Comparison of Simultaneous Single-position Oblique Lumbar Interbody Fusion and Percutaneous Pedicle Screw Fixation with Posterior Lumbar Interbody Fusion using O-arm Navigated C-arm free Technique for Lumbar Degenerative Diseases

Ying Tan
Okayama Rosai Hospital: Okayama Rosai Byoin
Masato Tanaka (tanaka0896@gmail.com)
Okayama Rosai Byoin https://orcid.org/0000-0001-6685-7451
Sumeet Sonawane
Okayama Rosai Hospital: Okayama Rosai Byoin
Koji Uotani
Okayama Rosai Hospital: Okayama Rosai Byoin
Yoshiaki Oda
Okayama Rosai Hospital: Okayama Rosai Byoin
Yoshihiro Fujiwara
Okayama Rosai Hospital: Okayama Rosai Byoin
Shinya Arataki
Okayama Rosai Hospital: Okayama Rosai Byoin
Taro Yamauchi
Okayama Rosai Hospital: Okayama Rosai Byoin
Tomoyuki Takigawa
Kobe Red Cross Hospital: Kobe Sekijuji Byoin
Yasuo Ito
Kobe Red Cross Hospital: Kobe Sekijuji Byoin

Research article

Keywords: C-arm free, O-arm navigation, simultaneous single position oblique lateral interbody fusion, indirect decompression

Posted Date: November 1st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-968619/v1

Abstract

Background: To compare the clinical, surgical and radiographic outcomes of O-arm navigated C-arm free, simultaneous single-position oblique lumbar interbody fusion (OLIF) and percutaneous pedicle screw (PPS) fixation with minimally invasive posterior/ transforaminal lumbar interbody fusion (MI-PLIF/TLIF).

Methods: This is retrospective comparative study. The study included 98 patients, 63 in single position OLIF (group SO) and 35 in MI-PLIF/TLIF (group P/T). Surgical time, blood loss, mobilization time after surgery and complications were analyzed for all patients. Clinical evaluation included visual analog scale (VAS) for back pain, oswestry disability index (ODI). Radiological parameters included cage height (CH), cage to disc ratio (CDR), DH change, pre and postoperative disc height (DH), foraminal height (FH), foraminal area (FA), segmental lordosis (SL).

Results: In group SO (vs group P/T), surgical time, blood loss and mobilization time were 117.7± 34.1 minutes (171.8 ± 40.6 minutes, $p<0.000001$), 139.2 ± 82.0 ml (vs. 374.2 ± 247.7 ml, $p<0.000001$) and 2.7 ±1 .0 days (vs 3.9 ± 2.4 days, $p<0.000001$) respectively. The CH, CDR, DH change and postoperative DH, FH, FA increase were statistically significant in group SO compared to group P/T. VAS and ODI improvement were similar in both groups. Mobilization time is shorter in group SO. Total complication rate in group SO was 7% while that in group P/T was 11%.

Conclusions: Simultaneous single position O-arm navigated C-arm free OLIF reduces the surgical time, blood loss, mobilization time after operation without the risk of an adverse event of intraoperative radiation to operating staff. Good indirect decompression can be achieved with this method. Clinical results were similar in both groups.

Introduction

Spinal instability due to degenerative, traumatic, infectious and neoplastic diseases may require fusion [1]. Posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) are widely accepted procedures for this purpose. However, they involve paraspinal muscles stripping, posterior vertebral bone removal, neural tissue handling and risk of dural tear which in long term may lead to chronic back pain [2]. To solve these problem, minimally invasive PLIF/TLIF (MI- PLIF/TLIF) were introduced to reduce some of these complications [3]. Mayer described less invasive retroperitoneal pre-psoas approach; which is now equivalent to oblique lumbar interbody fusion (OLIF) [4]. OLIF has advantages like indirect decompression with less exposure related morbidity, less postoperative pain [5]. This technique also reduces blood loss, accelerates recovery, preserves of posterior structures and there is no neural tissue handling [6]. In conventional OLIF, cage insertion is done in lateral position followed by posterior pedicle screw (PPS) insertion in prone position. This requires change of position which increases operative time and medical cost [7]. To reduce operative time, we started doing single-lateral position OLIF [8]. To further reduce the operative time we reported O-arm navigated single position OLIF with simultaneous PPS insertion by two surgeons in 2017 [9]. There are very few studies comparing the clinical, surgical and radiographic outcomes of the simultaneous single-position OLIF and PPS fixation with MI PLIF/TLIF performed with O-arm navigation. The aim of this study is to compare the same.

Methods

This study was approved by ethics committee of our institute. We retrospectively included 98 patients with lumbar degenerative disease treated with simultaneous single-position OLIF-PPS (63 patients - Group SO) and MI-PLIF/TLIF (7 patients PLIF and 28 patients TLIF total 35 - Group P/T) for a single level from May 2017 to January 2020. More than 1 year follow up were performed for all cases. Group SO included 20 men, 43 women while Group P/T included 15 men and 20 women.

Surgical settings and procedures for single-position OLIF

This procedure is performed in right lateral decubitus position with neuromonitoring. Hinged carbon fiber table is used to facilitate O-arm scan. Patient is kept at posterior aspect of table and secured with tape. Table is bent 15 to 20 degrees to open up the disc spaces. Bone graft is taken from posterior iliac crest and reference frame is applied to sacroiliac joint through same incision. O-arm scan is obtained and images are transmitted to Stealth station navigation system Spine7^{R} (Medtronic, Medtronic Sofamor Danek, Minneapolis, MN, USA). Navigation instruments are registered and using navigated pointer skin incision is marked for intended bilateral PPS and disc space. Through a 2 cm incision, cranial PPS are inserted on either sides into the cranial vertebra (L4) with the help of navigated instruments by the first assisting surgeon. The main surgeon simultaneously proceeds with OLIF cage insertion. The navigated probe helps to center the 4 cm left oblique skin incision. The fibers of external oblique, internal oblique and transversus abdominis muscles are split during exposure. The navigated first navigated dilator is placed anterior to psoas at the disc space level and sequential dilation is performed until a 22mm tubular retractor can be placed. The self-retaining retractors are applied over anterior aspect of psoas. Discectomy, cage insertion and PPS are done simultaneously by 2 separate surgeons using navigated instruments alternately (Figure 1, 2). The important point is after putting distal PPS (L5), then insert the cage because of the navigation accuracy will be changed if the OLIF cage is inserted first. Complete procedure is described in another article of ours [9].

Surgical settings and procedures for MI-PLIF/TLIF

In the MI-PLIF/TLIF group, with use of navigation PLIF patients undergo mini-open partial laminectomy, bilateral cage with bone graft insertion, and PPS. In navigated TLIF, patients are operated with mini-open unilateral facetectomy, bean cage with resected lamina tip bone graft insertion, and PPS. All patients undergo fixation with navigated PPS.

Clinical evaluation

Clinical outcomes assessment included visual analogue scale (VAS) for back pain and Oswestry disability index (ODI). This data was collected preoperatively and post surgery at 3, 6, 12 and 24 months.

The time for ambulation was documented in each group. Any intraoperative or postoperative complications were noted.

Surgical evaluation

Surgical time, blood loss, mobilization time post surgery, any complications like neurological deficit, dural tears, end plate fracture, infection, epidural hematoma, reoperation, implant failure and misplacement were noted.

Radiographic Evaluation

The following radiological outcomes were measured: Pre and postoperative disc height (DH), foraminal height (FH), foraminal area (FA), segmental lordosis (SL). The cage to disc ratio (CDR) and DH change were determined on CT. Cage height (CH) used during surgery was documented.

DH was calculated as the mean value of anterior disc height (ADH) and posterior disc height (PDH). ADH was measured as the distance between the 2 endplates at the anterior aspect of disc space and PDH was measured as the distance between the 2 endplates at the posterior aspect of disc. FH was measured as the distance between the inferior pedicle of cranial vertebra and the superior pedicle of the caudal vertebra. FA and CDR were measured by using a digitalized tool measuring the area in the picture archiving and communication system (SYNAPSE5, Fujifilm medical system, USA). All the data were assessed by 2 senior spine surgeons KU and YF.

The lumbar interbody union was evaluated in each group at one year follow-up CT.

Statistical Analysis

Continuous variables were presented as the mean ± SD and categorical variables as counts. Comparison between groups was performed using Mann–Whitney U test and Chi-squared test, with p value < 0.05 considered statistically significant. All analyses were performed using SPSS (version 19.0; IBM).

Results

Patients' demographic data and level of fusion are given in Table 1. Pre and postoperative clinical, surgical and radiographic data are summarized in Table 2 and Figure 3 to 5. Mean follow up period for group SO was 32.9 ± 7.0 months and that for group P/T was 33.7 ± 7.5 months (ranging from 34 to 12 months) in both groups. Surgery time was less in group SO (112.0 ± 32.4 minutes) than group P/T (171.8 ± 40.6 minutes) with p <0.00001. Blood loss was 139.2 ± 82.0 milliliters in group SO while that in group P/T was 374.2 ± 247.7 milliliters with p <0.00001 (Figure 3). The time for ambulation was significantly shorter in group SO than group P/T (2.7 ± 1.0 days vs 3.9 ± 2.4 days, respectively; p <0.00001).

In radiological parameters, preoperative statistical difference in DH, FA, SL was not significant between both groups except FH which showed statistically significant difference (group SO 14.4 ± 4.5 millimeters vs group P/T 11.7 ± 5.3 millimeters; p < 0.021). Cage height used was significantly more in group SO

(10.1 ± 1.3millimeters) than group P/T (7. 8 ± 1.0 millimeters) with *p* <0.00001. CDR was 5.2 ± 1.9 in group SO and 2.5 ± 2.3 in group P/T. The CDR, postoperative DH, FH and FA were high in group SO than group P/T and the difference was statistically significant with percentile increase of 64% in DH, 25% in FH and 30% in FA in group SO (Figure 4, 5). The fusion rate of group SO and group P/T at one year follow-up were 96.8% and 94.2%, respectively (*p* =0.9849).

The change in VAS and ODI were not statistically significant between both groups. There was one case of reference frame site incision infection which was treated with dressings and antibiotics and four cases had thigh pain and hip flexion weakness which resolved in 2 months in group SO. While two cases in group P/T had dural tear and two cases had hematoma which required evacuation. Thus, total complication rate was 6.3% in group SO and 14.1% in group P/T. These results are summarized in Table 3.

Discussion

PLIF and TLIF are established procedures for lumbar fusion. However, these techniques are associated with complications like paraspinal muscle injury, damage to posterior support structures, prolonged muscle retraction, difficulty in disc space visualisation and preparation, need for revision surgery [1, 10]. These led surgeons towards indirect decompression which relies on restoration of disc height leading to increase in foraminal height, stretching of ligamentum flavum and posterior longitudinal ligament restoring central spinal canal [11]. OLIF and lateral lumbar interbody fusion (LLIF) provide advantages like, indirect neural decompression with solid bone fusion, large cage insertion, low risk of cage subsidence, less incidence of dural tears. Compared to posterior procedures, there is better restoration of coronal and sagittal profile [12, 13]. One of the indirect decompression procedures is LLIF which utilizes trans-psoas route [14]. But LLIF has unique disadvantages like lumbar plexus injury and psoas muscle weakness [15]. With conventional LLIF, C-arm usage is necessary and navigated implants and instruments are difficult to use. For these reasons, OLIF has received considerable attention as it provides enhances the visual operative field, reduces, neurological complications, approach is anterior to psoas and navigated implants are available [1, 13, 16].

Traditionally with OLIF procedure, a cage is inserted in lateral position and PPS is done in prone position. This needs change of position leading to increase surgical time. It has been proved that single position OLIF reduced surgery time by almost 60 minutes [7, 8]. Another comparative study reported that, navigated single position OLIF reduces operative time by 30 minutes compared to repositioning OLIF [17]. With our technique, OLIF can be performed under navigation in lateral position in single sitting with simultaneous interbody fusion and PPS fixation. With our procedure, mean operative time reduces by around 60 minutes compared group P/T. This less operative time reduces medical cost and allows faster turnover of cases. With OLIF there is less tissue trauma and no damage to posterior structure. Due to this reason patients can be mobilized and discharged earlier [16]. The time for ambulation in our study for group SO was 2.7 ± 1.0 days while that in group P/T was 3.9 ± 2.4 days. Clinical results of ODI and VAS were no difference between two groups. This indicates indirect decompression was effective for group

SO (OLIF cases). In our patients operated with OLIF, DH increased by 64%, FH by 25% and FA by 30% due to indirect decompression. Lin et al. in their study showed that after OLIF, DH, FH, FA increased by 49%, 19% and 64% respectively [6].

The total complication rate in group SO was 6.3% and that in group P/T was 14.1%. In the study by Lin *et al* complication rate was 36% in the OLIF group and 32% [16]. A meta-analysis reported that complication rate after OLIF was 26.7% with psoas weakness being most common complication [18]. There are less complications in OLIF our cases compared to literature [19–21]. This can be because of use of neuromonitoring and O-arm navigation. Though not statistically significant group P/T showed better correction of SL compared to group SO in our patients. This can be because of use of lateral position for OLIF which does not allow for greater correction of lordosis.

There is concern about radiation hazard is for MIS surgeons and staff working high volume centres. Our O-arm navigated C-arm free technique is without any radiation exposure to operating staff. There is argument about increased radiation to patients, but it has been observed that it takes around 20 to 24 seconds to get O-arm scan. This is equivalent to 1.5 minutes of fluoroscopy [22]. We further reduce radiation exposure to patient by setting low field of view and low dose mode of O-arm.

Though indirect decompression being an excellent method, it too has some limitations. It has been reported that indirect decompression fails to give good results in severe central canal stenosis, gross motor deficit and cauda equina syndrome [22]. There are limitations of our study. Foremost, sample size in group P/T was relatively smaller than in group SO, with increased sample size required to confirm our findings. The preoperative FH was higher in group SO than group P/T, this can be selection bias of surgeon towards PLIF or TLIF for severely stenotic cases. Further research is warranted to clarify the long-term clinical outcome.

Conclusion

Simultaneous single position O-arm navigated C-arm free OLIF reduces the surgical time, blood loss, ambulation time after operation without the risk of an adverse event of intraoperative radiation to operating staff. Good indirect decompression can be achieved with this method. Clinical results were similar in both groups.

Abbreviations

ADH: anterior disc height

CDR: cage to disc ratio

CH: cage height

DH: disc height

FA: foraminal area

FH: foraminal height

Group P/T: MI-PLIF/TLIF

Group SO: single position OLIF

MI: minimally invasive

MIS: minimally invasive surgery

MRI: magnetic resonance of imaging

ODI: Oswestry disability index

OLIF: oblique lumbar interbody fusion

PDH: posterior disc height

PLIF: Posterior lumbar interbody fusion

PPS: percutaneous pedicle screw

SL: segmental lordosis

TLIF: transforaminal lumbar interbody fusion

VAS: visual analog scale

LLIF: lateral lumbar interbody fusion

Declarations

Ethics approval and consent to participate

The institutional ethics committee provided approval for this study (No.294). Necessary consents were obtained from the patient.

Consent for publication

We, the undersigned, give our consent for the publication of identifiable details, which can include figures, tables, case history and details within the text to be published in the Journal of Orthopaedic Surgery and Research.

Availability of data and materials

This study does not contain any third material.

Competing interests

The authors declare that they have no competing interests

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

YT performed most of the practical work, analyzed the data and prepared the manuscript. MT participated in the planning of the preparation of the manuscript. SS, SA,TT, YI and KU participated in the data gathering. YO, TY and YF supervised the study planning, data analysis and preparation of the manuscript. All authors read and approved the final manuscript.

Acknowledgements

This study was supported by Okayama Spine Group.

Authors' information

Department of Orthopaedic Surgery, Okayama Rosai Hospital, Okayama 702-8055, Japan

Department of spinal surgery, Weifang Traditional Chinese Medicine Hospital, Weifang 261041, China

Department of Orthopaedic surgery, Kobe Red Cross Hospital, Hyogo 651-0073, Japan

References

1. Mobbs RJ, Phan K, Malham G, et al. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg. 2015;1:2–18.
2. Okuda S, Miyauchi A, Oda T, et al. Surgical complications of posterior lumbar interbody fusion with total facetectomy in 251 patients. J Neurosurg Spine. 2006;4:304–9.

3. Foley KT, Holly LT, Schwender JD. Minimally Invasive Lumbar Fusion. Spine. 2003;28:26–35.
4. Mayer M. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine. 1997;22:691–9.
5. Wu M, Li J, Zhang M, et al. Efficacy and radiographic analysis of oblique lumbar interbody fusion for degenerative lumbar spondylolisthesis. J Orthop Surg Res. 2019;14:399.
6. Lin GX, Akbary K, Kotheeranurak V. Clinical and Radiologic Outcomes of Direct Versus Indirect Decompression with Lumbar Interbody Fusion: A Matched-Pair Comparison Analysis. World Neurosurg. 2018;119:898–909.
7. Drazin D, Kim TT, Johnson JP. Simultaneous Lateral Interbody Fusion and Posterior Percutaneous Instrumentation: Early Experience and Technical Considerations. Biomed Res Int. 2015;2015:458284.
8. Uotani K, Yasuyuki S, Yoshihira S, Tanaka M. LLIF and Percutaneous Pedicle Screw Fixation Performed All in Lateral Position with O-arm. J C S Ortho Asso. 2017;29:39–42. (in Japanese).
9. Tanaka M, Ruparel S, Fujiwara Y, Uotani K, Yamauchi T. Simultaneous Oblique Lumbar Interbody Fusion (OLIF) and Lateral Percutaneous Pedicle Screw Fixation (Lateral PPS): A Technical Note. Res arthritis bone study. 2019;1:1–8.
10. Poppenborg P, Liljenqvist U, Gosheger G, et al. Complications in TLIF spondylodesis–do they influence the outcome for patients? A prospective two-center study. Eur Spine J. 2021;30:1320–8.
11. Kepler CK, Sharma AK, Huang RC. Indirect foraminal decompression after lateral transpsoas interbody fusion: Clinical article. J Neurosurg Spine. 2012;16:329–33.
12. Pawar AY, Hughes AP, Sama AA, Girardi FP, et al. A comparative study of lateral lumbar interbody fusion and posterior lumbar interbody fusion in degenerative lumbar spondylolisthesis. Asian Spine J. 2015;9:668–74.
13. Tanaka M, Fujiwara Y, Uotani K, Yamauchi T. C-Arm Free Circumferential Minimally Invasive Surgery for Adult Spinal Deformity: Technical Note. World Neurosurg. 2020;143:235–46.
14. Ozgur BM, Aryan HE, Pimenta L, et al. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. Spine. 2006;6:435–43.
15. Epstein NE. Review of Risks and Complications of Extreme Lateral Interbody Fusion (XLIF). Surg Neurol Int. 2019;10:237.
16. Li HM, Zhang RJ, Shen CL. Radiographic and Clinical Outcomes of Oblique Lateral Interbody Fusion Versus Minimally Invasive Transforaminal Lumbar Interbody Fusion for Degenerative Lumbar Disease. World Neurosurg. 2019;122:627–38.
17. Ouchida J, Kanemura T, Satake K, et al. Simultaneous single-position lateral interbody fusion and percutaneous pedicle screw fixation using O-arm-based navigation reduces the occupancy time of the operating room. Eur Spine J. 2020;29:1277–86.
18. Li HM, Zhang RJ, Shen CL. Differences in radiographic and clinical outcomes of oblique lateral interbody fusion and lateral lumbar interbody fusion for degenerative lumbar disease: A meta-analysis. BMC Musculoskelet Disord. 2019;20:1–11.

19. Blake Rodgers W, Gerber EJ, Patterson J. Intraoperative and Early Postoperative Complications in Extreme Lateral Interbody Fusion An Analysis of 600 Cases. Spine. 2011;36:26–33.
20. Khajavi K, Shen A, Lagina M, et al. Comparison of clinical outcomes following minimally invasive lateral interbody fusion stratified by preoperative diagnosis. Eur Spine J. 2015;24:322–30.
21. Wang TY, Nayar G, Brown CR, et al. Bony Lateral Recess Stenosis and Other Radiographic Predictors of Failed Indirect Decompression via Extreme Lateral Interbody Fusion: Multi-Institutional Analysis of 101 Consecutive Spinal Levels. World Neurosurg. 2017;106:819–26.
22. Prod'Homme M, Sans-Merce M, Pitteloud N, et al. Intraoperative 2D C-arm and 3D O-arm in children: A comparative phantom study. J Child Orthop. 2018;12:550–7.

Tables

Due to technical limitations, tables are only available as a download in the Supplemental Files section.

Figures

Fig 1

Figure 1

Intraoperative picture showing two surgeons operating simultaneously. The patient is in the right lateral position, left is the main surgeon, right is the assistant surgeon applying a rod percutaneously, reference frame is attached at the left posterior iliac crest.

Fig 2

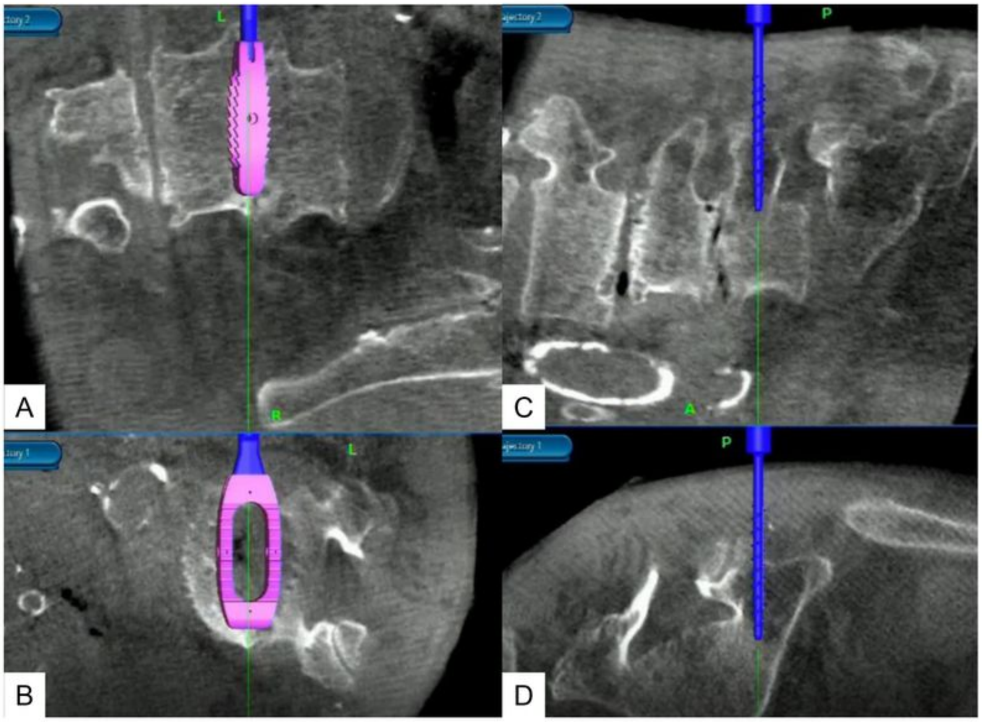

Figure 2

O-arm images showing navigated cage and screw placement. An OLIF cage is inserted in coronal view (A) and axial view (B). Pedicle screw tapping is performed in sagittal view(C) and axial view (D)

Fig 3

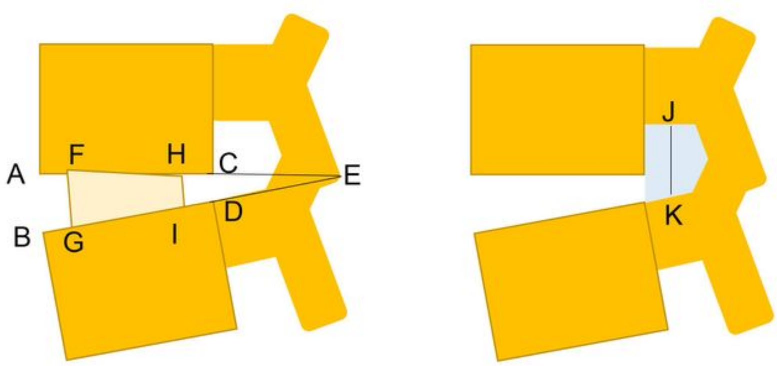

Figure 3

Radiological measurement Disc height=(AB+CD)/2, Segmental lordosis=angle AEB, Cage height=(FG+HI)/2, Cage to disc ratio=(AB+CD)/(FG+HI), Foraminal height= JK, Foraminal area=gray area

Fig 4

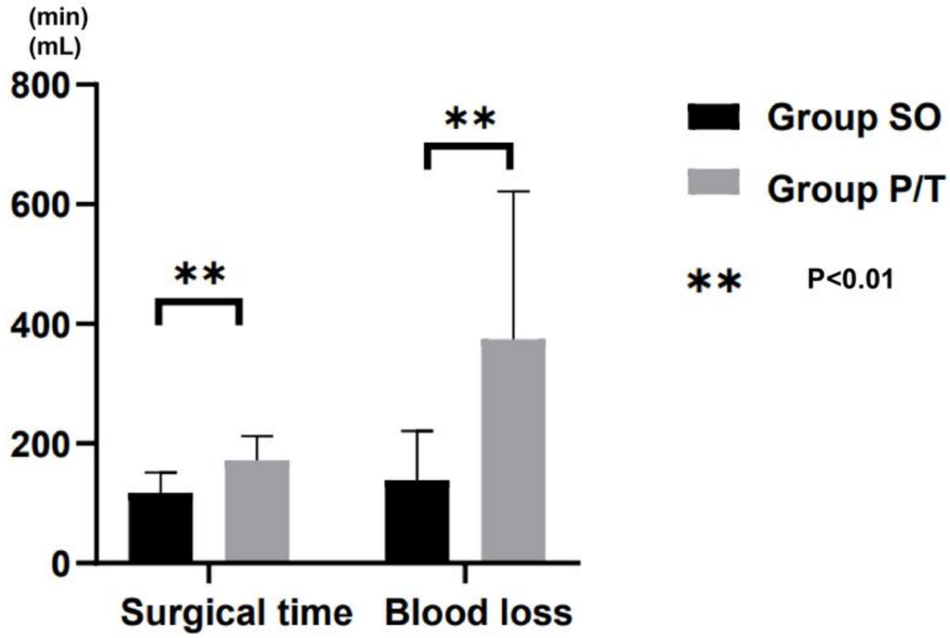

Figure 4

Difference in operative time and blood loss in group SO and group P/T. A; 69 years man L4-5 OLIF, B; 79 years woman L4-5 PLIF

Fig 5

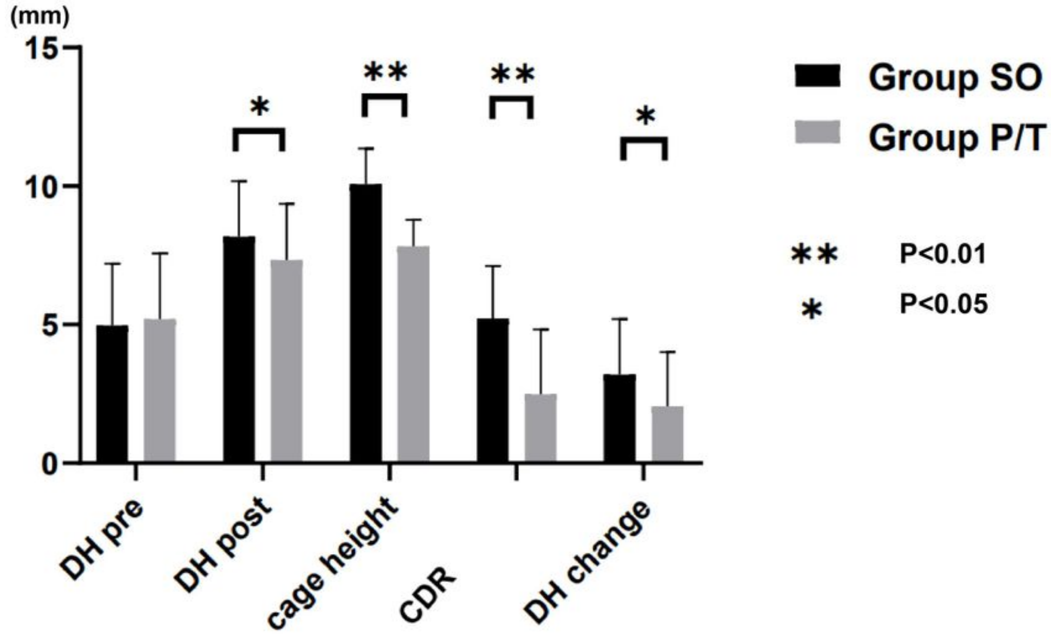

Figure 5

Difference of cage height used, preoperative and postoperative DH, CDR, DH change in group SO and group P/T.

Fig 6

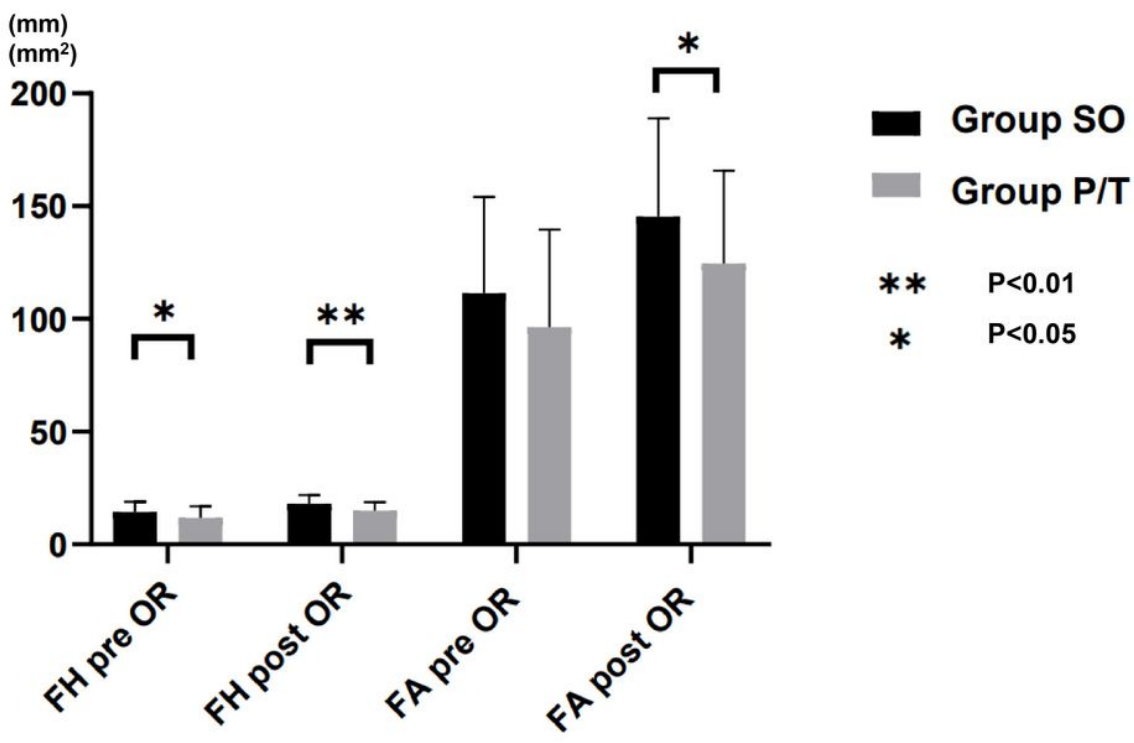

Figure 6

Preoperative and postoperative FH and FA change in group SO and group P/T.

Fig 7

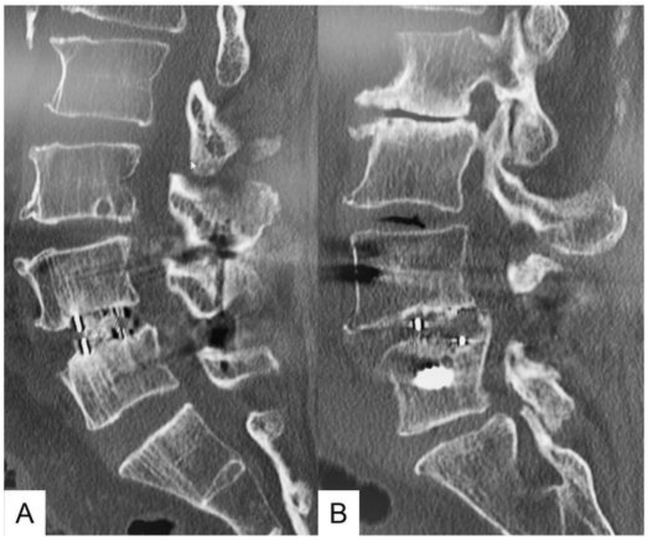

Figure 7

Legend not included with this version

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CoverpageOLIFTLIF.docx
- Table1New.pdf
- Table2New.pdf
- Table3New.pdf