

Comparison between topping-off technology and posterior lumbar interbody fusion in the treatment of chronic low back pain

A meta-analysis

Wei Wang, MD^{a,b,c}, Xiangyao Sun, MD, PhD^{a,b,c}, Tongtong Zhang, MD^{a,c,d}, Siyuan Sun, MD^e, Chao Kong, MD^{a,b,c}, Junzhe Ding, MD^{a,b,c}, Xiangyu Li, MD^{a,b,c}, Shibao Lu, MD^{a,b,*}

Abstract

Background: The difference between topping-off technique and posterior lumbar interbody fusion (PLIF) in postoperative outcomes is still controversial. The aim of this study is to compare all available data on outcomes of topping-off technique and PLIF in the treatment of chronic low back pain.

Methods: Articles in PubMed, EMBASE and Cochrane were reviewed. Parameters included radiographical adjacent segment disease (RASD), clinical adjacent segment disease, range of motion (ROM), global lumbar lordosis (GLL), visual analog scale (VAS), visual analog scale of back, (VAS-B) and visual analog scale leg (VAS-L), Oswestry disability index, Japanese Orthopaedic Association (JOA) score, duration of surgery, estimated blood loss (EBL), reoperation rates, complication rates.

Results: Rates of proximal RASD ($P = .001$) and CASD ($P = .03$), postoperative VAS-B ($P = .0001$) were significantly lower in topping-off group than that in PLIF group. There was no significant difference in distal RASD ($P = .07$), postoperative GLL ($P = .71$), postoperative upper intervertebral ROM ($P = .19$), postoperative VAS-L ($P = .08$), DOI ($P = .30$), postoperative JOA ($P = .18$), EBL ($P = .21$) and duration of surgery ($P = .49$), reoperation rate ($P = .16$), complication rates ($P = .31$) between topping-off group and PLIF.

Conclusions: Topping-off can effectively prevent the adjacent segment disease from progressing after lumbar internal fixation, which is more effective in proximal segments. Topping-off technique was more effective in improving subjective feelings of patients rather than objective motor functions. However, no significant difference between topping-off technique and PLIF can be found in the rates of complications.

Abbreviations: ASDs = adjacent segment diseases, CASD = clinical adjacent segment disease, CI = confidence intervals, CLBP = chronic low back pain, DIAM = Device for Intervertebral Assisted Motion, DTO = Dynesys-to-Optima, EBL = estimated blood loss, GLL = global lumbar lordosis, IPD = interspinous process device, JOA = Japanese Orthopaedic Association, NOS = Newcastle-Ottawa scale, ODI = Oswestry disability index, OR = odds ratios, PDS = pedicle-based stabilization devices, PLIF = posterior lumbar interbody fusion, RASD = radiographical adjacent segment disease, ROM = range of motion, SMD = standardized mean difference, VAS = visual analogue scale, VAS-B = VAS of back, VAS-L = VAS of leg.

Keywords: interbody fusion, lumbar degenerative disease, meta-analysis, topping-off technique

1. Introduction

Posterior lumbar interbody fusion (PLIF) has been considered to be the standard surgical treatment for patients suffering from chronic low back pain (CLBP) caused by lumbar degenerative

disease.^[1] In addition to its satisfactory clinical outcomes, there are still a series of complications in PLIF.^[2] The increase in the range of motion (ROM) of adjacent segments will cause the acceleration of adjacent segment diseases (ASDs), which are the most commonly seen complications in the follow-up.^[3] Posterior

Editor: Bernhard Schaller.

Ethics approval was not applicable in this article.

This study was funded by the China Scholarship Council (No.201908110337), National Natural Science Foundation of China, (No. 81672201, No. 81871794) Beijing Municipal Commission of Health, and Family Planning (No. PXM2017 026283 000002).

The authors have no conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

^a Department of Orthopedics, Xuanwu Hospital Capital Medical University, ^b National Clinical Research Center for Geriatric Diseases, ^c Capital Medical University, China,

^d Department of Orthopaedics, ChuiYangLiu Hospital affiliated to Tsinghua University, ^e Department of Interdisciplinary, Life Science, Purdue University.

* Correspondence: Shibao Lu, Department of Orthopedics, Xuanwu Hospital Capital Medical University, Beijing, 100053, China (e-mail: 15624967325@163.com).

Copyright © 2020 the Author(s). Published by Wolters Kluwer Health, Inc.

This is an open access article distributed under the Creative Commons Attribution License 4.0 (CCBY), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Wang W, Sun X, Zhang T, Sun S, Kong C, Ding J, Li X, Lu S. Comparison between topping-off technology and posterior lumbar interbody fusion in the treatment of chronic low back pain: A meta-analysis. *Medicine* 2020;99:5(e18885).

Received: 30 April 2019 / Received in final form: 3 November 2019 / Accepted: 21 December 2019

<http://dx.doi.org/10.1097/MD.00000000000018885>

dynamic stabilization systems, including interspinous process device (IPD); pedicle-based stabilization devices (PDS); total facet replacement system, have been used to decrease ASDs after PLIF since 1980s.^[4] The most commonly used hybrid dynamic stabilization system is “topping-off” technique. This technique combines the rigid fusion with dynamic nonfusion of adjacent segments, such as IPD or PDS, in order to reduce the hypermobility and overstress of the adjacent intervertebral disks.^[5–9] At the present study, there have been various flexible systems in spinal motion preservation technology, including PDS systems and IPS systems. The most commonly used PDS systems include Dynesys,^[10] NFlex,^[11] Isobar TTL,^[12] CD Horizon^[5] and DSS.^[13] Furthermore, the widely used IPS systems include Coflex,^[14] DIAM,^[15] Wallis.^[16]

Because there is a lack of clear clinical evidences, the difference between topping-off technique and PLIF in postoperative outcomes is still controversial.^[9,17,18] Therefore, a meta-analysis was carried out in this study to compare all available data on postoperative clinical and radiographic outcomes of topping-off technique and PLIF in the treatment of CLBP.

2. Materials and methods

2.1. Search strategy

The present review was conducted according to preferred reporting items for systematic reviews and meta-analyses statement.^[19] An experienced librarian (XYL) carried out a comprehensive literature search. Relevant studies in PubMed, EMBASE, Cochrane databases from 1980 to October 2019 were identified. The medical subject headings and keywords included: ([hybrid stabilization] or [topping off] or [hybrid stabilization device] or [dynamic hybrid] or [hybrid fixation]) and ([lumbar] or [lumbar degenerative disease] or [adjacent segment degeneration] or [ASD] and [fusion]). Manual searches of all retrieved research and review reference lists were used to supplement the computer searches.

2.2. Inclusion criteria and exclusion criteria

The inclusion criteria included: clinical evaluation was followed up for no less than 1 year; conservative treatment was frustrated on the treatment of CLBP; PLIF or topping-off surgery was used in the treatment; patients were in the same preoperative radiographic baseline. Exclusion criteria included: biomechanical studies and non-human or in vitro studies; abstracts, case reports, expert opinions, and non-comparative studies; therapies for tumors, infections, revision surgeries or congenital malformations.

2.3. Data extraction and quality assessment

All data was extracted from the text, pictures, and tables of the articles by 2 authors (SYS, JZD). The data included: age, gender, duration, study design, enrolled number, radiographical adjacent segment disease (RASD) and clinical adjacent segment disease (CASD), ROM, global lumbar lordosis (GLL), visual analog scale (VAS) of back and leg (VAS-B, VAS-L), Oswestry disability index (ODI), Japanese Orthopaedic Association (JOA) score, duration of surgery, estimated blood loss (EBL), reoperation rates, complication rates. If there is a disagreement about the outcomes, other authors (WW, SBL) would participate in the discussion to reach a consensus. Newcastle-Ottawa scale (NOS)^[20] was used to

assess the quality of the included studies by 2 authors (XYS, CK). A full score of 9 stars and a score of 7 or more is an excellent quality study.

2.4. Data analysis

The statistical analysis of the studies was performed in RevMan5.3 software. Odds ratios (OR) and standardized mean difference (SMD) with 95% confidence intervals (CI) were used for dichotomous data and continuous data. Heterogeneity across trials were explored according to the results of Chi-squared test and I^2 statistic. Random-effects model was considered if there was a significant heterogeneity assumed as P value less than .05 and $I^2 > 50\%$. Otherwise, data were pooled by using the fixed-effects model. If there was a potential heterogeneity, subgroup analysis and sensitivity tests would be performed in conjunction with possible clinical realities. Publication bias was analyzed by the funnel plot.

3. Results

3.1. Study characteristics

A total of 356 articles were identified in the initial examination. After exclusion of duplicate or irrelevant articles, 256 articles were retrieved. Ultimately, 10 studies^[7,14,15,21–27] were finally included in the meta-analysis (Fig. 1). Table 1 showed the characteristics of the included studies. Table 2 showed the results of NOS.

3.2. ASD

Five studies^[7,14,22,23,27] reported the incidence of proximal RASP (Fig. 2). Considering there is no significant heterogeneity between 2 groups, the fixed effect model was applied ($I^2 = 4\%$). The incidence of proximal RASD in topping-off group was significantly less than that in PLIF group (OR -0.12; 95% CI -0.20, -0.05; $I^2 = 4\%$; $P = .001$). The funnel plot showed no significant publication bias (Supplementary File 1, <http://links.lww.com/MD/D667>). The incidence of distal RASD was discussed in 2 studies.^[7,14] Because there is no significant heterogeneity between 2 groups ($I^2 = 5\%$), fixed effect model was applied in this analysis. No significant between-group difference was found in this analysis (OR 0.27; 95% CI 0.07, 1.11; $I^2 = 9\%$; $P = .07$). Three articles^[15,22,27] reported the incidence of CASD. The fixed effect model was applied considering there is no significant heterogeneity between 2 groups ($I^2 = 0\%$). The incidence of CASD in topping-off group was significantly less than that in PLIF group (OR 0.27; 95% CI 0.08, 0.89; $I^2 = 0\%$; $P = .03$) (Fig. 3). The funnel plot showed no significant publication bias (Supplementary File 2, <http://links.lww.com/MD/D668>).

3.3. Radiographic parameters

Postoperative GLL was discussed in 4 studies.^[7,15,25,26] Considering there is no significant heterogeneity between 2 groups, the fixed effect model was applied ($I^2 = 0\%$). No significant between-group difference was found in fixed-effects model (SMD -0.60; 95% CI -3.77, 2.57; $I^2 = 0\%$; $P = .71$, Fig. 4). The funnel plot showed no significant publication bias (Supplementary File 3, <http://links.lww.com/MD/D669>).

ROMs of upper intervertebral levels were discussed in two articles.^[14,22] The fixed effect model was applied considering

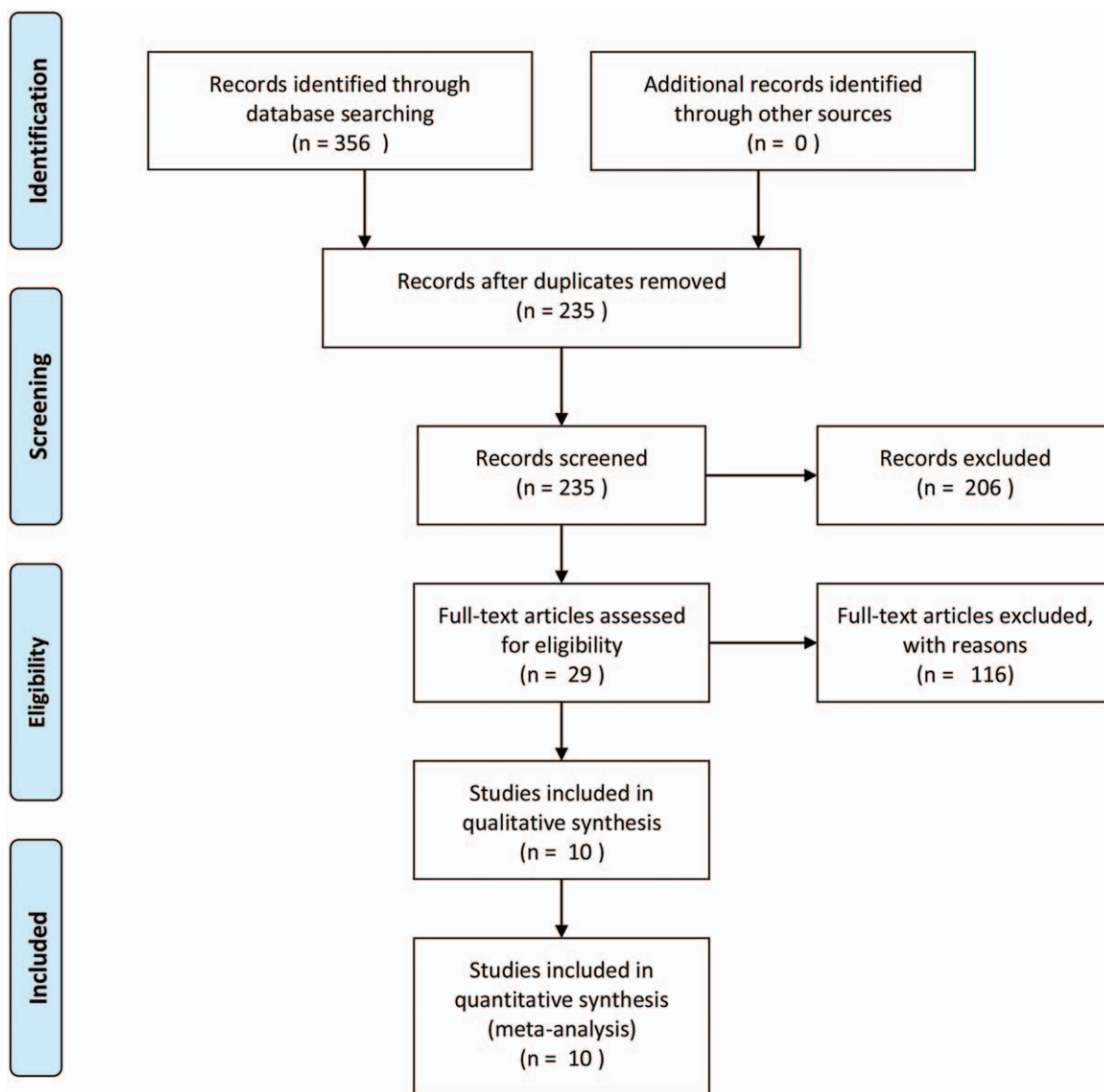


Figure 1. Flow chart showing identification and selection of cases.

Table 1

Characteristics of included studies.

Study	Year	Country	Study type	Quality (NOS)	LoE	Device	Patients (F/M)		Age, yr		Follow-up, mo	Segments
							PLIF	Topping-off techniques	PLIF	Topping-off techniques		
Li D ^[22]	2019	China	Retro	7	III	Coflex	54 (29/25)	45 (24/21)	53.5 (46–59)	65.7 (60–75)	4.7 ± 8.8 (36–37)	2
Herren C ^[23]	2018	Germany	RCT	9	I	Dynesys	14 (8/6)	15 (6/9)	61.78 (34–76)	60.9 (47–80)	37.68 (1.38–72)	1–5
Aygun H ^[24]	2017	Turkey	Retro	6	III	Cosmic	59 (34/25)	42 (19/23)	54.2 ± 5.11	52 ± 6.02	79	1–5
Chen XL ^[14]	2016	China	Retro	7	III	Coflex	88 (34/54)	76 (28/48)	58.31 ± 4.6	57.34 ± 5.1	47.2	1
Lee SE ^[7]	2015	Korea	Retro	8	III	DTO/Nflex	10 (5/5)	15 (11/4)	63.9 ± 7.8	60.7 ± 8.3	48	2
Lu K ^[15]	2015	China (Taiwan)	Retro	7	III	DIAM	42 (14/28)	49 (16/33)	64.5 ± 7.2	59.1 ± 8.6	41.5	2–4
Zhu Z ^[25]	2015	China	Retro	6	III	Wallis	23 (12/11)	22 (8/14)	40	44.5	24	1
Lee CH ^[21]	2013	Korea	Retro	7	III	DIAM	50 (20/30)	25 (10/25)	65.9 ± 8.5	65.4 ± 8.7	46.8	1
Liu HY ^[26]	2012	China	Retro	7	III	Coflex	48 (20/28)	31 (11/20)	41.5	44.6	24	1
Putzier M ^[27]	2010	Germany	Pro	7	II	Dynesys	30 (16/14)	30 (13/17)	44.6	44.9	76.4	1

DIAM = Device for Intervertebral Assisted Motion, DTO = Dynesys-to-Optima, F = female, M = male, NOS = Newcastle-Ottawa Scale score, PLIF = posterior lumbar interbody fusion, Pro = prospective cohort study, RCT = randomized controlled trial, Retro = retrospective cohort study.

Table 2
Newcastle-Ottawa scale (NOS).

Items Categories	Scales									
	Li D ^[22]	Herren C ^[23]	Aygun H ^[24]	Chen XL ^[14]	Lee SE ^[7]	Lu K ^[15]	Zhu Z ^[15]	Lee CH ^[21]	Liu HY ^[26]	Putzier M ^[27]
Selection										
(1) Is the case definition adequate?	1	1	1	1	1	1	1	1	1	1
(A) Yes, with independent validation.										
(B) Yes, eg record linkage or based on self reports.										
(C) No description.										
(2) Representativeness of the cases.	1	1	0	1	1	1	0	1	1	1
(A) Consecutive or obviously representative series of cases.										
(B) Potential for selection biases or not stated										
(3) Selection of Controls.	1	1	1	1	1	1	1	1	1	1
(A) Community controls.										
(B) Hospital controls.										
(C) No description.										
(4) Definition of Controls.	1	1	1	1	1	1	1	1	1	1
(A) No history of disease (endpoint).										
(B) No description of source.										
Comparability										
(1) Comparability of cases and controls on the basis of the design or analysis.	2	2	2	2	2	2	2	2	2	2
(A) Study controls for topping-off technique.										
(B) Study controls for any additional factor.										
Exposure										
(1) Ascertainment of exposure.	0	1	0	0	1	0	0	0	0	0
(A) Secure record (eg surgical records).										
(B) Structured interview where blind to case/control status.										
(C) Interview not blinded to case/control status.										
(D) Written self report or medical record only.										
(E) No description.										
(2) Same method of ascertainment for cases and controls.	1	1	1	1	1	1	1	1	1	1
(A) Yes.										
(B) No.										
(3) Non-Response rate.	0	1	0	0	0	0	0	0	0	0
(A) Same rate for both groups.										
(B) Non respondents described.										
(C) Rate different and no designation.										
Total	7	9	6	7	8	7	6	7	7	7

NOS = Newcastle-Ottawa scale score.

there is no significant heterogeneity between two groups ($I^2=51\%$). No significant between-group difference was found in this analysis (SMD -0.36; 95% CI -0.89, 0.17; $I^2=0\%$; $P=.71$, Fig. 5)

3.4. Clinical scoring system

VAS-B was documented in 7 articles^[7,14,15,25-27] (Fig. 6). Because there is no significant heterogeneity between 2 groups, the fixed effect model was applied ($I^2=41\%$). VAS-B in the Topping-off group was significantly less than in the PLIF group (SMD -0.35; 95% CI -0.54, -0.17; $I^2=41\%$; $P=.0001$). Funnel plot showed no significant publication bias in these studies (Supplementary File 4, <http://links.lww.com/MD/D670>). Three studies^[7,15,22] evaluated VAS-L. Fixed effect model was used in this analysis ($I^2=65\%$). No significant between-group difference was found in this analysis (SMD -0.21; 95% CI -0.45, 0.02; $I^2=65\%$; $P=.08$). The funnel plot showed no significant publication bias (Supplementary File 5, <http://links.lww.com/MD/D671>).

Four studies^[7,14,22,27] reported postoperative ODI. No significant heterogeneity ($I^2=30\%$) was found. The fixed-effect

model was used in this analysis. No significant between-group difference was found in this analysis (SMD 0.68; 95% CI -0.61, 1.96; $I^2=30\%$; $P=.30$) (Fig. 8). The funnel plot showed no significant publication bias (Supplementary File 6, <http://links.lww.com/MD/D672>). 2 studies^[25,26] discussed postoperative JOA. No between-group difference could be found in this analysis (SMD -0.90; 95% CI -2.22, 0.42; $I^2=0\%$; $P=.18$).

3.5. Intraoperative parameters

EBL was reported in 4 studies.^[14,22,24,26] Random effect model was used in this analysis, because a significant heterogeneity could be found ($I^2=92\%$). No between-group significance could be found in EBL (SMD -52.69; 95% CI -135.51, 30.13; $I^2=92\%$; $P=.21$) (Fig. 9). Duration of surgery was documented in 4 studies.^[14,22,24,26] Random effect model was used in this analysis, because there was a significant heterogeneity between these studies ($I^2=97\%$). There was no significant difference between these studies (SMD -10.34; 95% CI -39.54, 18.86; $I^2=97\%$; $P=.49$) (Fig. 10).

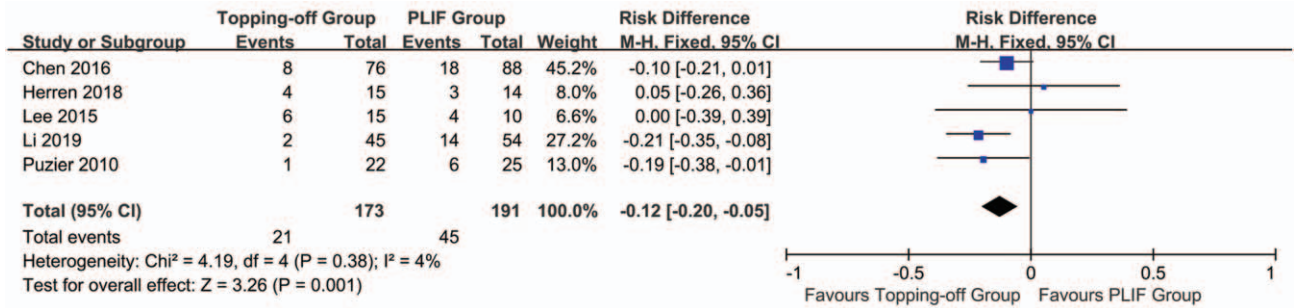


Figure 2. Forest plot of proximal RASD.

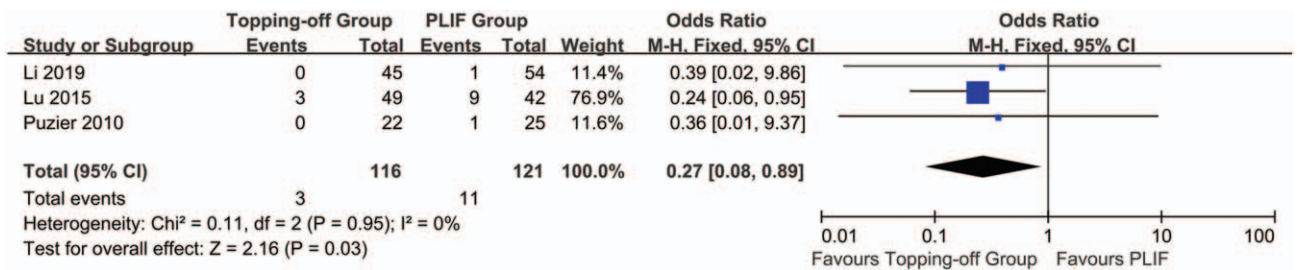


Figure 3. Forest plot of CASD.

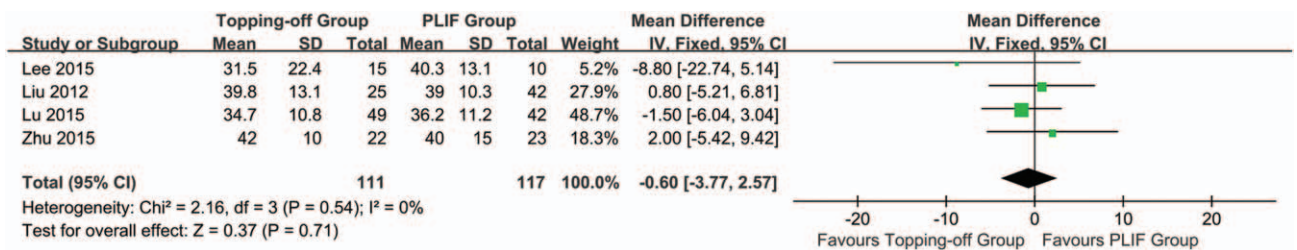


Figure 4. Forest plot of postoperative GLL. GLL = global lumbar lordosis.

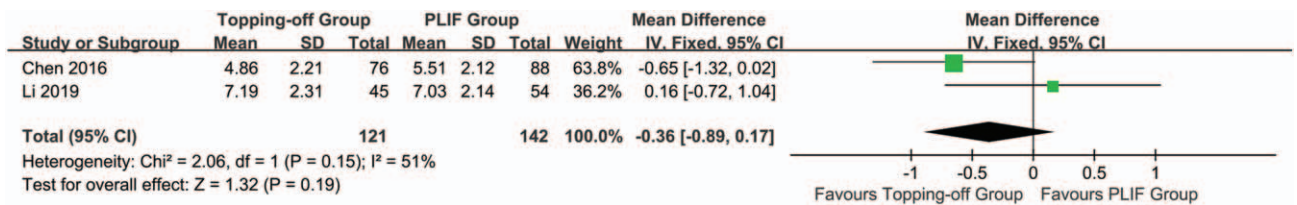


Figure 5. Forest plot of ROMs of intervertebral levels. ROMs = range of motions.

3.6. Complications

Six studies^[7,15,22-24,27] reported incidences of complications. Fixed effect model was used in this analysis without a significant heterogeneity (I² = 30%). No publication bias could be found in this evaluation (Supplementary File 7, <http://links.lww.com/MD/D673>). No significant between-group difference could be found in the results (OR 1.54; 95% CI 0.76, 3.11; I² = 40%; P = .23) (Fig. 11).

Dural tear rates was reported in 2 studies.^[15,24] Fixed effect model was used in this analysis (I² = 0%). No significant difference was found between topping-off group and PLIF group (OR 1.89; 95% CI 0.24, 15.10; I² = 0%; P = .55). Two studies discussed the infection rates.^[15,24] No significant between-group difference could be found in the results (OR 0.64; 95% CI 0.08, 5.11; I² = 0%; P = .67). Three articles^[7,24,27] discussed the pseudoarthrosis rates. Fixed effect model was used in this

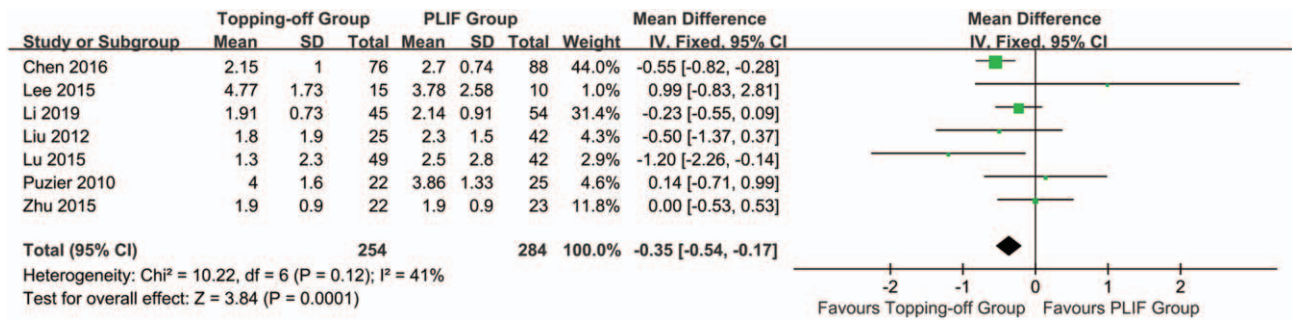


Figure 6. Forest plot of postoperative VAS-B. VAS-B = VAS of back.

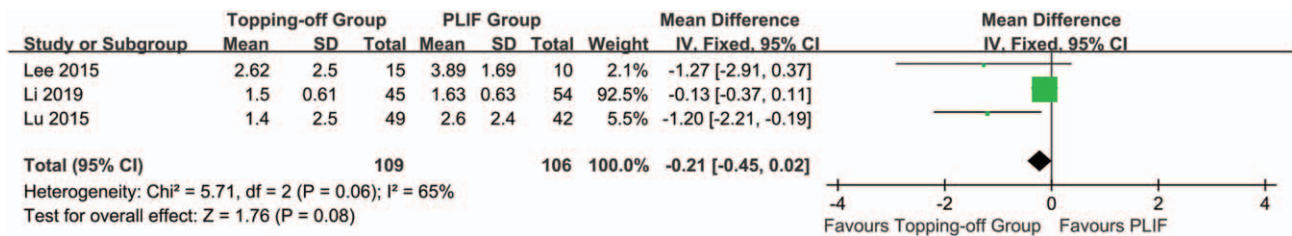


Figure 7. Forest plot of postoperative VAS-L. VAS-L = VAS of leg

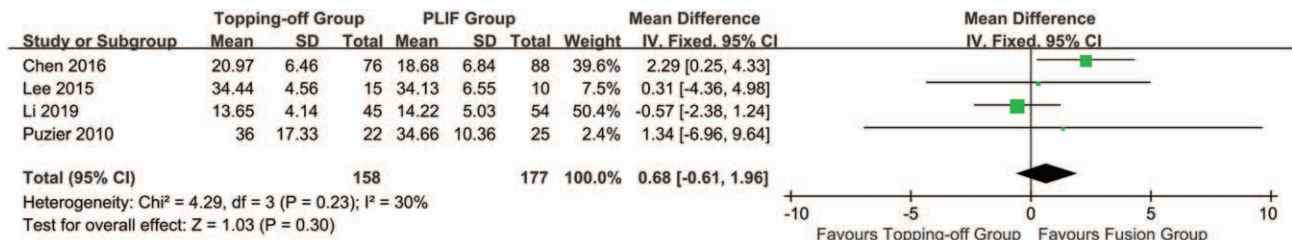


Figure 8. Forest plot of postoperative ODI. ODI = Oswestry disability index.

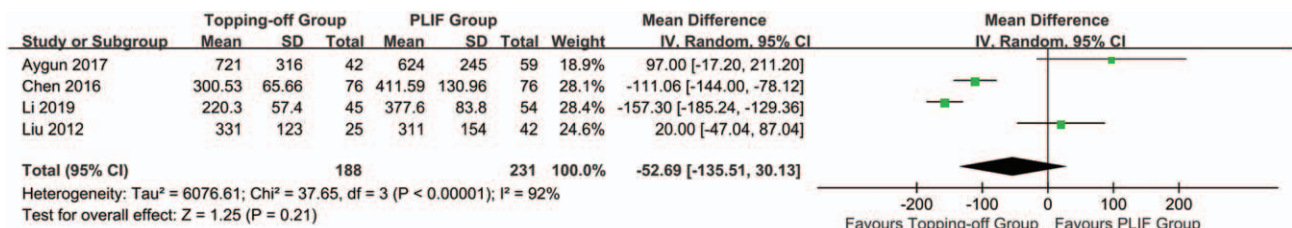


Figure 9. Forest plot of EBL. EBL = estimated blood loss.

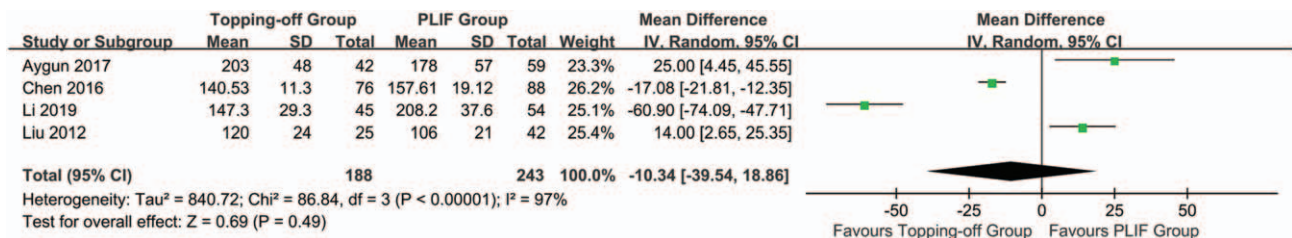


Figure 10. Forest plot of duration of surgery.

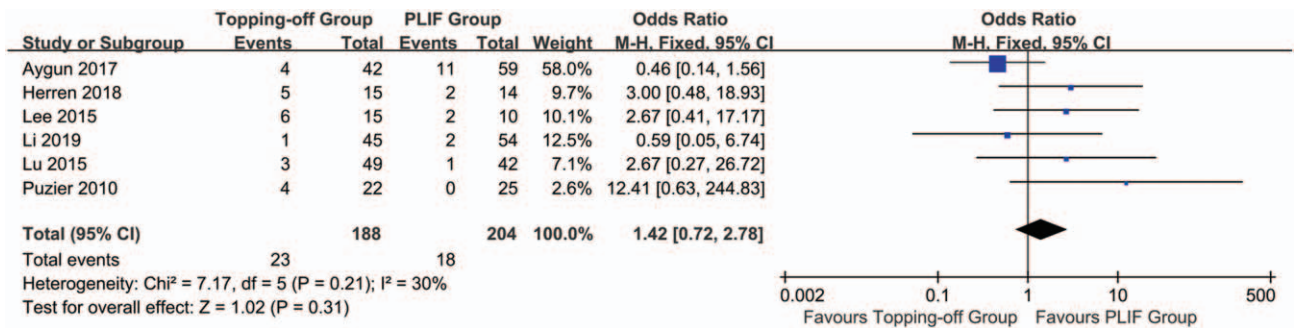


Figure 11. Forest plot of complication rates.

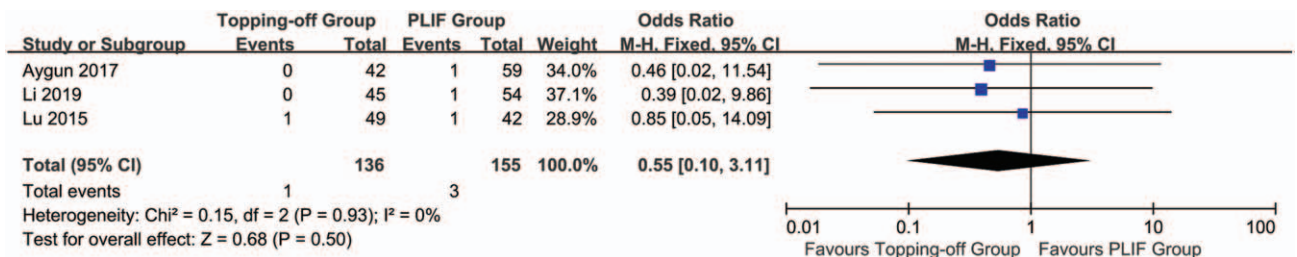


Figure 12. Forest plot of infection rates.

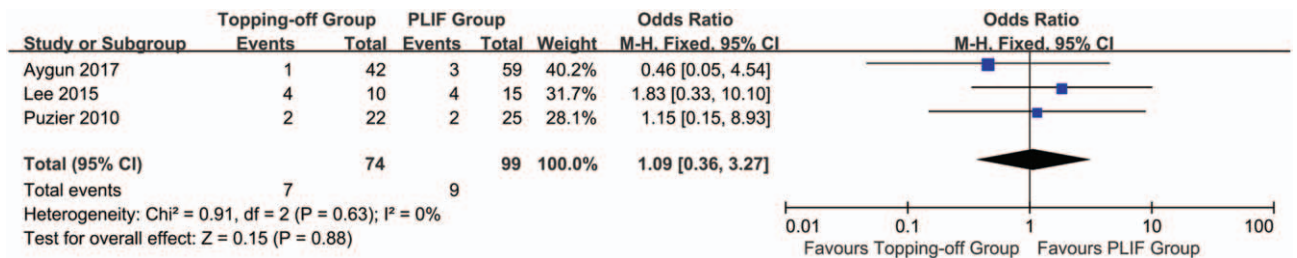


Figure 13. Forest plot of pseudoarthrosis rates.

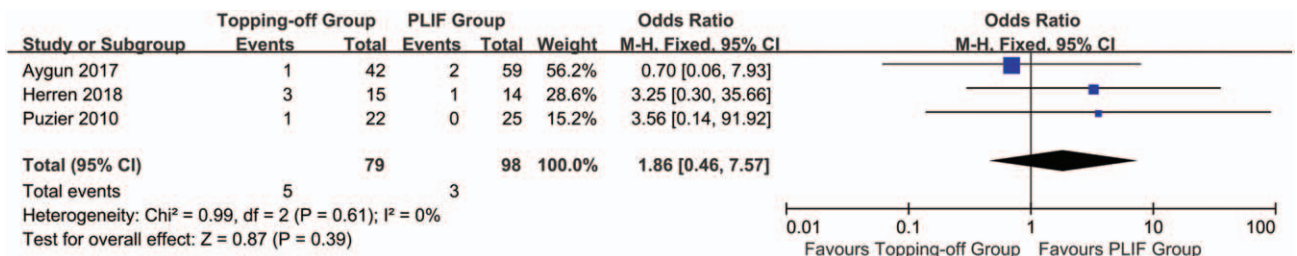


Figure 14. Forest plot of screw loosening rates.

analysis ($I^2=0\%$). No between-group significance could be found in the results (OR 1.09; 95% CI 0.36, 3.27; $I^2=0\%$; $P=.88$) (Fig. 13).

Incidences of screw loosening were discussed in 3 articles.^[23,24,27] Fixed effect model was used in this evaluation ($I^2=0\%$) and no significant difference was found between topping-off group and PLIF group (OR 1.86; 95% CI 0.46, 7.57; $I^2=0\%$; $P=.39$) (Fig. 14). The funnel plot showed no significant

publication bias (Supplementary File 8, <http://links.lww.com/MD/D674>). Two articles^[23,27] discussed implant breakage rates. There was no significant difference between topping-off group and PLIF group (OR 2.15; 95% CI 0.39, 11.81; $I^2=57\%$; $P=0.38$).

Five studies discussed reoperation rates.^[15,21-23,27] There was no significant heterogeneity in this analysis ($I^2=0\%$). Fixed effect model was used in this evaluation. No significant between-group

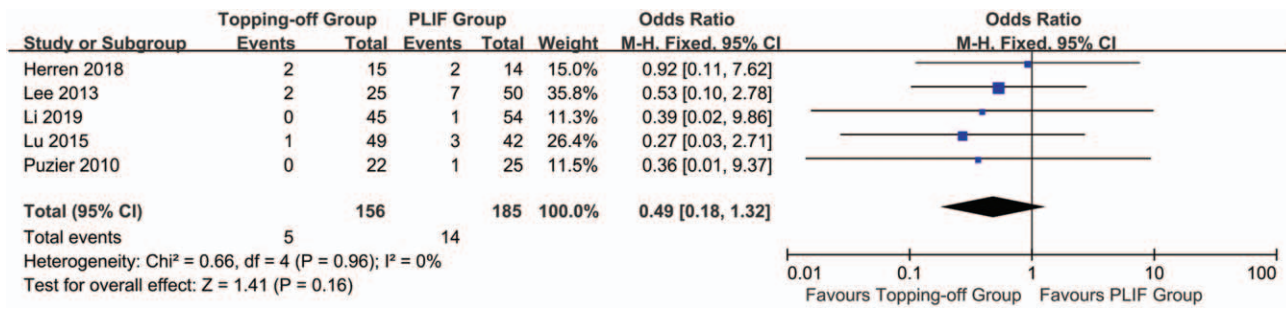


Figure 15. Forest plot of reoperation rates.

difference was found in the results (OR 0.49; 95% CI 0.18, 1.32; $I^2=0\%$; $P=.16$) (Fig. 15). Funnel plot showed there was no significant publication bias in these studies (Supplementary File 9, <http://links.lww.com/MD/D675>).

3.7. Age

Six studies discussed age.^[7,14,15,21,23,24] Random-effects model was used in this evaluation, because there was a significant heterogeneity in this analysis ($I^2=74\%$). No significant between-group difference was found in the results (SMD 0.10; 95% CI -2.08, 2.28; $I^2=74\%$; $P=.93$) (Fig. 16).

3.8. Gender

The influences of gender on the clinical outcomes of topping-off group and PLIF group were reported in 10 studies.^[7,14,15,21-27] There was no significant heterogeneity in this analysis ($I^2=0\%$). Fixed effect model was used in this evaluation. No significant between-group difference was found in the results (OR 0.85; 95% CI 0.64, 1.14; $I^2=0\%$; $P=.29$) (Fig. 17). Funnel plot showed there was no significant publication bias in these studies (Supplementary File 10, <http://links.lww.com/MD/D676>).

4. Discussion

It is still controversial that whether ASD is a natural evolution of an aging spine or a consequence of spinal fusion.^[28,29] Previous studies stated that the risk factors for ASD included age over 50 years,^[30,31] sagittal imbalance,^[32] increased length of fusion and surgical approaches.^[33] The elastic fixation in topping-off technique can act as a partially active buffer between fused segments and proximal mobile segments. Therefore, the ASD

could be reduced by topping-off technique via the application of dynamic fixation, which could prevent the proximal adjacent segments from degenerating.^[34]

Because there is still a lack of uniformity in the criteria of RASD, its definition in the previous studies were summarized: spondylolisthesis increase more than 3 mm, loss of intervertebral disc height, dynamic angulation of the interspinous space less than 10° .^[7,14,15,21,24,25,35] Considering that there is no significant heterogeneity in the analysis of RASD and CASD in our results, our research has good reference value. Our study showed that the incidences of proximal RASD and CASD in the PLIF group were significantly higher than those in topping-off group. The results of this study are consistent with previous studies.^[9,36] However, the result of distal RASD rate showed no significant between-group difference. This implied that topping-off technique was more effective in preventing proximal ASD. The possible explanation is that the compensatory mechanism of ROM in the proximal segments in the topping-off group can be improved.^[34,37] Our results showed that No significant between-group difference was found in ROMs of upper intervertebral levels. Therefore, the decrease of compensatory mechanism in topping-off technique may work through multiple segments. The postoperative GLL was similar between topping-off group and PLIF group in our results. This indicates that the expansion effect in topping-off technology can be negligible in global spine compared with PLIF. However, the correction of GLL may not be an advantage of topping-off technology.^[23,34]

The recovery of lumbar functions and the curative effects of operation were evaluated by JOA score, ODI and VAS. Our results showed that VAS-B in the topping-off group was significantly less than that in the PLIF group; however, no significant between-group difference was found in VAS-L. This

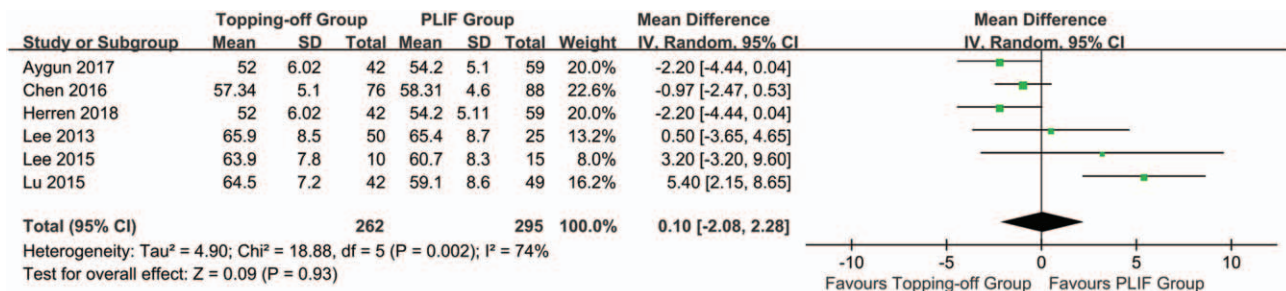


Figure 16. Forest plot of age.

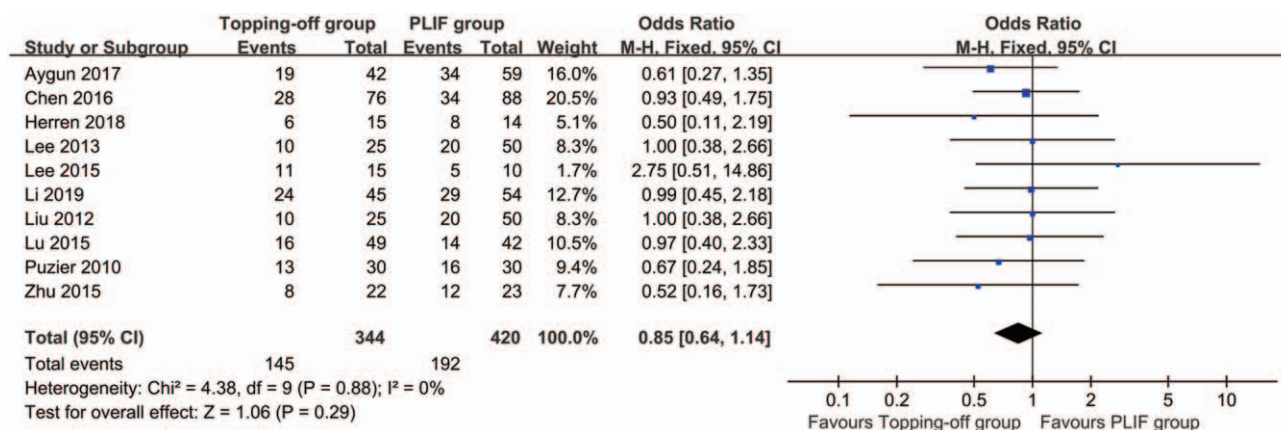


Figure 17. Forest plot of gender.

showed that topping-off technique was more effective in relieving CLBP. However, JOA score and ODI were similar between both groups. The possible explanation is that scoring systems are associated with the increasing age and the complications of dynamic equipment.^[38] VAS gives more weight to subjective feelings of patients, while JOA score and ODI are more focused on the objective motor functions of patients.^[25,26] All of these indicate that topping-off technique, compared with PLIF, is more effective in improving subjective feelings of patients rather than objective motor functions. This conclusion is in consistent with the founding of previous studies, which showed that topping-off technique could achieve a good clinical improvement even in the long-term follow-up.^[4,39,40]

Our study showed that no significant difference was found in EBL and duration of surgery between topping-off group and PLIF. The possible explanation is that additional exposure of anatomical structures is not needed in the insertion of dynamic implants; this will save the operation time.^[4] Considering there are many confounding factors in the included studies, this result needs to be interpreted carefully.

Whether topping-off technique can decrease the incidence of complications after fusion surgery or not has been inconclusive. The most commonly seen postoperative complications in topping-off technique are screw loosening, screw fracture and spinous process avulsion fracture.^[15,21,23,27] Screw loosening is most likely to be found in Hybrid Stabilization Devices; in addition, spinous process fracture is the most commonly seen complication in Interspinous Process Devices.^[41,42] The rates of complications, such as dural tear, infection, implant loosening, pseudoarthrosis, and implant breakage, were discussed in our study. However, no significant difference between topping-off group and PLIF group was found in our results. The “halo zone” in dynamic stabilization systems show that the forces conveyed from the dynamic implant can increase the stress on rigid fixation over time, and then implant-associated adverse events will occur.^[38] However, our study indicated that, compared with PLIF, the application of the topping-off technique would not be influenced by this effect. The application of hydroxyapatite coated pedicle screws might be an ideal method to prevent implant related complications.^[43] Previous studies showed that hydroxyapatite could promote bone deposition on the implant surface and promote the formation of direct chemical bonds between the implant and the bone interface, which might reduce the complication rates in patients.^[28,44]

It has been reported that ASD after PLIF is not a complication caused by the fusion itself; ASD is more likely to be caused by normal aging process.^[45] However, Lu et al.^[15] reported that different methods of surgical treatments had greater influences on ASD than age and gender. Similarly, our results showed that no significant between-group difference was found in age and gender. This indicated that age and gender have a relatively smaller influence on the outcomes of the surgery.

There are several limitations in this meta-analysis. First, lumbar degeneration was a series of diseases in which the overall outcome could vary depending on specific diagnosis, such as intervertebral disc herniation, stenosis, and spondylolisthesis. Second, most of the included studies were retrospective studies. As a result, there would be an inherent limitation associated with the risks of reporting or selection bias. Third, different types of dynamic devices used in adjacent segments could have different structures, which might influence the outcomes. Therefore, more randomized controlled trials were needed to verify the results of this study.

5. Conclusions

Topping-off can effectively prevent the ASD from progressing after lumbar internal fixation, which is more effective in proximal segments. Compared with PLIF, topping-off technique was more effective in improving subjective feelings of patients rather than objective motor functions. However, no significant difference between topping-off technique and PLIF can be found in the rates of complications.

Acknowledgments

This research was performed mainly at the Department of Orthopaedics of Xuanwu Hospital Capital Medical University and in the National Clinical Research Center for Geriatric Diseases.

Author contributions

Conceptualization: Wei Wang, Xiangyao Sun, Tongtong Zhang, Xingyu Li.

Data curation: Wei Wang, Xiangyao Sun, Tongtong Zhang, Xingyu Li.

Formal analysis: Wei Wang, Xiangyao Sun, Tongtong Zhang, Xingyu Li, Shibao Lu.

Funding acquisition: Shibao Lu.

Investigation: Wei Wang, Xiangyao Sun, Tongtong Zhang, Junzhe Ding, Shibao Lu.

Methodology: Wei Wang, Xiangyao Sun, Tongtong Zhang, Junzhe Ding.

Project administration: Wei Wang, Xiangyao Sun, Tongtong Zhang, Junzhe Ding.

Resources: Wei Wang, Xiangyao Sun, Siyuan Sun.

Software: Wei Wang, Xiangyao Sun, Siyuan Sun.

Supervision: Wei Wang, Xiangyao Sun, Siyuan Sun.

Validation: Wei Wang, Xiangyao Sun.

Visualization: Wei Wang, Xiangyao Sun, Chao Kong.

Writing – original draft: Wei Wang, Xiangyao Sun.

Writing – review & editing: Wei Wang, Xiangyao Sun.

Shibao Lu orcid: 0000-0002-2389-9683.

References

- [1] Kaiser MG, Eck JC, Groff MW, et al. Guideline update for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 17: bone growth stimulators as an adjunct for lumbar fusion. *J Neurosurg Spine* 2014;21:133–9.
- [2] Liu H, Xu Y, Yang SD, et al. Unilateral versus bilateral pedicle screw fixation with posterior lumbar interbody fusion for lumbar degenerative diseases: a meta-analysis. *Medicine* 2017;96:e6882.
- [3] Anandjiwala J, Seo JY, Ha KY, et al. Adjacent segment degeneration after instrumented posterolateral lumbar fusion: a prospective cohort study with a minimum five-year follow-up. *Eur Spine J* 2011;20:1951–60.
- [4] Khoueir P, Kim K A, Wang M Y. Classification of posterior dynamic stabilization devices. *Neurosurg Focus* 2007;22:E3.
- [5] Hoff E, Strube P, Rohlmann A, et al. Which radiographic parameters are linked to failure of a dynamic spinal implant? *Clin Orthop Relat Res* 2012;470:1834–46.
- [6] Reichl M, Kueny RA, Danyali R, et al. Biomechanical effects of a dynamic topping off instrumentation in a long rigid pedicle screw construct. *Clin Spine Surg* 2017;30:E440–7.
- [7] Lee SE, Jahng TA, Kim HJ. Hybrid surgery combined with dynamic stabilization system and fusion for the multilevel degenerative disease of the lumbosacral spine. *Int J Spine Surg* 2015;9:45.
- [8] Bredow J, Lohrer L, Oppermann J, et al. Pathoanatomic risk factors for instability and adjacent segment disease in lumbar spine: how to use topping off? *Biomed Res Int* 2017;2017:2964529.
- [9] Chou PH, Lin HH, An HS, et al. Could the topping-off technique be the preventive strategy against adjacent segment disease after pedicle screw-based fusion in lumbar degenerative diseases? A systematic review. *Biomed Res Int* 2017;2017:4385620.
- [10] Baioni A, Di Silvestre M, Greggi T, et al. Does hybrid fixation prevent junctional disease after posterior fusion for degenerative lumbar disorders? A minimum 5-year follow-up study. *Eur Spine J* 2015;24 (Suppl 7):855–64.
- [11] Coe JD, Kitchel SH, Meisel HJ, et al. NFlex dynamic stabilization system: two-year clinical outcomes of multi-center study. *J Korean Neurosurg Soc* 2012;51:343–9.
- [12] Hudson WR, Gee JE, Billys JB, et al. Hybrid dynamic stabilization with posterior spinal fusion in the lumbar spine. *SAS J* 2011;5: 36–43.
- [13] Greiner-Perth R, Sellhast N, Perler G, et al. Dynamic posterior stabilization for degenerative lumbar spine disease: a large consecutive case series with long-term follow-up by additional postal survey. *Eur Spine J* 2016;25:2563–70.
- [14] Chen XL, Guan L, Liu YZ, et al. Interspinous dynamic stabilization adjacent to fusion versus double-segment fusion for treatment of lumbar degenerative disease with a minimum follow-up of three years. *Int Orthop* 2016;40:1275–83.
- [15] Lu K, Liliang PC, Wang HK, et al. Reduction in adjacent-segment degeneration after multilevel posterior lumbar interbody fusion with proximal DIAM implantation. *J Neurosurg Spine* 2015;23:190–6.
- [16] Korovessis P, Repantis T, Zacharatos S, et al. Does Wallis implant reduce adjacent segment degeneration above lumbosacral instrumented fusion? *Eur Spine J* 2009;18:830–40.
- [17] Maserati MB, Tormenti MJ, Panczykowski DM, et al. The use of a hybrid dynamic stabilization and fusion system in the lumbar spine: preliminary experience. *Neurosurg Focus* 2010;28:E2.
- [18] Putzier M, Hoff E, Tohtz S, et al. Dynamic stabilization adjacent to single-level fusion: part II. no clinical benefit for asymptomatic, initially degenerated adjacent segments after 6 years follow-up. *Eur Spine J* 2010;19:2181–9.
- [19] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg* 2010;8:336–41.
- [20] Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol* 2010;25:603–5.
- [21] Lee CH, Hyun SJ, Kim KJ, et al. The efficacy of lumbar hybrid stabilization using the DIAM to delay adjacent segment degeneration: an intervention comparison study with a minimum 2-year follow-up. *Neurosurgery* 2013;73(2 Suppl Operative):s224–31.
- [22] Li D, Hai Y, Meng X, et al. Topping-off surgery vs posterior lumbar interbody fusion for degenerative lumbar disease: a comparative study of clinical efficacy and adjacent segment degeneration. *J Orthop Surg Res* 2019;14:197.
- [23] Herren C, Simons RM, Bredow J, et al. Posterior lumbar interbody fusion versus dynamic hybrid instrumentation: a prospective randomized clinical trial. *World Neurosurg* 2018;117:e228–37.
- [24] Aygun H, Yaray O, Mutlu M. Does the addition of a dynamic pedicle screw to a fusion segment prevent adjacent segment pathology in the lumbar spine? *Asian Spine J* 2017;11:715–21.
- [25] Zhu Z, Liu C, Wang K, et al. Topping-off technique prevents aggravation of degeneration of adjacent segment fusion revealed by retrospective and finite element biomechanical analysis. *J Orthop Surg Res* 2015;10:10.
- [26] Liu HY, Zhou J, Wang B, et al. Comparison of topping-off and posterior lumbar interbody fusion surgery in lumbar degenerative disease: a retrospective study. *Chin Med J* 2012;125:3942–6.
- [27] Putzier M, Hoff E, Tohtz S, et al. Dynamic stabilization adjacent to single-level fusion: Part II. No clinical benefit for asymptomatic, initially degenerated adjacent segments after 6 years follow-up. *Eur Spine J* 2010;19:2181–9.
- [28] Umehara S, Zindrick MR, Patwardhan AG, et al. The biomechanical effect of postoperative hypolordosis in instrumented lumbar fusion on instrumented and adjacent spinal segments. *Spine* 2000;25:1617–24.
- [29] Gillet P. The fate of the adjacent motion segments after lumbar fusion. *J Spinal Disord Tech* 2003;16:338–45.
- [30] Cheh G, Bridwell KH, Lenke LG, et al. Adjacent segment disease following lumbar/thoracolumbar fusion with pedicle screw instrumentation: a minimum 5-year follow-up. *Spine (Phila Pa 1976)* 2007;32:2253–7.
- [31] Okuda S, Oda T, Miyauchi A, et al. Surgical outcomes of posterior lumbar interbody fusion in elderly patients. *J Bone Joint Surg Am* 2006;88:2714–20.
- [32] Rothenfluh DA, Mueller DA, Rothenfluh E, et al. Pelvic incidence-lumbar lordosis mismatch predisposes to adjacent segment disease after lumbar spinal fusion. *Eur Spine J* 2015;24:1251–8.
- [33] Ghiselli G, Wang JC, Bhatia NN, et al. Adjacent segment degeneration in the lumbar spine. *J Bone Joint Surg Am* 2004;86-A:1497–503.
- [34] Hegewald AA, Hartmann S, Keiler A, et al. Biomechanical investigation of lumbar hybrid stabilization in two-level posterior instrumentation. *Eur Spine J* 2018;27:1887–94.
- [35] Imagama S, Kawakami N, Matsubara Y, et al. Radiographic adjacent segment degeneration at 5 years after 14/5 posterior lumbar interbody fusion with pedicle screw instrumentation: evaluation by computed tomography and annual screening with magnetic resonance imaging. *Clin Spine Surg* 2016;29:E442–51.
- [36] Pan A, Hai Y, Yang J, et al. Adjacent segment degeneration after lumbar spinal fusion compared with motion-preservation procedures: a meta-analysis. *Eur Spine J* 2016;25:1522–32.
- [37] Chien CY, Kuo YJ, Lin SC, et al. Kinematic and mechanical comparisons of lumbar hybrid fixation using dynesys and cosmic systems. *Spine* 2014;39:E878–84.
- [38] Ko CC, Tsai HW, Huang WC, et al. Screw loosening in the dynesys stabilization system: radiographic evidence and effect on outcomes. *Neurosurg Focus* 2010;28:E10.

- [39] Burton AK, Balague F, Cardon G, et al. Chapter 2. European guidelines for prevention in low back pain: November 2004. *Eur Spine J* 2006;15 (Suppl 2):S136–68.
- [40] Kashkoush A, Agarwal N, Paschel E, et al. Evaluation of a hybrid dynamic stabilization and fusion system in the lumbar spine: a 10 year experience. *Cureus* 2016;8:e637.
- [41] Zang L, Hai DUP, Su Y, et al. Device related complications of the Coflex interspinous process implant for the lumbar spine. *Chin Med J* 2013;126:2517–22.
- [42] Lee CH, Jahng TA, Hyun SJ, et al. Dynamic stabilization using the Dynesys system versus posterior lumbar interbody fusion for the treatment of degenerative lumbar spinal disease: a clinical and radiological outcomes-based meta-analysis. *Neurosurg Focus* 2016;40: E7.
- [43] Dakhil-Jerew F, Jadeja H, Cohen A, et al. Inter-observer reliability of detecting Dynesys pedicle screw using plain X-rays: a study on 50 post-operative patients. *Eur Spine J* 2009;18:1486–93.
- [44] Sanden B, Olerud C, Larsson S. Hydroxyapatite coating enhances fixation of loaded pedicle screws: a mechanical in vivo study in sheep. *Eur Spine J* 2001;10:334–9.
- [45] Okuda S, Iwasaki M, Miyauchi A, et al. Risk factors for adjacent segment degeneration after PLIF. *Spine* 2004;29:1535–40.