA protocol (Figure 3), only 2 articles met all the inclusion criteria. The selected RCT scored 5 out of 5 applying the Jadad scale (high quality rating) [20] and the observational study scored 7 out of 9 stars according to the Newcastle–Ottawa Quality Assessment Scale for quality assessment [21] of non-randomized studies.

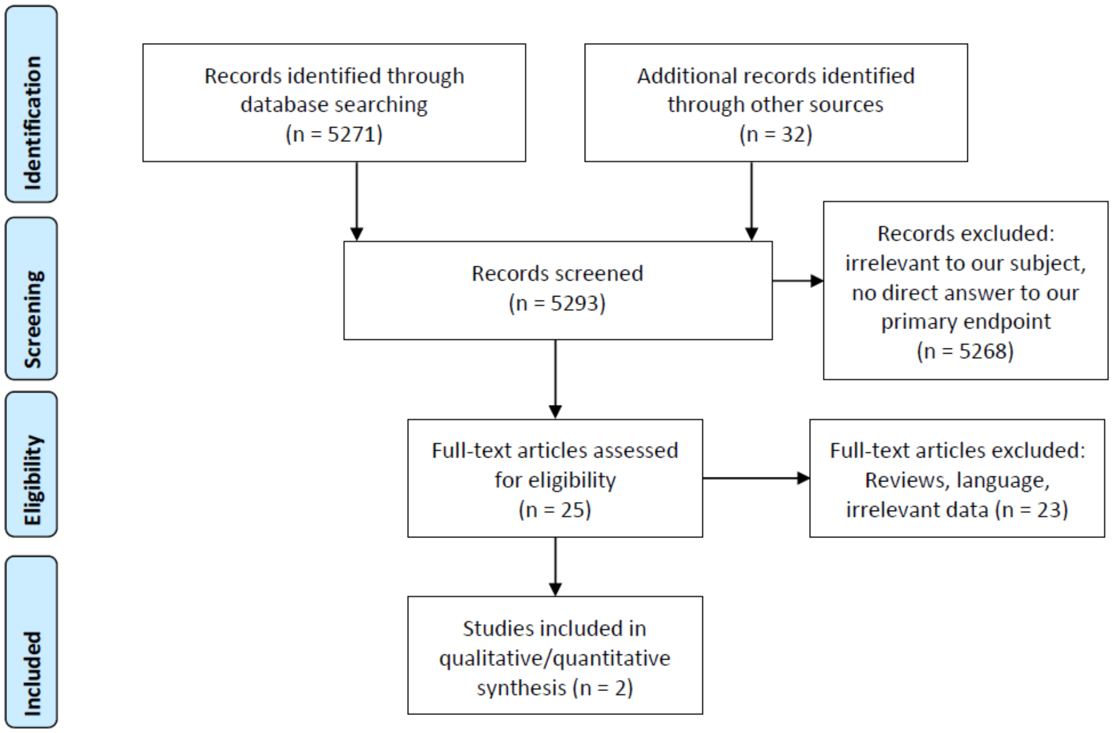

Figure 3. PRISMA-P flow chart and search strategy.

The level of evidence for each study was evaluated using the Oxford Centre for Evidence Based Medicine guidelines [22].

2.3. Data Collection

The following items were considered: (1) study design (author, year, country, prospective study or retrospective study); (2) patient characteristics; (3) surgical procedure; (4) sample size; (5) levels of fusion; (6) type of fusion; (7) technique, whether or not PILC was preserved; (8) duration of follow-up; (9) patient-related outcome measurements (PROMs), considering disability, ODI, and Japanese Orthopedic Association (JOA) and VAS pain scores; (10) fusion rates and incidence of ASD, pseudarthrosis, sagittal/coronal imbalance, and (11) parameters related to intra- and postoperative complications (such as blood loss and duration of surgery).

2.4. Statistical Analysis

Results of continuous variables are reported as mean ± standard deviation (SD). When these measures were not reported, we estimated them using the mean and SD according to the methodology described by Hozo et al. [23]. If the range is reported as 'a' to 'b', the median is reported as 'm', the sample size is 'n', then an estimate of the mean value was calculated as follows: mean = (a + 2m + b)/4. SD was calculated using the following formula: $S^2 = [(n+1)/48n(n-1)^2] \times [(n^2+3)(a-2m+b)^2 + 4n^2(b-a)^2]$.

Categorical variables are presented as median and quartiles or by absolute and relative frequencies.

3. Results

3.1. Search Results and Relevant Data Reported in Included Articles

With the initial keyword search strategy, we identified 5293 articles (Figure 3). After abstract screening, only 25 were read to assess final eligibility. After the full manuscripts were read, only two were selected for inclusion [24,25]. The remaining 23 articles, despite mentioning our main question in the introduction or discussion, did not focus on this aspect nor did they present any relevant results. Thus, they did not meet inclusion criteria (1) and (2).

One RCT [24] and one retrospective observational cohort study [25] were the only ones that satisfied all the inclusion criteria. The main purpose of the RCT [24] was to investigate the effect of the PILC on instability of the adjacent segment after lumbar instrumentation and the development of ASD. Three patient groups were described, each comprising 40 subjects undergoing only facet joint resection and fusion (TLIF), selective laminotomy and fusion (L+TLIF) (Figure 1), or complete laminectomy and fusion (CL+TLIF) (Figure 2). All fusions were approached via instrumented TLIF (pedicle screws) plus posterolateral fusion (PLF). In the observational cohort study [25], the patients were divided between those who underwent an instrumented PLIF (pedicle screws) with PLF and preservation of the PILC (n = 22) (PLIF) and those who underwent the same fusion but with resection of the PILC (n = 49) (L+PLIF). The main purpose of this study was to clarify the risk factors for upper ASD after multi-level posterior lumbar spinal fusion.

Tables 1–3 summarize the variables, patient characteristics, and a selection of results reported in each of the studies.

Table 1. Summary of some features of the two studies.

Author, Year	Design Type	Number of Patients		Mean Age (Years)	Fusion Levels (Range/Mean)	Intervention	Follow-Up Time (Years)	ASDG (A vs. B)	Other Sagittal Parameters
		No Injury to PILC (A)	Injured PILC (B)						
Liu, 2013 [24]	Prospective RCT	80	40	58	L4–L5/1	TLIF with PLF	6	7 vs. 17 (p < 0.01)	>Loss of LL in group B (p < 0.05)
Ma, 2019 [25]	Retrospective observa-tional	22	49	62	T11–S1/1.8	PLIF with PLF	3	5 vs. 24 (p = 0.042)	>PI in group B (p = 0.042)

ASDG = adjacent segment degeneration; PILC = posterior ligamentary complex; PI = pelvic incidence; LL = lumbar lordosis; PLF = postero-lateral interbody fusion; PLIF = posterior lumbar interbody fusion; RCT = randomized controlled trial; TLIF = transforaminal lumbar interbody fusion.

Table 2. Summary of most relevant data from the RCT [24].

Characteristic	TLIF Group (PILC Preserved)	L+TLIF Group (PILC Preserved)	CL+TLIF Group (PILC Injured)	p Value
Surgical technique	TLIF with PLF	TLIF with PLF	TLIF with PLF	
Number of patients	40	40	40	
Mean age of patients (y)	58	58	58	
Women:men ratio	3	3	3	
Fusion level	L4-L5	L4-L5	L4-L5	
Follow-up (y)	6	6	6	
Number of patients with ASDG	3	4	17	0.01

Table 3. Summary of most relevant data from the retrospective cohort [25].

Characteristic	PLIF Group (PILC Preserved)	L+PLIF Group (PILC Pesected)	p Value
Surgical technique	PLIF with PLF	PLIF with PLF	
Number of patients	22	49	
Mean age of patients (y)	60.6 ± 9.0	63.0 ± 8.6	0.294
Women:men ratio	11:11	26:23	0.811
Fusion levels	T11-S1	T12-S1	
Follow-up (y)	3	3	
Number of patients with ASDG	5	24	0.042

A meta-analysis was judged to be inappropriate given the heterogeneity between study populations and variables and the small number of articles.

3.2. Demographic Results

Degenerative stenosis and herniations were reported to be the main reason for performing surgery.

The RCT [24] had better separation between groups and less heterogeneity: all 120 patients were operated on only at the L4–L5 level (single-level fusion). The observational cohort study [25] included patients operated on between T11 and S1. Its authors described significant differences between the PLIF and L+PLIF groups concerning the mean of fused levels (4.8 ± 1.0 vs. 4.2 ± 0.5), decompressed levels (2.4 ± 0.7 vs. 3.0 ± 0.7), and interbody fusions (1.2 ± 0.9 vs. 2.0 ± 1.0).

In each of the studies, pre-operative evaluations found no significant differences in mean ODI score and mean JOA score between the groups (with or without preservation of the PILC).

3.3. Surgical Parameters and Complications

Neither study reported the incidence of complications, duration of surgery, or amount of blood loss.

3.4. Clinical and Radiological Outcomes

In each of the studies [24,25], all patient groups had an improved JOA score at 3 months after surgery and at last follow-up, with no statistical differences between groups. However, Liu et al. [24] reported that the JOA score in the CL+TLIF (more aggressive) group at the last follow-up (5.9 years) was lower than in the other two groups, and this difference was statistically significant. Also, the ODI improved for all groups (with or without preservation of the PILC) in the retrospective cohort study [25].

The retrospective study [25] measured pre- and postoperative lumbar lordosis (LL), sacral slope (SS), pelvic incidence (PI), pelvic tilt (PT), and coronal Cobb angle, whereas the RCT compared LL, proximal adjacent disc (L3–L4) height and respective angle, range of motion (ROM), listhesis, and L4–L5 disc height.

A difference in the criteria for defining postoperative ASDG was also observed. In the retrospective cohort study [25], ASDG was defined as a disc height reduction of more than 20% and progressive spondylolisthesis or osteophyte formation greater than 3 mm on lateral radiographs. According to these criteria, 5 (22.7%) cases of ASDG were identified in the PLIF group and 24 (49.0%) in the L+PLIF group at the 3-year follow-up. The rate of radiographic ASDG was significantly higher for the PILC resection (L+PLIF) group (p = 0.042, Pearson's chi-square test). On the other hand, in the RCT [24], ASDG was defined as a disc height reduction and spondylolisthesis progression greater than 3 mm together with a dynamic intervertebral space ROM greater than 10°. Twenty-four patients showed all those signs of ASDG after the operation. Three cases of ASDG occurred in the TLIF group (7.5%), four in the L+TLIF group (10.0%), and seventeen in the CL+TLIF group (42.5%). The percentage of ASDG was significantly different for this last group without sparing of the PILC ($p < 0.01$). The combined results of the two studies give an incidence of ASDG of 27.7% with only seven patients (3.7%) from the CL+TLIF group having benefited from a reoperation after a symptomatic ASD.

Apart from the pre-operative PI (higher in the group that underwent more destructive L+PLIF, p = 0.042), none of the other sagittal balance parameters measured showed any statistically significant differences between groups according to Ma et al. [25]. The Cox proportional hazards model pointed to the following as risk factors for ASDG: upper disc of proximal instrumented vertebrae with a modified Pfirmann grade > 3 degeneration, a high degree of PI preoperatively, and more decompressed levels.

In parallel, according to Liu et al. [24], all measured parameters at the proximal adjacent segment (L3–L4) in the PILC more invasive group showed a trend towards an

ASDG phenomenon. Mean proximal adjacent disc height decreased whereas intervertebral disc angle, dynamic intervertebral angular ROM, and listhesis increased significantly in the more destructive CL+TLIF group. LL also decreased significantly in the group that underwent more invasive treatment (CL+TLIF) [24].

4. Discussion

4.1. Summary of Evidence

This systematic review of the literature focused on preservation of PILC and outcome of PLIF/TLIF and revealed several interesting features (Tables 1–3). First, although many series have been published describing and comparing MIS-TLIF with open techniques, PLIF versus TLIF or, more recently, posterior versus anterolateral approaches in terms of clinical and radiological outcomes, feasibility, and ASD [5], few of them targeted the importance of PILC preservation and subsequent outcomes. Thus, damage to the PILC could be underreported and underestimated. Second, the definition of ASD and ASDG lacks uniformity. Third, the authors [24,25] concluded that ASDG occurs more frequently after disrupting the PILC. Fourth, sagittal balance parameters were poorly reported, preventing discussion of a possible correlation between PILC preservation and sagittal alignment.

Technical and methodological differences between the reviewed studies precluded a meta-analysis or a stronger causality between PILC anatomy and lumbar spine balance.

The reviewed studies [24,25] had different levels of evidence. The RCT [24] had a clear structure and design, focusing on only one lumbar level (L4–L5) at the apex of the lordosis, which made the sample more homogeneous. Also, the progression of anatomical destruction through three groups from simple facet joint resection to complete laminectomy was well conceived to highlight the importance of the PILC as a distinctive element. However, not all patients received follow-up MRIs and the follow-up time was short (6 years). The retrospective observational cohort study [25] analyzed patients with multilevel degenerative thoraco-lumbar pathologies (at least three or more levels). This heterogeneity hampers interpretation of postoperative sagittal and coronal mechanical behavior and compensation mechanisms (and subsequent ASD). Furthermore, duration of follow-up was very short (3 years) and not all patients had subsequent CT or MRI, leading to the possibility that ASDG was underdiagnosed. Also, use of the PLIF technique probably allowed some sparing of the facet joints, which could impact these results.

Despite these limitations, both studies reported a significantly increased rate of ASDG in patients who underwent a posterior fusion involving destruction of the PILC. The RCT [24] also pointed to a significant loss of LL in the same group of patients, implying negative changes in sagittal balance after PILC resection (kyphosis as seen in the cervical spine). It remains unclear whether the lack of evidence connecting ASD to PILC injury is due to the short follow-up time (3–6 years), which allows the classical compensatory mechanisms to act against the onset of such symptoms.

4.2. Biomechanical Considerations and Future Perspectives on ASD Pathophysiology

Lumbar fusion offers several mechanical advantages through restoration and maintenance of disc height and secondarily of LL5 [26–28], while strengthening the anterior column and its load-bearing capacity. Despite the anterior column fusion (even together with PLF), the lumbar spine is still vulnerable to mechanical forces at the adjacent segments and should be accompanied by careful preservation of the posterior ligament's anatomy to decrease the risk of ASD [29,30]. The PILC remains the main stabilizing element during flexion of the lumbar spine during physiological motion and, therefore, the removal of the posterior complex eliminates the tension band effect in the flexion motion and accelerates ASD [29–31].

Huang et al. [32] stated that ROM during flexion movements at the proximal adjacent level increased by 24.7% for the PILC disruptive method model and by 4.3% for the PILC preservation model during a finite element analysis. Other cadaveric studies also demonstrated a motion transfer after fusion; in other words, the loss of segmental ROM because of instrumentation is compensated with an increased ROM in flexion at adjacent levels, even though the differential remains higher in models with PILC disruption [32,33]. Also, intradiscal pressure showed a higher increase in PILC disruptive models [31].

From a clinical standpoint, preservation of the PILC allows resuture of the lumbar dorsal fascia to the supra-spinous and inter-spinous ligaments, these latest acting as important bony anchors to the paraspinal muscles which are also stabilizing elements themselves [7,9,18,32]. Thus, the paraspinal muscles work synergistically for better spinal stabilization.

It is also of note that a good muscular attachment to bone, with less disruptive forces, is less likely to cause chronic soft tissue injury, facet joint degeneration, as well as hypertrophy of the facet joints and ASD [7,18,32].

Many other patient- and surgery-related factors have been associated with the development of ASD [7–16,26–29]. These include presurgical degeneration of the adjacent segment disc or listhesis, violation of the superior facet joint capsule by screw insertion or Bovie cautery preparation, multi-level fusion, facet joint sagittalization, laminar inclination, stiffness of the fusion, older age (>50 years), and abnormal sagittal alignment [25–28]. In this context, Di Martino et al. [34] highlighted the importance of a high SS (>39°) and a low PT (<21°) in preventing ASD. Similarly, Rothenfluh et al. [33] correlated a high PI and diminished LL with ASDG.

Lai et al. [7] reported a threefold increase in risk for ASD after disruption of the PILC. Wai et al. [9] also reported less ASD after anterior fusion surgeries, preserving the posterior structures. Sears et al. [13] found that laminectomy of the level adjacent to the spinal fusion increased the rate of revision surgery by 2.4 times. Recent results of in vitro finite element analysis supported these findings [35,36]. In a porcine model, Chen et al. [37] compared PLF with total laminectomy with PLF plus hemilaminectomy, and Huang et al. [32] reported a finite element analysis comparing PLIF with laminectomy to PLIF with hemilaminectomy. Both studies concluded that preserving the PILC delays the onset of ASD and results in less ROM and degeneration of the proximal adjacent segment.

One last technical detail also seems to be underestimated. It concerns the implant position during TLIF procedures as these can vary between 'banana' shaped cages that are ideally positioned in the anterior third of the disc, the same cages placed in the mid-third or straight cages, with or without the ability to expand, and placed in an oblique fashion and covering around two thirds of the antero-posterior disc diameter. The implant position might also result in different effects on load sharing in the sagittal plane and on overall construct stiffness. Cadaveric experiments by Sim et al. [35] suggest that TLIF implants positioned anteriorly appear to provide more stability than the posteriorly placed ones. Though, it is also important to express the variability of techniques among surgeons, with most adding bone graft anterior to the posteriorly placed TLIF implant, which may provide additional stability anyway, therefore confounding further interpretations.

Despite all the evidence, correlating ASDG with subsequent ASD remains a challenge.

4.3. Limitations

No data were found on PILC preservation and duration of surgery, complications, or fusion rates. The available data were also limited in terms of PROMs analysis. Also, the follow-up time was short, which probably influenced the absolute mean ASD incidence in the study cohorts [24,25]. It is emphasized that only two relevant studies met all the inclusion criteria used in our work. Therefore, firm conclusions on differences in clinical measures and outcomes cannot be drawn.

The heterogeneity between the two reviewed studies made a meta-analysis impossible, thus limiting our results to a systematic interpretation and narrative point of view. An example of this heterogeneity is the different criteria used to define ASD between the two reviewed studies, the levels having benefited from surgery, as we all know that ROM and average lordosis varies between L1 and S1, or even the number of levels included in the fusion procedure. This last can influence the segmental rigidity that is directly proportional to the magnitude of the fusion.

In each of the aforementioned studies, there is mixture of the type of statistical methods used for test of significance of difference (the Student *t*-test, Mann–Whitney test, chi-squared test). The Student *t*-test is a parametric test whereas the Mann–Whitney and chi-square tests are non-parametric tests. It should be noted that, unless a test of normality of each of populations (study group results) to be compared is performed first, only non-parametric tests should be used because this type of test does not require that each of the study populations be normally distributed.

5. Conclusions and Recommendations for Future Research

Herein we presented the first systematic review of studies that investigated the effect of preserving the PILC during posterior thoraco-lumbar fusion on surgical outcomes. Although the level of evidence is limited, mostly because of the heterogeneity and retrospective nature of one of the two reviewed studies, some important trends were identified, and recommendations made.

It appears that the incidence of ASDG and ASD is higher in patients who underwent PLIF or TLIF with complete laminectomy and disruption of the PILC. Also, LL decreased more often after loss of the same ligamentary structures. We therefore recommend, whenever possible, to preserve these posterior ligaments even in cases of additional instrumentation while trying to achieve an effective decompression. This should minimize the risk of future ASD and reduce the need for reoperation.

Further research is needed to correlate radiographic ASDG with ASD. We propose new comparative studies to better define the operative technique. These should specify the extent of resection of the PILC as well as extensive evaluation of PROMs (clinical scores and radiological sagittal balance parameters), together with a longer follow-up period.

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