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Radiological and Clinical Outcomes of Transforaminal vs. Posterior Lumbar Interbody Fusions: A Systematic Review

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ABSTRACT

AIM: To compare 1 and 2 level posterior lumbar interbody fusion (PLIF) to transforaminal lumbar interbody fusion (TLIF) techniques in an effort to elucidate trends in overall radiological and clinical outcome, rate of complications, operation time, length of hospital stay, reoperation rate, pseudoarthrosis or failure rate, and estimated blood loss.

MATERIAL and METHODS: Online databases including Scopus, Science Direct, Clinical key, Ovid, Embase, and PubMed/Medline were queried over the period encompassing January 2000 to August 2021 for suitable studies. Search criteria consisted of ("TLIF" AND "PLIF") OR ("Transforaminal Lumbar interbody fusion" AND "Posterior lumbar interbody fusion") AND ("comparative" OR "comparison") OR ("fusion" OR "outcome" Or "reoperation" OR "Failure rate" OR "Failure" OR "Complication rate" OR "Complication").

RESULTS: Fourteen eligible studies were selected. Neurological deficits were considerably higher in the PLIF group (24%vs.10%). The mean operation time and estimated blood loss for PLIF and TLIF were 178.5 min and 515 ml; and 160 min and 405 ml, respectively. No significant difference was found regarding the fusion rate. The reoperation rate was greater in PLIF (2%) than TLIF (0%). No clear difference was found regarding the length of stay (LOS) and surgical site infection (SSI).

CONCLUSION: The superiority of TLIF over PLIF may be evidenced by the lower rate of neurologic deficit, surgical technical aspects, less blood loss and shorter operation time. Cage migration, screw displacement, infection, and pseudoarthrosis may be influenced by a variety of factors, including the facility, the surgeon, and the instrumentation/ graft used, and do not appear to be different. Multicenter non-randomized prospective trials are recommended to determine the possible superiority of one method over the other.

KEYWORDS: Transforaminal lumbar interbody fusion, Posterior lumbar interbody fusion, Complications, Fusion rate, Outcome

ABBREVIATIONS: BMI: Body mass index, **BMP:** Bone morphogenetic protein, **DBM:** Demineralized bone matrix, **EBL:** Estimated blood loss, **JOA:** Japanese orthopedic association, **LOS:** Length of stay, **ODI:** Oswestry disability index, **PLIF:** Posterior lumbar interbody fusion, **PRISMA:** Preferred reporting items for systematic reviews and meta-analyses, **rhBMP-2:** Recombinant bone morphogenetic protein-2, **SSI:** Surgical site infection, **TLIF:** Transforaminal lumbar interbody fusion, **VAS:** visual analogue scale

INTRODUCTION

Spinal fusion was introduced in 1911 by two independent surgeons, Albee & Hibbs (2,14). The surgical method introduced by these two pioneering surgeons was mostly dependent on autograft bone and harvesting techniques. Over the ensuing decades, the use of metallic spinal implants and graft options gradually evolved, leading ultimately to the development of the myriad options available today. In recent years, genetically engineered growth factors, such as bone

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morphogenetic proteins (Infuse™, rhBMP-2, Medtronic, Minneapolis, MN, USA) have revolutionized the concept of spinal fusion, with a dramatically increased rate of radiological fusion (25).

Transforaminal lumbar interbody fusion (TLIF) and posterior lumbar interbody fusion (PLIF) are the two most common inter-vertebral fusion techniques used during lumbar spinal fusion surgeries. The potential indications for both PLIF and TLIF include degenerated disks with marked instability, broad-based and recurrent disk herniation, pseudarthrosis in the absence of epidural scarring, back pain as a result of symptomatic degenerative disk disease and/or symptomatic spondylosis, and deformity correction including scoliosis or kyphosis.

Posterior lumbar interbody fusion (PLIF) was first described in 1943 by Briggs and Milligan, (6) and subsequently modified by Clowardin in 1953 (8). TLIF is a more recent modification on the same basic technique, being introduced in the 1990s. It was recognized that PLIF carried a greater incidence of retraction injury, particularly at more cephalad levels, and working in Kambin's Triangle has the advantage of less retraction on the nerve root and thecal sac, owing to its more lateral trajectory into the disk space. It is generally accepted that the radiological fusion and clinical improvement are the two main indicators of a successful fusion surgery (13). It is also argued that radiological pseudarthrosis may be seen in the presence of clinical improvement.

TLIF may be considered to be a less invasive technique, particularly if approached through a paramedian exposure, with associated decreases in the estimated blood loss (EBL), operative time, length of stay (LOS), and dural tearing rate.

Overall, no significant difference has been found between the surgical outcome of TLIF and PLIF (3), although the results for the fusion rate for PLIF vs. TLIF have been discordant in previous studies, and some variation in complication rate has been reported, such as bone chip extrusion following TLIF than PLIF (23).

Herein, we present a systematic review to compare PLIF vs. TLIF concerning the most conflicting results in the literature.

MATERIAL and METHODS

The English language literature was queried using Search engines including Scopus, Science Direct, Clinical key, Ovid, Embase, and PubMed/Medline from the period spanning January 2000 until August 2021, using the following key words:"TLIF", "PLIF", "comparative", "fusion", "outcome", "Transforaminal Lumbar interbody fusion", "Posterior lumbar interbody fusion". Review articles, abstracts, case reports, and studies of minimally invasive techniques were excluded. A total of 193 articles were resulted initially, of which 14 studies were felt suitable for inclusion based on our exclusion criteria (Figure 1). A systematic review was then conducted on the most inconsistent results in the literature, including the oper-

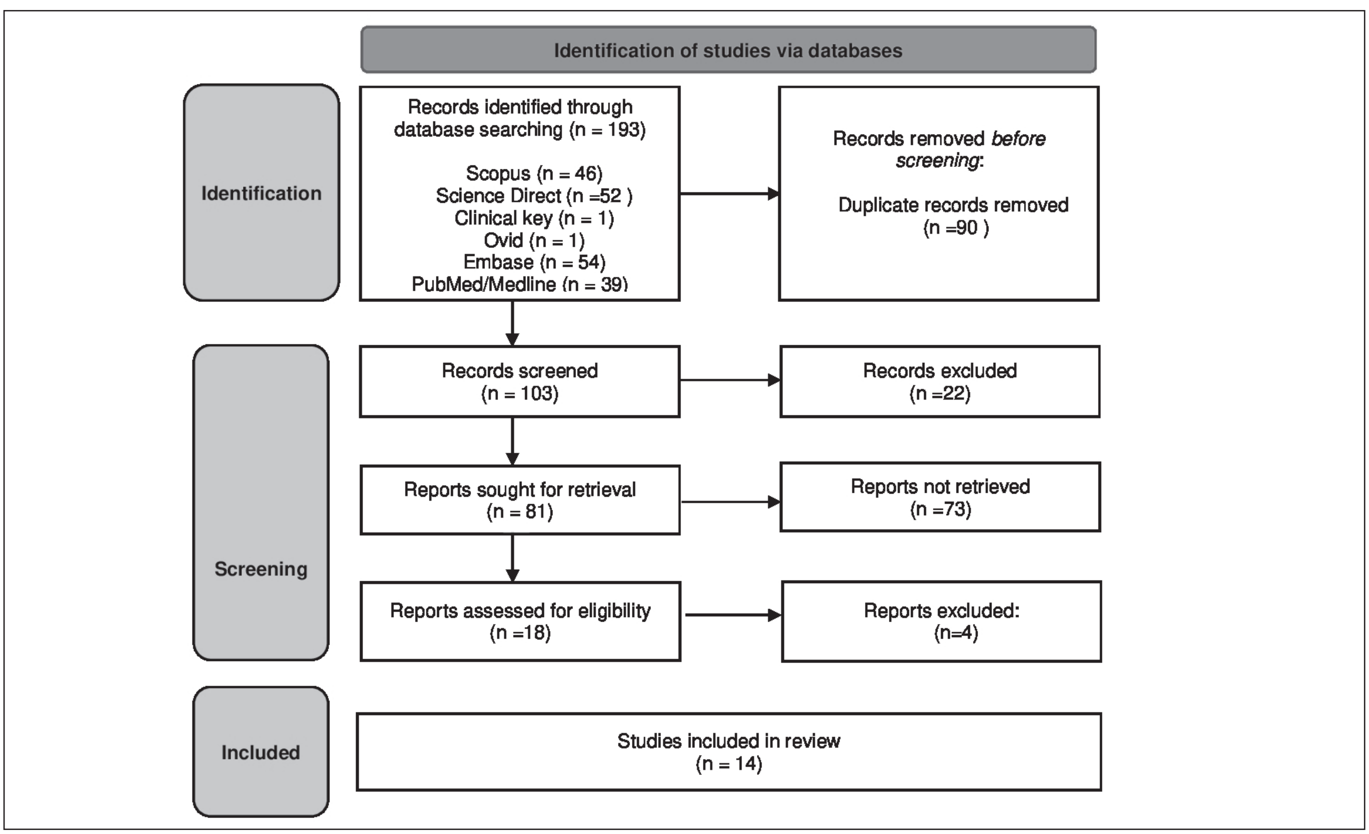

Figure 1: The PRISMA flowchart for the systematic review.

ation time, estimated blood loss (EBL), length of stay (LOS), complications of all types, need for revision surgery, surgical site infection, pseudarthrosis rate, post-operative symptoms improvement, and early or late failure rate of all etiologies.

RESULTS

Fourteen papers were extracted from the literature based on the exclusion criteria of this systematic review. From the included articles, thirteen (92.85%) were retrospective and only one (7.96%) was prospective.

A total of 710 TLIF and 794 PLIF patients were included. The mean age was 52 for both groups. Female to male ratio was found to be 29:21 in TLIF and 34:22 in the PLIF group. The mean BMI for TLIF and PLIF was 25.5 and 24 Kg/m^2, respectively (Table I).

The mean operation time for TLIF was 160 min and the mean estimated blood loss (EBL) was 405 ml, while for the PLIF group, compared to 178.5 min and 515ml for TLIF, respectively. The mean length of stay (LOS) for PLIF and TLIF group was 6.5 and 6 days, respectively. The mean rate of surgical site infection (SSI) for PLIF was slightly higher than TLIF (4% vs. 3%). The mean duration of follow up time for PLIF and TLIF was 24 months (Table II).

The overall complication rate for PLIF was found to be higher than TLIF (24%vs.10%). The reoperation rate for PLIF was also higher than the TLIF according to these studies (Table III).The early and late failure rate of either technique was not reported in most studies (Table III).

Overall, various means were used to report improvement of leg and back pain including Oswestry disability index (ODI), Visual analogue scale (VAS), and Japanese orthopedic association (JOA) (Table IV). Regarding the scores, no significant difference was observed between PLIF and TLIF groups.

CT scan and X-rays were employed in most studies for the assessment of solid fusion. The mean fusion rate for both studies was considerably high (TLIF: 94%, PLIF: 92%). In most reports, the rate of pseudoarthrosis for both groups was insignificant and was only reported in 2 studies clearly (13, 15). The types of graft used in both groups are discussed in Table V.

DISCUSSION

The present systematic review mainly aims to compare the clinical and radiological outcomes of TLIF vs. PLIF in single or two-level lumbar fusion surgeries. Based on the results obtained from the literature and the mean value for each variable, the superiority of one technique over the other

Table I: Study Groups: Demographics

Author (Year)	Mean Age ± SD (year)		Mean BMI ± SD (kg/m^2)		Female/Male (Number)		LOE	Bias Risk
	TLIF	PLIF	TLIF	PLIF	TLIF	PLIF		
Al Barbarawi et al. (2015) (1)	45.90*	5.60*	N/A	N/A	31/19	28/12	2 B	High
Mehta et al. (2011) (21)	48.12 ± 14.63	48.56 ± 12.34	N/A	N/A	27/16	42/34	4	High
Park et al. (2005) (22)	54.00*	57.00*	N/A	N/A	19/10	56/43	4	High
Liu et al. (2016) (19)	54.10 ± 12.91	55.05 ± 10.16	23.02 ± 5.18	21.45 ± 4.00	59/42	85/40	4	High
Li et al. (2016) (18)	44.50 ± 12.40	43.80 ± 12.10	N/A	N/A	7/18	9/17	4	High
Yang et al. (2016) (27)	44.10*	42.70*	N/A	N/A	19/13	20/14	2 B	High
de Kunder et al. (2016) (9)	58.00 ± 13.00	58.00 ± 12.00	28.00*	27.00*	31/17	25/23	4	High
Humphreys et al. (2001) (15)	41.00*	40.00*	N/A	N/A	20/20	12/22	2 B	High
Asil and Yaldiz (2016) (4)	53.76 ± 7.95	55.76 ± 7.78	N/A	N/A	29/12	25/8	4	High
Lee et al. (2017) (17)	59.43 ± 13.00	56.47 ± 13.13	N/A	N/A	16/5	23/7	2 B	High
Audat et al. (2012) (5)	45.80 ± 12.30	54.20 ± 13.60	N/A	N/A	23/14	10/7	2 B	High
Sakeb and Ansan (2013) (24)	49.00*	46.00*	N/A	N/A	36/14	41/11	4	High
Yan et al. (2008) (26)	57.51 ± 11.17	58.73 ± 9.61	N/A	N/A	45/46	44/41	2 B	High
Han et al. (2016) (12)	59.69 ± 8.00	57.31 ± 9.34	N/A	N/A	16:20	10:16	4	High
Mean	52.00	52.00	25.50	24.00	416:294	476:318	4	High

LOE: *Level of evidence,* ***PLIF:*** *Posterior lumbar inter-body fusion,* ***TLIF:*** *Trans-foraminal lumbar inter-body fusion,* ***SD:*** *Standard deviation*
**No standard deviation reported.*

Table II: TLIF vs. PLIF: Operative Variables, Infection Rate and Mean Follow Up

Author (Y)	Level of Surgery		Operation Time (min) Mean ± SD		p-value	EBL (ml) Mean ± SD		p-value	LOS (Day)		p- value	SSI (%)		p-value	Follow Up (Month)	
	TLIF	PLIF	TLIF	PLIF		TLIF	PLIF		TLIF	PLIF		TLIF	PLIF		TLIF	PLIF
Al Barbarawi et al. (2015) (1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6	5	N/A	60	60
Mehta et al. (2011) (21)	1 or 2	1 or 2	N/A	N/A	N/A	867.00 ± 500.00	994.00 ± 530.00	0.840	4	4	0.780	7	5	0.700	60	60
Park et al. (2005) (22)	1 or 2	Up to 3	198.00*	210.00*	N/A	N/A	N/A	N/A	8	9	N/A	N/A	N/A	N/A	10	20
Liu et al. (2016) (19)	1 or 2	1 or 2	187.67 ± 45.54	241.61 ± 67.31	**0.037**	308.06 ± 385.16	482.91 ± 403.12	**0.035**	N/A	N/A	N/A	4	7	0.486	24	24
Li et al. (2016) (18)	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43	43
Yang et al. (2016) (27)	1	1	113.20*	124.80*	**0.008**	432.50 *	521.30 *	**0.043**	N/A	N/A	N/A	3	3	N/A	30	30
de Kunder et al. (2016) (9)	1	1	145.00 ± 52.00	177.00 ± 56.00	**0.005**	485.00 ± 355.00	590.00 ± 327.00	0.202	6	6	0.748	6	2	N/A	48	48
Humphreys et al. (2001) (15)	1 and 2	1 and 2	159*	173*	*<0.05*	378.00*	509.00*	***<0.050***	5	5	*>0.05*0	0	3	N/A	13	13
Asil and Yaldiz (2016) (4)	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	12	N/A	24	24
Lee et al. (2017) (17)	1	1	161.19 ± 41. 37	180.33 ± 49.72	0.181	548.57 ± 358.38	725.67 ± 462.75	0.077	8	8	**0.014**	N/A	N/A	N/A	22	19
Audat et al. (2012) (5)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	4	N/A	36	36
Sakeb and Ansan (2013) (24)	1	1	165 ± 06.63	182 ± 10.91	***<0.050***	215.00 ± 12.00	245.00 ± 19.00	*>0.05*0	6	7	***<0.050***	0	4	N/A	12	12
Yan et al. (2008) (26)	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	24	24
Han et al. (2016) (12)	1 or 2	1 or 2	134.00*	130.00*	**0.039**	247.00*	272.00*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21	18
Mean	1	1	160.00*	178.50*	N/A	405.00	515.00	N/A	6	6.5	N/A	3	4	N/A	24	24

TLIF: *Transforaminal lumbar interbody fusion;* ***PLIF:*** *Posterior lumbar interbody fuion;* ***EBL:*** *Estimated blood loss;* ***LOS:*** *Length of stay;* ***SSI:*** *Surgical site infection;* ***NA:*** *Not applicable.*

Table III: Complication and Reoperation Rates, Early and Late Failure of TLIF vs. PLIF

Author (year)	Complication Rate (%)		p-value	Reoperation Rate (%)		p-value	Early Failure (<1 month postop)		p-value	Late Failure (>1 month postop)		p-value
	TLIF	PLIF		TLIF	PLIF		TLIF	PLIF		TLIF	PLIF	
Al Barbarawi et al. (2015) (1)	18	17	0.332	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mehta et al. (2011) (21)	21	36	N/A	16	12	0.260	N/A	N/A	N/A	N/A	N/A	N/A
Park et al. (2005) (22)	0	9	N/A	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Liu et al. (2016) (19)	11.13	28.39	**0.018**	2	10	**0.011**	N/A	N/A	N/A	N/A	N/A	N/A
Li et al. (2016) (18)	1	38	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yang et al. (2016) (27)	9	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
de Kunder et al. (2016) (9)	25	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	4	N/A
Humphreys et al. (2001) (15)	0	25	***<0.050***	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Asil and Yaldiz (2016) (4)	12	30	N/A	6	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lee et al. (2017) (17)	2	17	0.990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Audat et al. (2012) (5)	13	26	0.340	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sakeb and Ansan (2013) (24)	12	29	*>0.050*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yan et al. (2008) (26)	3	3	*>0.050*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Han et al. (2016) (12)	3	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mean	10	24	N/A	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*A great part of the literature is sparse on important surgical outcomes like re-operation rate, early and late failure. **TLIF:** Transforaminal lumbar interbody fusion; **PLIF:** Posterior lumbar interbody fusion; **N/A:** Not applicable*

cannot be determined. Both techniques offer excellent results in terms of radiological fusion and clinical outcomes, with selection of one technique over the other being based on surgeon discretion.

As shown in Table I, the level of evidence of the existing literature has not exceeded a level higher than 2B. Moreover, 8 out of the 14 studies remain at the low level of evidence (IV). Hence, all the studies in this systematic review show a high risk of bias based on their level of evidence. It is also of note that the data presented by selected studies are mostly retrospective (13 out of 14 studies) and most data retrieved from these papers may be prone to multiple biases, accordingly.

TLIF is regarded as the extracanalicular version of PLIF technique (11). It has been claimed that TLIF affords many advantages over PLIF. First, since the removal of the facet joint is done unilaterally, it preserves this anatomy for fusion mass at the time of initial surgery, but also serves as a useful landmark should revision become necessary, as one may proceed without encountering the epidural scar tissue on the contra-lateral side (7). Secondly, this approach increases the segmental lordosis while leaving the contra-lateral foramen undisturbed (10). Thirdly, unlike PLIF, over-retraction of neural elements is avoided, with subsequently fewer instances of dural tears or iatrogenic nerve root injury. This issue of retraction of neural elements may make TLIF particularly more appealing at upper lumbar levels, given the proximity to the conus medullaris. Fourthly, it has been suggested that TLIF provides more surface area to serve as a fusion substrate, as it traverses obliquely and ventrally into the disk space, which makes possible the insertion of larger diagonally-oriented cages, as opposed to the straight PLIF cages. And finally, in terms of biomechanical stability, there is a potential benefit of TLIF over PLIF in the ability to preserve the posterior ligamentous tension band, including supra- and inter-spinous ligaments.

The cage dependent distraction of the lumbar disk space may lead to an increased cross-sectional area of neural foramen and reserves disk space height. The hypothesis that this could serve to achieve better clinical outcomes has been questioned by Chang et al., who argued that there is a strong tendency for the disk space to collapse back into its initial position despite the presence of the instruments (7). Also, there have been excellent clinical outcomes without any significant change in foraminal height. The elimination of the segmental motion, in the absence of foraminal height increment, could halt the irritation of the nerve root and explain the reported good clinical outcomes (7).

Regarding the clinical outcome measures, outcome data has been reported using a variety of different scales, making

Table IV: TLIF vs. PLIF in Terms of Outcome Assessment Tools

Author (Year)	**ODI Mean ± SD**					**VAS Mean ± SD**					**JOA Mean ± SD**				
	TLIF		**PLIF**		**p-value**	**TLIF**		**PLIF**		**p-value**	**TLIF**		**PLIF**		**p-value**
	Pre- op	**Last F/U**	**Pre- op**	**Last F/U**		**Pre- op**	**Last F/U**	**Pre- op**	**Last F/U**		**Pre- op**	**Last F/U**	**Pre- op**	**Last F/U**	
Al Barbarawi et al. (2015) (1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.547	N/A	N/A	N/A	N/A	N/A
Mehta et al. (2011) (21)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Park et al. (2005) (22)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Liu et al. (2016) (19)	N/A	N/A	N/A	N/A	N/A	7.18 ± 1.09	2.84 ± 0.91	7.08 ± 1.13	2.84 ± 0.89	0.320	N/A	N/A	N/A	N/A	N/A
Li et al. (2016) (18)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.00 ± 1.30	26.60 ± 1.70	16.10± 1.30	27.3 ± 0.7	**<0.050**
Yang et al. (2016) (27)	49.60 ± 14.30	14.10 ± 10.20	47.9 0± 14.30	15.4 0± 8.70	>0.050	47.20 ± 19.60	13.30 ± 8.90	48.80 ± 17.70	12.60 ± 7.60	>0.050	24.40 ± 2.50	24.20 ± 2.30	16.20 ± 3.40	17.0 0 ± 3.40	>0.050
de Kunder et al. (2016) (9)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Humphreys et al. (2001) (15)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Asil and Yaldiz (2016) (4)	N/A	N/A	N/A	N/A	>0.050	N/A	N/A	N/A	N/A	>0.050	N/A	N/A	N/A	N/A	N/A
Lee et al. (2017) (17)	N/A	N/A	N/A	N/A	N/A	7.13 ± 0.97	1.97 ± 1.42	7.33 ± 1.19	1.52± 1.20	**0.017**	N/A	N/A	N/A	N/A	N/A
Audat et al. (2012) (5)	N/A	N/A	N/A	N/A	0.547	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sakeb and Ansan (2013) (24)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yan et al. (2008) (26)	N/A	N/A	N/A	N/A	N/A	7.18 ± 1.09	2.84 ± 0.91	7.08 ± 1.13	2.84 ± 0.89	**<0.001**	N/A	84.60*	N/A	83.50 *	>0.050
Han et al. (2016) (12)	67.50 ± 13.43	20.56 ± 10.33	68.08 ± 13.31	20.69 ± 10.63	>0.050	7.11 ± 0.95	2.25 ± 1.59	7.12 ± 0.91	2.35 ± 1.38	>0.050	N/A	N/A	N/A	N/A	N/A

JOA: *Japanese orthopedic association,* ***ODI:*** *Oswestry disability index,* ***SD:*** *Standard deviation,* ***VAS:*** *Visual analogue score.*
**No standard deviation reported.*

Table V: PLIF vs. TLIF: Fusion Rate, Pseudo-Arthrosis Rate, Type of Graft, and Imaging Technique Used for Fusion Assessment

Author (Y)	Fusion Rate (%)		Pseudo-Arthrosis (%)		p-value	Type of Graft Used		Radiologic Fusion Assessment
	TLIF	PLIF	TLIF	PLIF		TLIF	PLIF	
Al Barbarawi et al. (2015) (1)	94	92	0	0	N/A	N/A	N/A	X-ray /MRI
Mehta et al. (2011) (21)	N/A	N/A	4.6	2.6	N/A	53% DBM, 35% BMP, and 12% Allograft	67% DBM, 11%BMP, and 22% Allograft	CT scan
Park et al. (2005) (22)	N/A	N/A	0	0	N/A	N/A	N/A	X-ray /MRI/ CT scan
Liu et al. (2016) (19)	N/A	N/A	0	0	N/A	Autograft or Allograft	Autograft or Allograft	CT scan
Li et al. (2016) (18)	100	100	0	0	N/A	Local autograft	Local autograft	CT scan
Yang et al. (2016) (27)	100	100	0	0	N/A	Local autograft	Local autograft	X-ray/ CT scan
de Kunder et al. (2016) (9)	N/A	N/A	0	0	N/A	Local autograft	Local autograft	X-ray
Humphreys et al. (2001) (15)	100	97	0	0	N/A	Iliac Bone autograft	Iliac Bone autograft	N/A
Asil and Yaldiz (2016) (4)	N/A	N/A	0	0	N/A	N/A	N/A	X-ray/CT scan
Lee et al. (2017) (17)	100	93	0	0	N/A	Local autograft	Local autograft	CT scan /MRI
Audat et al. (2012) (5)	92	89	0	0	N/A	Local autograft	Local autograft	CT scan / MRI
Sakeb and Ansan (2013) (24)	N/A	N/A	4	9.62	N/A	N/A	N/A	X-ray /MRI/ CT scan
Yan et al. (2008) (26)	100	100	0	0	>0.050	Local autograft	Local autograft	X-ray
Han et al. (2016) (12)	94	92	0	0	N/A	Local autograft	Local autograft	X-ray

BMP: *Bone morphogenetic protein,* ***CT:*** *Computed tomography,* ***DBM:*** *De-mineralized bone matrix,* ***MRI:*** *Magnetic resonance imaging,* ***PLIF:*** *Posterior lumbar inter-body fusion,* ***TLIF:*** *Trans-foraminal lumbar inter-body fusion.*

a strong conclusion less possible (Table IV). Overall, the leg and back pain improved significantly in both groups, and regardless of the manner in which the data was reported. Although unilateral TLIF may be less destructive, most studies support equivalence of post-operative pain over the long-term clinical outcomes (1,6,10,11,21).

With regard to complication rate, TLIF appears to be superior to PLIF overall (mean: 10% vs. 24%, Table III). This difference appears to be driven by the reduced invasiveness of TLIF concerning the soft tissue and bony structures. As compared to PLIF, TLIF mostly involves unilateral facetectomy and discectomy, the surgical corridor into the disk space is comparatively far away from the exiting and traversing nerve roots and the resulting applied traction on the thecal sac is minimized. Hence, the rate of dural tear and nerve root injury is greater in the PLIF procedure. Hence, the rate of dural tear and nerve root injury is significantly less in TLIF in comparison to PLIF. Nevertheless, we cannot draw strong conclusions on the reoperation rate, early and late failure of either technique, as the data is insufficient in the current literature (Table III).

Although hardware failure such as cage migration or screw displacement has been rarely reported with either of the techniques, we believe that this represents a technical failure, and not a necessarily a complication, as it is often dependent on intrinsic factors such as patient-specific risks (e.g. osteoporotic disease, metabolic bone disease), as well as surgeon's preferences such as appropriate cage selection.

Most studies conclude that the operative time and EBL is reduced in TLIF compared to PLIF (Table II). There is only one study claiming that single-level PLIF is achieved more quickly than TLIF, however, the difference has not been substantiated statistically (1). The less invasive nature of TLIF, which is mainly a unilateral approach, may explain the general agreement on the observed difference in operative time and EBL between the two techniques.

A preponderance of studies have found SSI rate to be greater in PLIF (1,10,21). Although the mean rate of SSI shows no significant difference between the two techniques in this systematic review (Table II), we believe that the conflicting results on the rate of SSI should be interpreted as an institutional difference, which may be affected by different factors including the surgical equipment, size and members of the surgical team, facility used (surgical microscope, surgical loupes, use of fluoroscopy), choice of antibiotic, patient variables such as BMI, among other variables.

Interestingly, the pseudoarthrosis was only observed in 2 studies (Table V). While Mehta et al, believe that this rate is higher in PLIF than TLIF. Park et al. (21), found the opposite to be true (22). Owing to the very few studies reporting significant rate of pseudoarthrosis, the current literature is unable to yield a strong consensus on the difference between TLIF and PLIF.

In terms of the fusion rate, there is a consensus between the studies that TLIF demonstrates a slightly better radiological fusion rate than PLIF (Mean 94% vs. 92%, Table V); however, this does not reach statistical significance and is not reflected in the clinical outcome. This may be explained by the more anterior placement of the TLIF cage, as compared to a PLIF cage, as well as the increased surface for fusion. Although most studies in this systematic review have used a combination of autograft and allograft bone material, the fusion rate may also be affected by both the type of synthetic graft used (DBM, BMP, etc), and the patient's primary bone stock. In most reports, the rate of pseudo-arthrosis for both groups was insignificant, indeed and was only reported in 2 studies (21,22).

Difference mean length of stay of TLIF vs. PLIF was found to be insignificant in our study (6 and 6.5 days, respectively, Table II). This is in contrast with the old conception that LOS would be less in TLIF than in PLIF.

A recent systematic review and meta-analysis by de Kunder et al, in 2017 analyzed nine prior studies (one randomized and eight case series) (9). de Kunder reported statistically meaningful differences between TLIF and PLIF in terms of postoperative ODI scores; however it failed to find similar meaningful results with the follow-up VAS. Nonetheless, the difference of ODI scores between TLIF and PLIF was not found to be clinically significant. The authors suggest this would be due to the more preservation of the para-spinal muscles in unilateral TLIF, which makes the surgical outcome more appealing to the patients. Another systematic review and meta-analysis completed in 2018 reported no statistically difference in terms of ODI, VAS and JOA scores between TLIF and PLIF; although TLIF demonstrates a slight trend towards improved scores than PLIF (16). Our systemic review recruiting fourteen studies found neither significantly statistical nor clinical differences between TLIF and PLIF in terms of VAS and ODI scores.

Even though the accumulative evidence suggests that TLIF is advantageous over PLIF based on the operation time, EBL, pains cores, fusion rates, complication rates, and SSI, we strongly believe that the surgeon, the surgical facilities, and the patient factors have a great impact on the final radiological and clinical fusion of both techniques.

As can be seen in Table I, the level of evidence of the current literature has not exceeded 2B. Moreover, 8 of the 14 studies remain at the low level of evidence (IV). Indeed, most of the studies are retrospective in nature, and some of the questions may remain unanswered until randomized controlled trials are conducted. Multicenter non-randomized clinical trials are recommended with a large database of patients with an acceptable long-term follow up, to show a clear superiority of each of the methods over the other.

CONCLUSION

The literature comparing the traditional PLIF to TLIF is incongruent in terms of strong evidence supporting one technique over the other. In part this is due to the overall low quality of data and lack of randomized trials. High risk of bias is expected due to the low level of evidence that characterized most studies. Nevertheless, there is a consensus that neurological deficit may be more likely with PLIF due to the degree of retraction of neural elements. Some evidence has also suggested shorter operation times and less blood loss with TLIF, particularly if a more minimally invasive approach is used. Although both techniques can be invaluable when employed in the correct setting, no strong conclusions can be drawn on the re-operation rate, early and late failure of either techniques, as the comparative data is insufficient in the current literature. Even though cumulative and anecdotal evidence suggests that TLIF is advantageous over PLIF based on the operation time, EBL, pains cores, fusion rates, complication rates, and SSI, we strongly believe that the surgeon's, as well as the patient's factors simultaneously play a pivotal role to achieve ideal radiological and clinical outcome with either of the techniques. Multi-center large scale non randomized clinical trials are recommended with an acceptable long-term follow up, to show a clear superiority of each of the methods over the other. Ultimately, the decision rests with the surgeon, and should be based upon personal preference, surgeon's experience, and individual patient-based factors.

AUTHORSHIP CONTRIBUTION

Study conception and design: PV, GR

Data collection: PV, MG

Analysis and interpretation of results: PV, MG, GR

Draft manuscript preparation: PV, MG, GR

All authors (PV, MG, GR) reviewed the results and approved the final version of the manuscript.

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