



Clinical outcomes and complications after biportal endoscopic spine surgery: a comprehensive systematic review and meta-analysis of 3673 cases

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Abstract

Purpose Current literature suggests that biportal spinal endoscopy is safe and effective in treating lumbar spine pathology such as lumbar disc herniation, lumbar stenosis, and degenerative spondylolisthesis. No prior study has investigated the postoperative outcomes or complication profile of the technique as a whole. This study serves as the first comprehensive systematic review and meta-analysis of biportal spinal endoscopy in the lumbar spine.

Methods A PubMed literature search provided over 100 studies. 42 papers were reviewed and 3673 cases were identified with average follow-up time of 12.5 months. Preoperative diagnoses consisted of acute disc herniation (1098), lumbar stenosis (2432), and degenerative spondylolisthesis (229). Demographics, operative details, complications, and perioperative outcome and satisfaction scores were analyzed.

Results Average age was 61.32 years, 48% male. 2402 decompressions, 1056 discectomies, and 261 transforaminal lumbar Interbody fusions (TLIFs) were performed. Surgery was performed on 4376 lumbar levels, with L4-5 being most common (61.3%). 290 total complications occurred, 2.23% durotomies, 1.29% inadequate decompressions, 3.79% epidural hematomas, and < 1% transient nerve root injuries, infections, and iatrogenic instability. Significant improvement in VAS-Back, VAS-Leg, ODI, and Macnab Scores were seen across the cohort.

Conclusion Biportal spinal endoscopy is a novel method to address pathology in the lumbar spine with direct visualization through an endoscopic approach. Complications are comparable to previously published rates. Clinical outcomes demonstrate effectiveness. Prospective studies are required to assess the efficacy of the technique as compared to traditional techniques. This study demonstrates that the technique can be successful in the lumbar spine.

Keywords Biportal endoscopic spine surgery · Endoscopic spine surgery · Minimally invasive spine surgery

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Introduction

With the growing demand for increasingly less invasive surgery, spinal endoscopy has grown in utilization particularly in Asia and Europe [1]. Spinal endoscopy has been employed for a variety of indications ranging from degenerative pathology to malignancy. There are multiple endoscopic techniques and platforms, including uniportal endoscopy, microendoscopy, and biportal endoscopy. In general, the literature to date has shown that biportal spinal endoscopy is safe and effective in treating lumbar spine pathology. Similar in principle to arthroscopy, biportal endoscopic spinal surgery has been employed successfully in the lumbar spine for the treatment of degenerative lumbar stenosis, primary and recurrent disc protrusion/extrusion, spondylolisthesis,

and segmental instability [2–5]. If the trends of arthroscopic utilization in knee and shoulder pathology hold, it is likely that endoscopic surgery for spine will be in greater demand by both patients and clinicians alike in the future. It is thus of great clinical importance to determine the safety profile and expected postoperative outcomes of these procedures.

While there have been multiple case reports and series detailing surgical technique, post-operative complications and outcomes of biportal endoscopy, comprehensive evaluations in the form of prospective/randomized controlled trials or systematic reviews are lacking. While prior studies have evaluated the performance of the techniques, no study has investigated the postoperative outcomes or complication profile of the technique as a whole. Furthermore, no extensive analyses have been done with regard to clinical outcomes after endoscopic decompression via discectomy, laminectomy, and transforaminal lumbar Interbody fusions (TLIFs). We aim to investigate the post-operative outcomes and complication profile of biportal endoscopic lumbar spine surgery with a comprehensive systematic review and meta-analysis. We hypothesize that outcomes will be favorable with a low complication profile overall.

Methods

Literature Search

The PubMed library database was utilized in the development of this systematic review. A comprehensive search was completed collecting all articles dates prior to March 31st, 2022. Utilizing search terms “Biportal” and “Lumbar”, abstracts and article titles were individually reviewed in conjunction with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist. This yielded over 100 articles for review. Literature was selected and analyzed to ensure that it followed the following inclusion criteria: 1) Studies written in the English language; 2) Primary reports, series, clinical trials, or cohort studies; 3) Published in Peer-Reviewed Journals; 4) Contained subjects, demographics, complication profiles, and functional outcome scores. Any meta-analyses, systematic reviews, cadaveric, biomechanical or animal-based experiments were excluded for the purposes of this study. After inclusion/exclusion, a total of 46 studies were evaluated further. One study was removed due to copyright access restrictions. A technique paper without patient demographics, complications, or outcomes profiles was also removed from analysis. Lastly, 2 additional studies were removed as duplicates. A total of 42 studies, with 3673 cases, were

subsequently included for analysis [2, 3, 5–43]. A total of 28 articles were retrospective studies, 12 were prospective, and 2 were case reports.

Data Abstraction

A full text review of each article took place after inclusion/exclusion criteria were applied. Data on patient age, sex, study period, clinical follow-up, preoperative diagnosis/indications, biportal endoscopic decompression technique (laminectomy, discectomy, and TLIF), operative detail (including lumbar level, operative time and blood loss), hospital stay length, and functional outcome scores were abstracted and reported.

Statistics

Only studies reporting estimates of variance, such as standard deviation, for functional outcome scores were included in the meta-analysis. Functional outcomes were analyzed using a random effects model with sub-group analysis performed for different procedure types using the “meta” package [44]. Between study heterogeneity was quantified using I^2 [2] and Cochran’s Q . The between study variance, τ^2 , was used to generate prediction intervals for each sub-group and the study population as a whole. In analysis of complication rates, only studies reporting clinically diagnosed complications, rather than those uncovered during routine post-operative MRI without any clinical symptoms, were included in analysis. To generate estimates of complication rates across studies, multi-level logistic regression models with 95% prediction intervals generated using bootstrapping with 1000 replicates to account for between study heterogeneity using the “lme4” package in R [45]. All tests were unpaired with a significance level defined as a 2-tailed P of 0.05. Statistical analysis was carried out in R 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Demographics (Table 1)

A total of 42 papers were included for analysis and review, providing 3673 patients and 3719 cases with an average follow-up time of 12.5 months. Leading preoperative diagnoses consisted of acute disc herniation (1098), lumbar stenosis (2432), and degenerative spondylolisthesis (229). The average age of the population was 61.32 years, with 48% identifying as male. Surgery was performed on

Table 1 Table depicting the overall demographic data collected for the study from the papers that fit the inclusion criteria

Demographics	
Average study period(Years)	1.6
Total patients	3673
Average age	61.3
Total males	1752
Total females	1899
Total operative levels	4376
Average follow-up (Months)	12.5
Preoperative disc herniation	1098
Preoperative lumbar stenosis	2432
Preoperative degenerative spondylolisthesis	229
Preoperative facet cysts	2

4376 lumbar levels, with L4-5 as the most common level (61.3%).

Operative Detail and Complication Profile

A total of 1056 Biportal Endoscopic Discectomies and 2402 Biportal Endoscopic Laminectomies were employed. The least utilized intervention for Biportal Endoscopic decompression in the lumbar spine was TLIF, with a total of 261 cases. Mean age was significantly different between groups ($p < 0.001$). The average age for Biportal Discectomy was 50, whereas the ages for Biportal Laminectomy and TLIF were 65 and 67 respectively. The most common lumbar level was L4-5 followed widely by adjacent levels above and below (Table 2). Of a total 3761 operative levels, the average operative time was 89.53 min (range: 36–182). Estimated blood loss (EBL) was noted at 119.24 cc on average (range: 34.67–332.1). Total Hospital

stay varied widely, but was found to be 5.38 days on average (range: 0.33–14.53).

There were 290 total complications, with 2.23% durotomies, 1.29% inadequate decompressions, 3.79% epidural hematomas, and < 1% for transient nerve root injuries, infections, and iatrogenic instability (Table 3). Total complication percentage was 7.79% amongst all cases.

Subgroup complication analysis noted dural tear, epidural hematoma, and incomplete decompression to be most common. Dural tear and epidural hematoma were most common in the TLIF group at 2.1% and 2.4%, respectively. The highest reported incidence of dural tear and epidural hematoma was 5%. Incomplete decompression was highest at 1.7% in biportal laminectomy cases. In general, no complication occurred at a rate greater than 2.5%, irrespective of surgical procedure (Table 4).

Functional Outcome and Patient-Reported Satisfaction Scores

Perioperative outcome scores (VAS – Visual Analog Scale, and ODI – Oswestry Disability Index), as well as patient satisfaction MacNab scores were analyzed from 36 papers which included this data. Significant improvements in total scores for VAS-Back, VAS-Leg, and ODI ($p < 0.01$) were seen across the cohort when assessing perioperative change (Figs. 1, 2, 3). When calculating the mean difference in preoperative to postoperative outcome scores, VAS-Back improved by a mean of 4.06 (95% CI: 3.59–4.53), VAS-Leg improved by 5.47 (95% CI: 5.04–5.91), and ODI improved by 40.62 (95% CI: 36.13–45.10). Patients reported a mean MacNab score of 80.06% (Range: 56.1%–95%). On average, Biportal discectomy had the highest patient satisfaction scores at 82.4%, followed by decompression at 80.8% and TLIF at 70.3%.

Table 2 Operative Detail

Biportal endoscopic discectomy	Biportal endoscopic decompression	Biportal endoscopic TLIF	Surgery performed at lumbar levels				
			L1-L2	L2-L3	L3-L4	L4-L5	L5-S1
1056	2402	261	2	101	351	1255	338

Table depicting the number of each surgery type performed and the lumbar levels involved in the surgeries

Table 3 Global Complication Profile

	Dural tear	Incomplete decompression	Epidural hematoma	Nerve root injury (transient)	Iatrogenic instability	Infection
Total	83	48	141	9	6	3
% of cases	2.23%	1.29%	3.79%	0.24%	0.16%	0.08%

Table depicting the number of occurrences for the respective complications and the percentage rate of each complication

Table 4 Subgroup complication analysis

	Group	Min	Mean	Max
Dural tear	TLIF	0.002	0.021	0.050
	Laminectomy	0.009	0.018	0.029
	Discectomy	0.001	0.018	0.041
Epidural hematoma	TLIF	0.004	0.024	0.050
	Laminectomy	0.008	0.014	0.020
	Discectomy	0.000	0.000	0.000
Nerve injury	TLIF	0.000	0.009	0.022
	Laminectomy	0.000	0.000	0.001
	Discectomy	0.000	0.007	0.018
Incomplete decompression	TLIF	0.021	0.004	0.021
	Laminectomy	0.017	0.017	0.167
	Discectomy	0.023	0.005	0.050
Iatrogenic instability	TLIF	0.018	0.004	0.018
	Laminectomy	0.006	0.002	0.006
	Discectomy	0.000	0.000	0.000
Infection	TLIF	0.014	0.004	0.014
	Laminectomy	0.001	0.000	0.001
	Discectomy	0.002	0.001	0.002

Table depicting the subgroup analysis of the complications for each of the surgery types

Perioperative outcome scores were also analyzed by surgical procedure. Similar significant improvements ($p < 0.01$) in VAS-Back, VAS-Leg, and ODI scores were noted for biportal endoscopic laminectomy, discectomy, and TLIF, respectively (Figs. 1, 2, 3). For biportal endoscopic TLIF, VAS-Back improved by a mean of 3.86 (95% CI: 2.91–4.81; $p < 0.01$), VAS-Leg improved by 5.35 (95% CI: 3.77–6.94; $p < 0.01$), and ODI improved by 41.62 (95% CI: 30.90–52.34; $p < 0.01$). Similarly, for biportal endoscopic discectomy, VAS-Back improved by a mean of 4.43 (95% CI: 3.35–5.51; $p < 0.01$), VAS-Leg improved by 6.10 (95% CI: 5.57–6.64; $p < 0.01$), and ODI improved by 44.87 (95% CI: 27.57–62.18; $p < 0.01$). Lastly, for biportal endoscopic laminectomy, VAS-Back improved by a mean of 3.95 (95% CI: 3.32–4.59; $p < 0.01$), VAS-Leg improved by 5.25 (95% CI: 4.72–5.79; $p < 0.01$), and ODI improved by 39.36 (95% CI: 34.48–44.25; $p < 0.01$). Overall, improvements were noted in these scores regardless of population heterogeneity or procedure type.

Discussion

Biportal spinal endoscopy is a novel method to address pathology in the lumbar spine, offering surgeons direct visualization through an ultra-minimally invasive approach. Biportal spinal endoscopy differs from uniportal and microendoscopic techniques in that the endoscope is separate from the surgical instruments and triangulated in the surgical region of interest. The use of endoscopic irrigation allows for excellent visualization, especially in obese populations, while providing hemostasis through hydrostatic pressure [46]. This technique is similar to the basic principles of arthroscopy, which is now considered the standard of care in most shoulder and knee surgeries.

This study analyzed a large sample size of 3673 lumbar biportal endoscopic cases, ranging from discectomies, decompressions, and TLIFs, and demonstrated the clinical effectiveness with improved clinical outcome scores demonstrating clinical success. Across all the various surgery types, the biportal technique significantly improved post-operative VAS-back, VAS-leg and ODI scores as compared to the preoperative status. These findings were consistent for all 3 procedures across all reporting studies, despite $> 80\%$ heterogeneity amongst available literature. Most importantly, confidence intervals remained narrow, with all mean differences remaining > 0 for functional outcome scores above ($p < 0.01$). This suggests that reported functional improvements hold true for each procedure despite significant differences in patient population. Additionally, using the MacNab score, $\sim 80\%$ patient satisfaction overall was reported. Thus, functional outcome improvements mirror patient satisfaction reports with respect to each procedure. Differences in perioperative metrics such as EBL, Hospital-Stay, and Operative Time did not influence these findings.

The 3 main complications seen with the highest rates in our study were (1) dural tears, (2) incomplete decompression, and (3) epidural hematoma. Although dural tears had the highest proportion of the reported complications across the published studies, the overall dural tear rate was 2.23%, which is in the lower range of the previously reported incidence of dural tears in the literature (1.6 to 10%) [47–49]. Biportal discectomy had the lowest rate of dural tears at 1.8% while biportal TLIF had the highest rate at 2.1%, which is likely associated with the use of osteotomes to perform the facetectomy during the TLIF procedure. In contrast, biportal decompressions had the highest rates of inadequate decompression at 1.7%, which may be related to the surgeons' technique during their learning curve, which were included in many of the studies included in this analysis. Biportal studies included in the analysis are unique in that the vast majority of biportal cases had post-operative MRIs

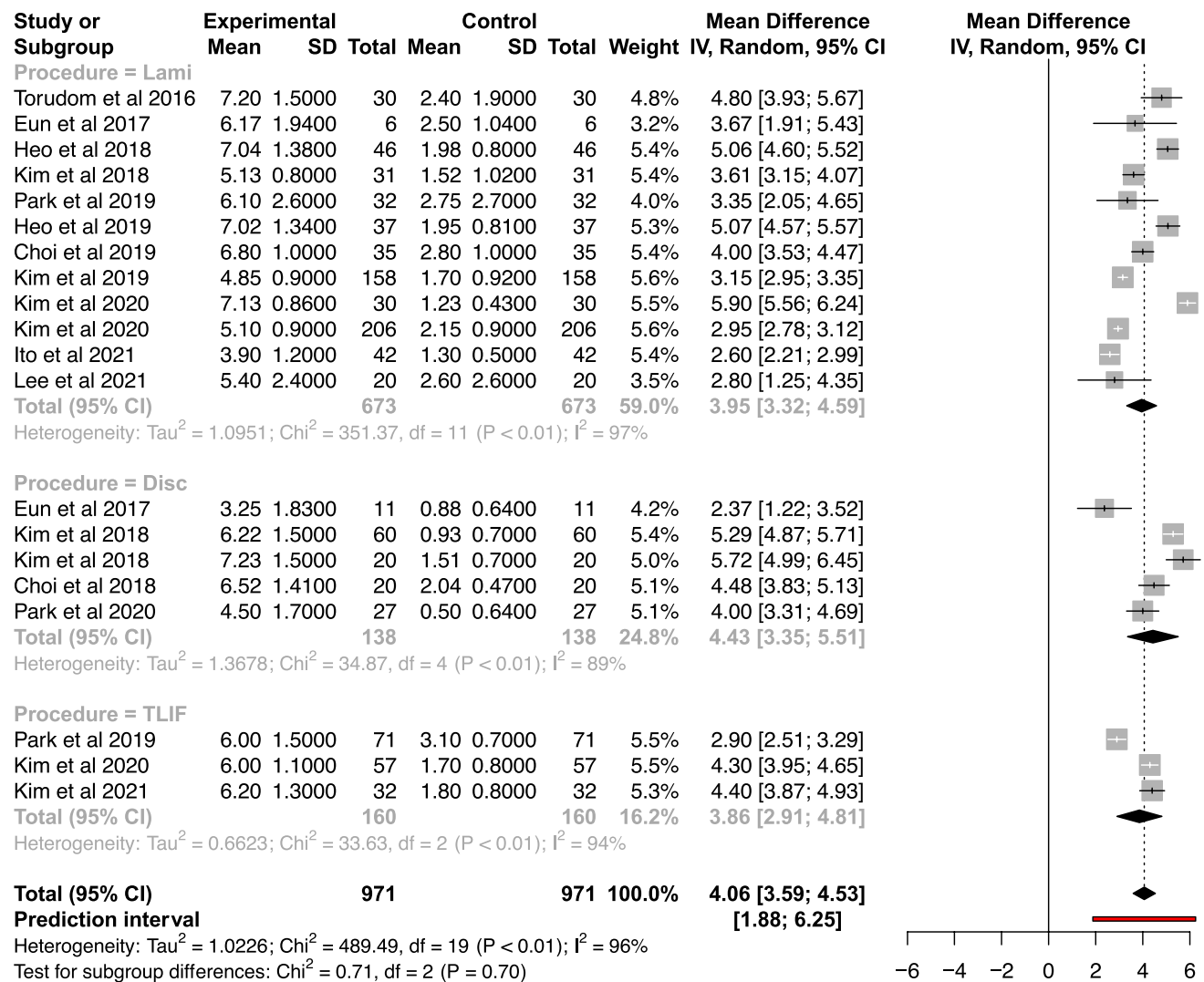


Fig. 1 Mean Difference in VAS-Back Scores by Surgical Procedure. Analysis of Heterogeneity. Figure depicting meta-analysis of the VAS-Back Scores for each of the surgery types and the analysis of

heterogeneity. Improvement was demonstrated regardless of population heterogeneity or surgery type

for analysis, allowing us to determine an accurate rate of complications such as inadequate decompression. This rate is consistent with the rate of reoperation within 30 days after a standard lumbar laminectomy or discectomy (2.2%), which is the closest comparison in the literature since most studies do not routinely obtain post-operative MRIs to evaluate the surgical results [50].

The overall rate of epidural hematoma was 3.79% and was the highest in biportal TLIF at 2.4%, likely due to the increased bony resection required for TLIF leading to more bony bleeding into the epidural space. The paraspinal musculature and soft tissue envelope closes quite effectively after biportal endoscopy due to very small fascial incisions for the endoscope and working portal, potentially retaining any bleeding at the surgical site with reduced egress. In

addition, the hydrostatic pressure of the endoscopic fluid assists with hemostasis but once the endoscopic fluid is removed and the pressure dissipates, bleeding can occur within the laminotomy site, leading to a false sense of security. Strategies such as keeping the fluid pressure low, examining for sources of bleeding under endoscopic visualization with the fluid pressure off, and the use of a post-operative drain can mitigate the risk of post-operative epidural hematoma. With the strength of routine post-operative MRIs in these biportal studies, our study accurately reflects the incidence of post-operative epidural hematomas with biportal endoscopy, while other studies in the literature only report the incidence of symptomatic hematomas that require evacuation and likely underreport the true incidence [51].

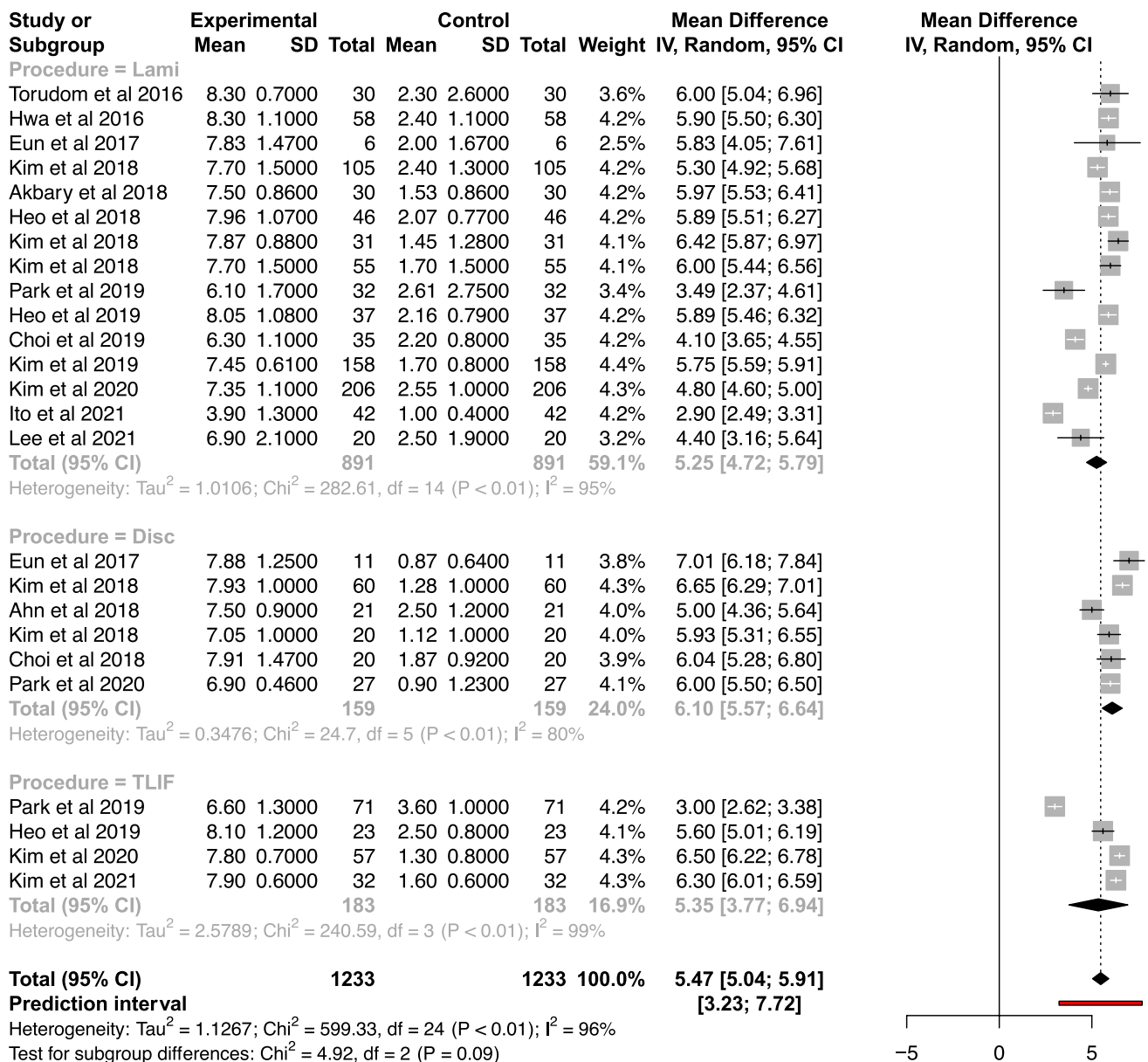


Fig. 2 Mean Difference in VAS-Leg Scores by Surgical Procedure. Analysis of Heterogeneity Figure depicting meta-analysis of the VAS-Leg Scores for each of the surgery types and the analysis of het-

erogeneity. Improvement was demonstrated regardless of population heterogeneity or surgery type

Another important complication to consider is transient nerve root injury as this weigh heavily on the minds of many surgeons considering to learn the technique. Our study demonstrated that the rates were low with the lowest rate with biportal laminectomy decompression at 0%, biportal discectomy at 0.7%, and the highest rate seen with biportal TLIF at 0.9%. The endoscopic fluid creates hydrostatic pressure that helps gently displace the thecal sac and nerve roots away from the endoscope. This allows for more of a working space for the surgical instruments without significant retraction of the neural elements. Evaniew et al. performed

a meta-analysis on nerve root injuries after open lumbar discectomy, which resulted in a 2.25% rate and Mehta et al. demonstrated that TLIF had a 2% rate of post-operative nerve root injury [52, 53].

Biportal decompressions had the highest rate of iatrogenic instability with 0.6%, which may be correlated with performing the decompression with concomitant degenerative spondylolisthesis that may be at the cusp of instability. Despite the preservation of the posterior ligamentous complex and paraspinal muscular attachments, facet violation may not be avoidable to perform a complete decompression,

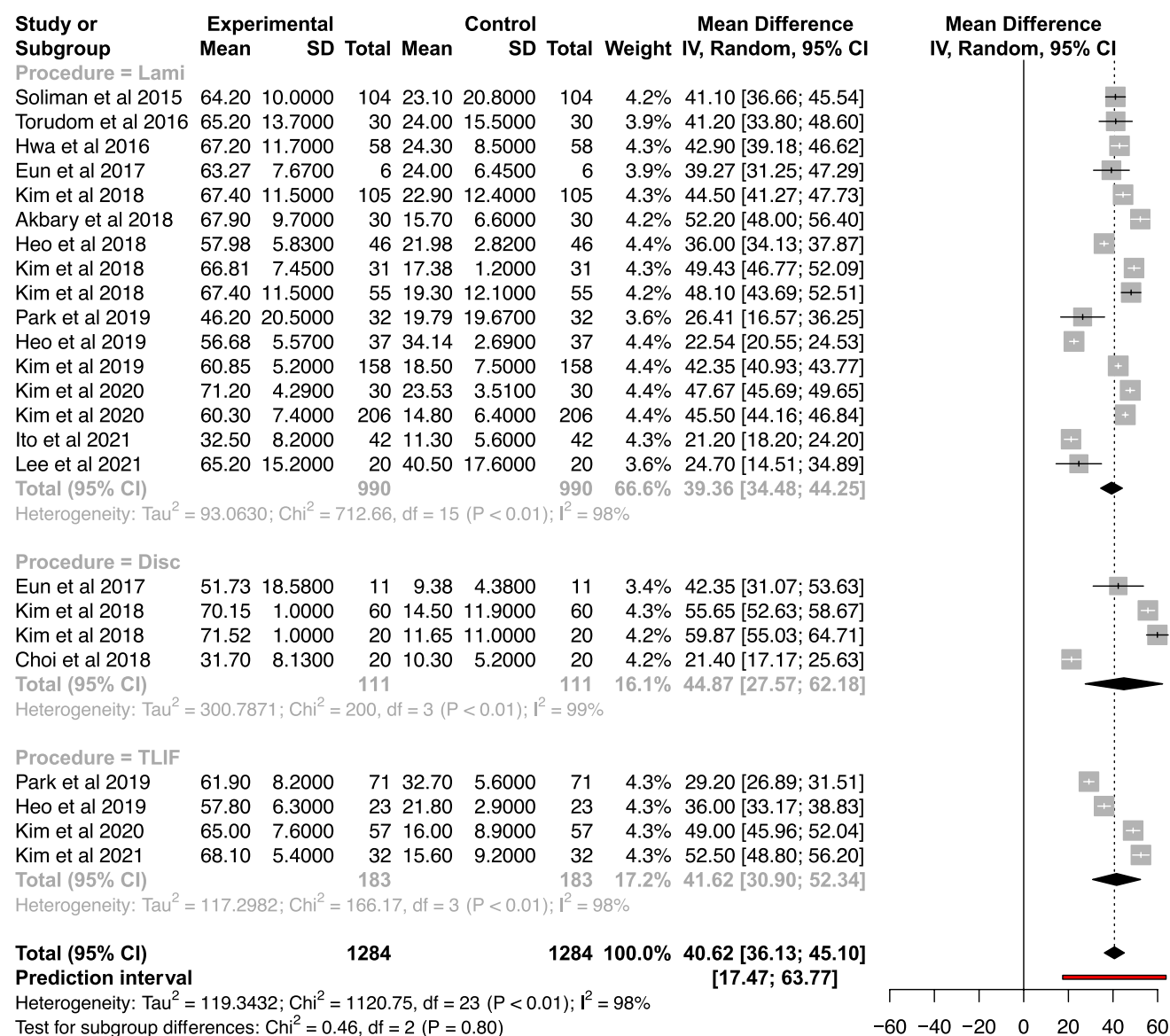


Fig. 3 Mean Difference in ODI Scores by Surgical Procedure. Analysis of Heterogeneity. Figure depicting meta-analysis of the ODI Scores for each of the surgery types and the analysis of heterogeneity.

Improvement was demonstrated regardless of population heterogeneity or surgery type

hence leading to iatrogenic instability. However, the rates of iatrogenic instability were quite low in our study. As expected, the rate of post-operative infection was very low with only 3 total cases of the entire cohort, which is likely due to the constant flow of endoscopic irrigation through the surgical field and the ultra-minimally invasive nature of the technique. In all, our study demonstrated that the complication rates with biportal endoscopy are at least comparable or even lower than the published rates in the literature, demonstrating the safety of the technique.

There are several limitations to this study. (1) Utilizing heterogeneous populations in our analysis for external publications exposes potential for publication bias. We attempted

to control for bias within PRISMA guidelines by selecting for primary clinical studies, analyzing only raw data. (2) There were less cases reported for the TLIF group. As such, despite attempting to control for heterogeneity, analyses may be underpowered for this particular surgical technique. (3) MRI was obtained postoperatively for the vast majority of patients who underwent biportal endoscopic surgeries in Korea. This artificially inflates the complication profile as the majority of the incomplete decompressions and epidural hematomas were asymptomatic and only noted due to available data from advanced imaging. This potentially overestimates the reported complications associated with biportal techniques. (4) Given the nature of systematic reviews and

meta-analyses in general, we are limited by the data presented in each article. Certain studies were excluded from analysis given absence data, or failures to report standard deviations, means, etc. However, this is likely due to the lack of literature within the field of endoscopic spine surgery globally. This relatively novel technique has remained in a unique niche, only recently introduced in the Western Hemisphere. Nonetheless, our findings show favorable results, which may help increase the employment of these techniques; increasing the likelihood of future quality comparative studies.

In conclusion, our study examining 3673 cases demonstrated that biportal spinal endoscopy is safe and effective. Complications are comparable or less than previously published rates with respect to open and microscopic techniques. Overall, durotomy, inadequate decompression, and epidural hematoma occur < 4% of the time. Clinical outcomes are promising with approximately 80% overall patient satisfaction and significant improvements in pain and disability scores postoperatively. Large, prospective studies are required to assess the efficacy of the technique as compared to traditional techniques; however, this comprehensive review and meta-analysis demonstrates that biportal spinal endoscopy can be successfully utilized in the lumbar spine.

Declarations

Conflict of interest No funds, grants, or other support was received.

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