

Imaging anatomy and clinical significance of percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine

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Research

Keywords: Imaging anatomy, Lumbar spine, Oblique fixation, Posterior corner

Posted Date: May 15th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-28074/v1>

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Abstract

Background

Percutaneous endoscopic transforaminal lumbar interbody fusion (PE-TLIF) has been widely discussed due to its advantages of less trauma, less bleeding, quick recovery, high safety, and relatively fewer complications, as well as other adverse factors such as incomplete decompression, steep learning curve, low fusion rate, and high radiation risk. It can keep the posterior structure of spine intact to the greatest extent, ensure the stability of spine after surgery, and achieve decompression with minor trauma. However, posterior percutaneous pedicle screws are often needed for fusion and fixation after decompression, and additional posterior trauma, postural changes and anesthesia methods are often required. Interbody fixation and fusion are often independent and not one-stop completion. The authors consider whether the percutaneous spinal endoscopy can be used to achieve complete decompression and fusion under a single minimally invasive channel, while achieving one-stop endoscopic decompression, fusion and fixation. The purpose of this paper is to provide the anatomic feasibility for oblique fixation by measuring the imaging anatomic parameters, especially to provide the anatomic basis for the design of new endoscopic lumbar interbody fusion cage.

Methods

Sixty volunteers (22 men and 38 women) who underwent lumbar CT scans were collected and sent to the GEAW4.4 workstation. The distances from posterior corner in the lumbar spine to the corresponding targets of the contralateral anterior corner and the included angles between each path line in sagittal and axial plane were measured and analyzed statistically.

Results

In the medium group, PC path was the shortest, PA path and PB path had little difference ($P=0.123$), with no statistical significance. In the full-length group, PF path was the shortest, and there was no significant difference between PD path and PE path ($P =0.177$). PE was the optimal path. The included angles a1, a2, a3, b1, b2, and b3 in sagittal plane and c1, c2 and c3 in axial plane were significantly different ($P=0.000$), namely, $a1 >a2>a3$, $b1>b2>b3$, and $c1<c2<c3$.

Conclusions

This study provides anatomic feasibility for percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine and particularly provides anatomic basis for the design of new endoscopic lumbar interbody fusion cage.

Background

Lumbar interbody fusion is an effective method to restore the stability of spine and correct the abnormal load bearing mode of lumbar spine [1], which has been widely used to treat diseases such as disc degeneration, degenerative lumbar instability, lumbar spondylolisthesis, extensive decompression of spinal stenosis, and lumbar infection [2]. Since Hibbs et al first reported the stability of spinal fusion in 1911 and Mercer proposed that the ideal method of spinal fusion was interbody fusion in 1936, and good effects have been achieved from

anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), cortical bone trajectory (CBT) to minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF), oblique lateral interbody fusion (OLIF), minimally invasive big-channel endoscopic fusion combined with posterior percutaneous pedicle screw fixation [3].

Currently, percutaneous endoscopic transforaminal lumbar interbody fusion (PE-TLIF) has been widely discussed due to its advantages of less trauma, less bleeding, quick recovery, high safety, and relatively fewer complications, as well as other adverse factors such as incomplete decompression, steep learning curve, low fusion rate, and high radiation risk [4]. It can keep the posterior structure of spine intact to the greatest extent, ensure the stability of spine after surgery, and achieve decompression with minor trauma.

However, posterior percutaneous pedicle screws are often needed for fusion and fixation after decompression, and additional posterior trauma, postural changes and anesthesia methods are often required. Interbody fixation and fusion are often independent and not one-stop completion. The authors consider whether the percutaneous spinal endoscopy can be used to achieve complete decompression and fusion under a single minimally invasive channel, while achieving one-stop endoscopic decompression, fusion and fixation. The purpose of this paper is to provide the anatomic feasibility for oblique fixation by measuring the imaging anatomic parameters, especially to provide the anatomic basis for the design of new endoscopic lumbar interbody fusion cage.

Materials And Methods

Materials

Sixty normal adult volunteers (22 men and 38 women), who do not have lumbar tumors, trauma, deformity or a history of lumbar surgery, underwent CT scan in lumbar spine with GE Light Speed 64CT in the East Hospital of Shandong Provincial Hospital from June 1, 2019 to Dec 31, 2019. The volunteers' age are from 20 to 51 years, with an average age of 33.8 years. Male volunteers' height was 168 to 182 cm, with an average of 174.6 cm, and the female volunteers' height was 157 to 171 cm, with an average of 165.3 cm. All scan information was transmitted to the GE AW4.4 workstation for measurement.

Data measurement

To investigate fully the imaging anatomy of oblique fixation path from posterior corner in lumbar spine, the authors chose to measure the distance from the posterior corner (P point, Fig. 1) in lumbar spine to the corresponding targets (A: the middle point of the contralateral anterior-middle 1/3, B: the contralateral anterior-middle point, C: the middle point of the contralateral side, D: the upper point of contralateral anterior-middle 1/3, E: the contralateral anterior-upper point, F: the middle-upper point of the contralateral side) in the contralateral anterior region (Fig. 2).

PUA path: distance from the posterior-lower corner of the upper vertebral body to the middle point of the contralateral anterior-middle 1/3.

PUB path: distance from the posterior-lower corner of the upper vertebral body to the contralateral anterior-middle point.

PUC path: distance from the posterior-inferior corner of the upper vertebral body to the middle point of the contralateral side.

PUD path: distance from the posterior-lower corner of the upper vertebral body to the upper point of contralateral anterior-middle 1/3.

PUE path: distance from the posterior-lower corner of the upper vertebral body to the contralateral anterior-upper point.

PUF path: distance from the posterior-lower corner of the upper vertebral body to the middle-upper point of the contralateral side.

PDA path: distance from the posterior-upper corner of the lower vertebral body to the middle point of the contralateral anterior-middle 1/3.

PDB path: distance from the posterior-upper corner of the lower vertebral body to the contralateral anterior-middle point.

PDC path: distance from the posterior-upper corner of the lower vertebral body to the middle point of the contralateral side.

PDD path: distance from the posterior-upper corner of lower vertebral body to the upper point of the contralateral anterior-middle 1/3.

PDE path: distance from the posterior-upper corner of lower vertebral body to the contralateral anterior-lower point.

PDF path: distance from posterior-upper corner of lower vertebral body to the middle-lower point of the contralateral side.

The angle between the oblique fixed path line from posterior corner in lumbar spine and the parallel line of the corresponding vertebral endplate in sagittal and axial plane (Fig. 3–5).

a1: the angle between the line, which is from the posterior-lower corner of the upper vertebral body to front-middle 1/3 of the upper endplate, and lower endplate parallel line.

a2: the angle between the line, which is from the posterior-lower corner of the upper vertebral body to anterior-upper corner, and lower endplate parallel line.

a3: the angle between the line, which is from the posterior-lower corner of the upper vertebral body to the midpoint of the anterior border, and lower endplate parallel line.

b1: the angle between the line, which is from the posterior-upper corner of the lower vertebral body to front-middle 1/3 of the lower endplate, and upper endplate parallel line.

b2: the angle between the line, which is from the posterior-upper corner of the lower vertebral body to anterior-lower corner, and upper endplate parallel line.

b3: the angle between the line, which is from the posterior-upper corner of the lower vertebral body to the midpoint of the anterior border, and upper endplate parallel line.

c1: the angle between the projection, which is generated from the posterior corner of the upper vertebral body to contralateral front-middle 1/3 on the endplate, and the tangent line to the posterior border of the vertebral body.

c2: the angle between the projection, which is generated from the posterior corner of the upper vertebral body to contralateral anterior corner on the endplate, and the tangent line to the posterior border of the vertebral body.

c3: the angle between the projection, which is generated from the posterior corner of the upper vertebral body to the midpoint of the anterior border on the endplate, and the tangent line to the posterior border of the vertebral body.

Statistical methods

The measured data, including 3,600 length data and 2,880 angle data, were counted and compared with the independent sample t test by Statistical Package for Social Sciences (SPSS) 25.0 statistical software.

Results

The length of each path (Table 1)

Table 1

Each path length for oblique fixation from the posterior corner in lumbar spine(mm)

Path	L1-PU	L2-PU	L3-PU	L4-PU	L5-PU	F ₁	P ₁
	L2-PD	L3-PD	L4-PD	L5-PD	S1-PD		
A	$37.87 \pm 3.48^*$	40.04 ± 2.75	40.96 ± 2.98	41.36 ± 3.20	42.11 ± 4.15	9.759	0.000
	39.51 ± 3.32	39.96 ± 2.75	40.76 ± 2.99	41.27 ± 3.20	42.47 ± 4.22		
B	38.95 ± 3.29	40.86 ± 3.24	41.61 ± 3.01	41.28 ± 3.50	41.06 ± 3.81	2.963	0.002
	40.71 ± 3.39	40.78 ± 3.24	41.42 ± 3.02	41.19 ± 3.47	41.42 ± 3.88		
C	37.29 ± 3.21	39.16 ± 2.82	39.10 ± 2.74	38.52 ± 3.50	37.90 ± 3.72	2.124	0.026
	38.95 ± 3.23	39.08 ± 2.82	38.90 ± 2.75	38.43 ± 3.47	38.30 ± 3.76		
D	43.20 ± 3.09	45.57 ± 2.73	46.19 ± 2.82	46.03 ± 2.97	46.50 ± 3.83	8.220	0.000
	45.12 ± 3.12	45.31 ± 2.64	45.50 ± 2.82	45.73 ± 2.98	47.80 ± 4.10		
E	44.15 ± 2.96	46.30 ± 3.09	46.76 ± 2.88	45.96 ± 3.27	45.54 ± 3.55	3.371	0.000
	46.18 ± 3.18	46.04 ± 3.02	46.08 ± 2.89	45.66 ± 3.21	46.86 ± 3.80		
F	42.69 ± 2.91	44.80 ± 2.72	44.55 ± 2.62	43.50 ± 3.26	42.72 ± 3.44	4.192	0.000
	44.63 ± 3.03	44.53 ± 2.62	43.83 ± 2.61	43.19 ± 3.17	44.13 ± 3.60		

* the length in the table consists of mean and standard deviation.

In the process of oblique fixation from posterior corner in lumbar spine, each path could be divided into two groups, medium group and full-length group. The medium group included PA, PB and PC, while the full-length group included PD, PE and PF, and the medium group < full-length group. In the medium group, PC path was the shortest [(38.56 ± 3.25)mm], PA path and PB path had little difference ($P = 0.123$), and there was no statistical significance. In the full-length group, PF path was the shortest[(43.86 ± 3.09)mm], and there was no significant difference between PD path and PE path ($P = 0.177$) (Fig. 6). Oblique fixation paths from posterior corner in lumbar spine increased successively from L1 to S1, among which PA and PD paths were the most obvious, followed by PB and PE paths. PC path and PF path first increased and then decreased (Fig. 7,8). PE was the optimal path for oblique fixation from posterior corner in lumbar spine, and its upward path first increased and then decreased, reaching the highest point at L3 [(46.76 ± 2.88)mm]; its downward path showed a trend of first decreasing and then increasing, with the lowest decline at L5[(45.66 ± 3.21)mm] (Fig. 9).

The angle of each path (Table 2)

Table 2
Each path angle for oblique fixation from posterior corner in lumbar spine(°)

Plane	Angle	L1	L2	L3	L4	L5	S1	F _{II}	P _{II} *	
Sagittal	a1	50.19 ± 4.50	50.43 ± 4.09	51.15 ± 4.18	51.17 ± 3.97	54.21 ± 4.33		8.770	0.000	
	a2	39.21 ± 4.39	39.37 ± 3.72	40.00 ± 4.26	39.72 ± 4.06	42.03 ± 4.58		4.392	0.002	
	a3	24.70 ± 3.20	24.26 ± 2.96	23.81 ± 3.06	23.43 ± 4.29	24.36 ± 2.94		1.337	0.256	
	b1		46.79 ± 3.73	46.08 ± 4.37	47.13 ± 3.99	48.33 ± 3.61	69.49 ± 8.28	237.613	0.000	
	b2			36.39 ± 3.39	36.21 ± 3.51	36.95 ± 3.47	39.30 ± 3.76	61.23 ± 7.74	268.915	0.000
	b3				23.01 ± 2.34	22.47 ± 3.01	22.88 ± 2.40	23.94 ± 2.61	36.60 ± 5.00	212.251
Axial	c1	39.17 ± 2.76	40.07 ± 2.75	39.28 ± 2.65	37.9 ± 2.44	36.01 ± 2.90	33.87 ± 2.94	44.275	0.000	
	c2	54.08 ± 3.66	55.1 ± 3.32	54.22 ± 3.25	52.92 ± 3.48	50.25 ± 3.27	47.92 ± 3.54	39.329	0.000	
	c3	71.39 ± 5.89	72.35 ± 4.24	73.11 ± 2.10	72.49 ± 2.64	70.5 ± 2.54	67.15 ± 3.60	20.298	0.000	

* $p < 0.05$, the comparison between groups is statistically significant.

The included angles a1, a2, a3, b1, b2, b3 and c1, c2 and c3 were significantly different ($P = 0.000$) (Fig. 10). a1 > a2 > a3, b1 > b2 > b3, c1 < c2 < c3. In the angle of the sagittal down-path, b1, b2 and b3 change significantly and consistently, showing a trend of decreasing first and then increasing, which is the smallest at L3[(46.08 ± 4.37)°, (36.21 ± 3.51)°, (22.47 ± 3.01)°] and the largest at S1[(69.49 ± 8.28)°, (61.23 ± 7.74)°, (36.60 ± 5.00)°]. In the angle of the sagittal up-path, a1 and a2 change in the same way, showing an increasing trend, while a3 goes down

and then goes up, and it's the smallest at L4[(23.43 ± 4.29) °] and the largest at L5[(24.36 ± 2.94) °]. In the angle of axial plane, c1, c2 and c3 change in the same way, showing a trend of increasing first and then decreasing, in which c1 and c2 are the largest at L2[(40.07 ± 2.75)°, (55.1 ± 3.32)°], and c3 is the largest at L3[(73.11 ± 2.10)°], and all are the smallest at S1[(33.87 ± 2.94)°, (47.92 ± 3.54)°, (67.15 ± 3.60)°](Fig. 11,12).

Discussion

The advantages of imaging measurement

Dry bone or specimen were used for anatomic measurement in the past because of its visibility and accuracy. However, there are certain limitations, such as the difficulty of obtaining specimens and the insufficient number of specimens, and in the process of handling specimens, the normal anatomical structures are easily destroyed, which affects the authenticity of measurement data, etc. In this paper, the author adopted the method of imaging measurement, and successfully solved the limitation in the measurement of dry bone and cadaver specimen. The author summarizes several advantages of imaging measurement: (1) it improves the measurement efficiency. Meanwhile, it omits the process of measuring tool measurement and the reader reading the measurement value, which reduces the systematic error and accidental error to some extent.(2) imaging measurement does not destroy the measuring object, which preserves its integrity and improves the accuracy of the measurement result to some extent.(3) we could obtain enough objects through imaging measurement.

Development, Change and Limitation of Spinal Fixation Technology

The clinical application of pedicle screw fixation technique is a significant development in spinal surgery. The fusion and fixation of the lumbosacral vertebra using screws from the pedicle to the vertebral body, which was first applied by Boucher in 1959, have achieved good clinical results [5]. Steffee and Roy-Camille et al reported that pedicle screw technique for posterior short-segment internal fixation of spine obtained good results in 1986 [6, 7]. The advantages of pedicle screw rod spinal fixation system, which can simultaneously fix the three columns and reconstruct the stability of spine in a timely and reliable manner, have been gradually popularized in clinical application. In the past ten years, pedicle screw technology has developed rapidly and gradually been used in the fixation of thoracic and even cervical vertebrae. The application of computer navigation system has greatly improved the accuracy of screw implantation [8]. The research and clinical application of percutaneous pedicle screw surgery has also begun [9].

On account of complex, important anatomy structure and limited exposure in the back of spine, there are lots of difficulties in accurate positioning and screw setting. So it is easy to damage the important surrounding structures due to slightly careless. Incorrect screw placement may perforate the canal wall of the pedicle, damage the spinal cord, nerve roots, or break through the anterior cortex of the vertebral body, damage the anterior major vessels or viscera with disastrous consequences.

The stability of PS fixation declines in patients with osteoporosis, who was losing a large amount of bone, so as to affects the surgical effect [10]. Therefore, how to ensure the strength of pedicle screw fixation in patients with osteoporosis has become a challenge in the field of spinal surgery. In order to solve the clinical problem, Cortical bone channel (cortical bone trajectory, CBT) scheme was suggested by Santoni et al in 2009 and applied to the

lumbar pedicle nailing [11]. Compared with PS, CBT screw has the characteristics of smaller diameter, shorter length and tighter thread [12, 13]. The screw is placed at an inward and outward tilt to maximize the contact with cortical bone. It has the advantages of strong control, less trauma, fewer complications, less intraoperative bleeding and lower postoperative infection rate [14–16], which has a broad clinical value and application prospect. However, there are still risks and postoperative complications in clinical practice, including failure of internal fixation, pedicle splitting, pseudarthrosis and dural tear. Some scholars [17–19] pointed out that the early complications of CBT screw technology mainly included postoperative screw loosening, intraoperative articular process fracture, dura mater breakage and pedicle splitting.

Translaminar facet joint screw fixation technology is a fixation method setting the screw, who was known as Magerl screw, through the base of the contralateral spinous process, contralateral lamina, articular facet joint. Jang JS et al reported that this screw has the advantages of firm fixation, fewer complications, less trauma and shorter operation time when combining with lumbar interbody fusion in the anterior approach [20]. However, the fixation strength of facet joint screw is limited, So it is often used when the structure of the posterior column is unbroken.

Interspinous internal fixation technique is a minimally invasive non-fusion internal fixation technique for lumbar posterior approach. This technology has the advantages of simple operation, low trauma risk and short operation time [21]. This technique is suitable for young patients with good physiological curvature in lumbar spine, which can effectively improve the symptoms of pain and maintain a certain degree of activity and then improving the quality of life. It can also improve the sagittal balance of spine and increase the diameter of the interbody foramen. Common complications include implant displacement and spinous process fractures, especially in patients with vertebral slippage and osteoporosis. Epstein [22] and Kim et al [23] found that this technology had poor clinical efficacy in patients over the age of 50, with a high incidence of complications and a high rate of reoperation, and its effectiveness and safety were questioned, suggesting in-depth evaluation of its clinical application.

Establishment of Percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine

At present, PE-TLIF through Kambin's triangle have attracted much attention due to less trauma, less bleeding, faster recovery, higher safety, and fewer complications. They also have drawbacks such as incomplete decompression, steep learning curve, low fusion rate, high radiation risk, and injury to exiting roots and dural sacs, in particular. Lumbar interbody fusion after decompression often requires the use of posterior percutaneous pedicle screws, additional approach and posterior injury, and changes in intraoperative position or anesthesia. Interbody fixation and fusion are often separated and not completed in one process. We propose that, with the help of percutaneous spinal endoscopy, it is possible to achieve one-stop endoscopic decompression, fusion and fixation in a single minimally invasive channel. (Fig. 13).

Therefore, it is of profound clinical significance to study oblique fixation paths from posterior corner in lumbar spine, quantify its anatomical parameters, and then conduct biomechanical research on the basis of anatomy and try to develop a new type of endoscopic fusion-fixation device. In this study, the lengths of oblique fixation paths from posterior corner in lumbar spine and their angles in the sagittal and axial planes are measured comprehensively, and the feasibility of oblique fixation from the posterior corner of the vertebral body was

illustrated. In this study, it was found that different target points and target areas of oblique fixation through posterior corner in lumbar spine resulted in different length of each path and different placement angles. At the same time, considering that the operating space in the safety triangle is small and there are important structures such as nerve roots and blood vessels, it is necessary to design a new type of endoscopic fusion-fixation device with a precise, compact and safe structure. In addition, several commonly used sizes and models should be designed, or even customized (Fig. 14).

the Placement of Screws in Percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine (Fig. 1)

Posterior corner in lumbar spine was selected as the entry point for oblique fixation. The entry point in posterior-inferior corner is the bony area between the upper margin of the pedicle and the upper endplate. The entry point in posterior-superior corner is the bony area between the lower margin of the pedicle and the lower endplate.

Inward inclined angle, head tilt angle and tail tilt angle of screw placement, namely c1, c2, c3, a1, a2, a3, b1, b2 and b3, was measured and analyzed in this study. In the angle of the sagittal down-path, b1, b2 and b3 change significantly and consistently, showing a trend of decreasing first and then increasing, which is the smallest at L3[(46.08 ± 4.37)°,(36.21 ± 3.51)°,(22.47 ± 3.01)°] and the largest at S1[(69.49 ± 8.28)°,(61.23 ± 7.74)°,(36.60 ± 5.00)°]. In the angle of the sagittal up-path, a1 and a2 change in the same way, showing an increasing trend, while a3 goes down and then goes up, and it's the smallest at L4[(23.43 ± 4.29) °] and the largest at L5[(24.36 ± 2.94) °]. In the angle of axial plane, c1, c2 and c3 change in the same way, showing a trend of increasing first and then decreasing, in which c1 and c2 are the largest at L2[(40.07 ± 2.75)°,(55.1 ± 3.32)°], and c3 is the largest at L3[(73.11 ± 2.10)°], and all are the smallest at S1[(33.87 ± 2.94)°,(47.92 ± 3.54)°,(67.15 ± 3.60)°](Fig. 11,12).

Screw length were also measured and analyzed in this study, namely PA, PB, PC, PD, PE and PF. The medium group included PA, PB and PC, while the full-length group included PD, PE and PF, and the medium group < full-length group. In the medium group, PC path was the shortest [(38.56 ± 3.25) mm], PA path and PB path had little difference ($P = 0.123$), and there was no statistical significance. In the full-length group, PF path was the shortest [(43.86 ± 3.09) mm], and there was no significant difference between PD path and PE path ($P = 0.177$) (Fig. 6). Oblique fixation paths from posterior corner in lumbar spine increased successively from L1 to S1, among which PA and PD paths were the most obvious, followed by PB and PE paths. PC path and PF path first increased and then decreased (Fig. 7,8). PE was the optimal path for oblique fixation from posterior corner in lumbar spine, and its upward path first increased and then decreased, reaching the highest point at L3 [(46.76 ± 2.88)mm]; its downward path showed a trend of first decreasing and then increasing, with the lowest decline at L5[(45.66 ± 3.21)mm] (Fig. 9).

The PE Path should be the Optimal (long) Path

PE path was the longest of all the paths for oblique fixation from posterior corner in lumbar spine, with an average length of 45.95 mm, which was significantly longer than other paths in the same vertebral body (Fig. 5, 6, 7). Its upward path first increases and then decreases, reaching the highest point at L3. Firstly, its downward path shows a trend of decreasing and then increasing, with the lowest decline at L5 (Fig. 8). At the same time, the fixed angles (a2, b2, c2) of the PE path in the sagittal and axial planes are between a1-a3, b1-b3, and c1-c3, which may neither penetrate into the interbody space nor injure the anterior large vessels. The PE path is safe and easy to grasp in practice (Fig. 9, 11).

In addition, the fixation holding force strength of the PE path is higher because the bone canal was across the entire vertebral body from the posterior (upper and lower) corner of one side in lumbar spine to the anterior (lower and upper) corner of the contralateral side. The PE path is considered to be the optimal one for oblique fixation from posterior corner in lumbar spine.

Shortcoming and Further Research

In this study, the imaging measurement method is not compared with the dry bone measurement, and the correlation analysis between each index and body length is not carried out, which will be improved in the subsequent study. What needs to be emphasized is whether the entry point of oblique fixation posterior corner in lumbar spine is safe, and whether dural sac/traversing nerve roots and exiting nerve roots will be injured, which will be emphasized in the next article.

In addition, the biomechanical evaluation of compressive stress, stretch stress, torsion stress and fatigue load between the lumbar spine should be made in order to obtain objective evaluation for its bearing capacity before the new endoscopic fusion-fixation device are produced. Three-dimensional finite element analysis is also required after the device model is completed. Finally, the feasibility of one-stop fusion-fixation in lumbar spine under the microscope is preliminarily determined.

Conclusion

In this study, the distances from posterior corner in lumbar spine to the corresponding targets (A, B, C, D, E, and F) of the contralateral anterior corner and the included angles between each path line and the parallel line of corresponding vertebral endplate in sagittal and axial plane are measured comprehensively, which provides anatomic feasibility for oblique fixation from posterior corner in lumbar spine and particularly provides anatomic basis for the design and manufacture of new microscopic fusion-fixation device. Further studies and biomechanical evaluations are presently being conducted to explore its clinical significance.

Abbreviations

PE-TLIF: Percutaneous endoscopic transforaminal lumbar interbody fusion; ALIF: Anterior lumbar interbody fusion; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar interbody fusion; CBT: Cortical bone trajectory; MIS-TLIF: Minimally invasive transforaminal lumbar interbody fusion; OLIF: Oblique lateral interbody fusion; SPSS: Statistical Package for Social Sciences.

Declarations

Ethics approval and consent to participate

Permission to conduct this retrospective study was obtained from the Hospital Ethics Committee.

Consent for publication

Not applicable

Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declare that they have no competing interests.

Funding

The study received funding from key research and development program of Shandong Province: 2018GSF118074.

Acknowledgements

The authors sincerely acknowledge the entire staff of the Department of Spine, Shandong Provincial Hospital Affiliated to Shandong University, who offered assistance throughout the course of this study.

Authors' contributions

F-FC contributed to the research design, analysis of the data, and manuscript writing. X-YL and J-MS contributed to the acquisition and analysis of the data and wrote the program. J-X and C-S contributed to the acquisition and analysis of the data. GD-W contributed to the acquisition and analysis of the data. X-GC initiated and designed the study. All authors were fully involved in the study and approved the final version of this manuscript.

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Figures

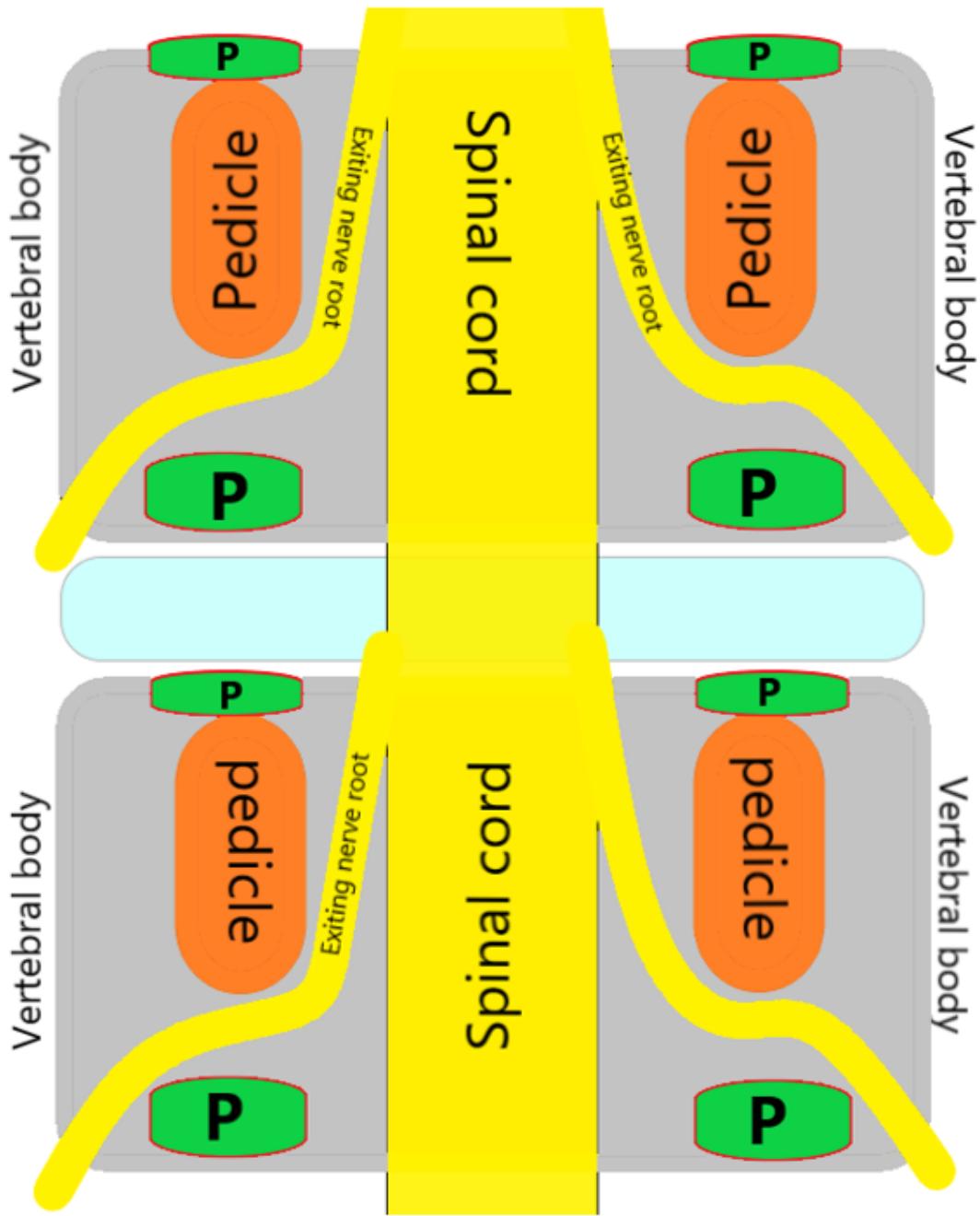


Figure 1

The entry point of oblique fixation paths from posterior corner in lumbar spine.

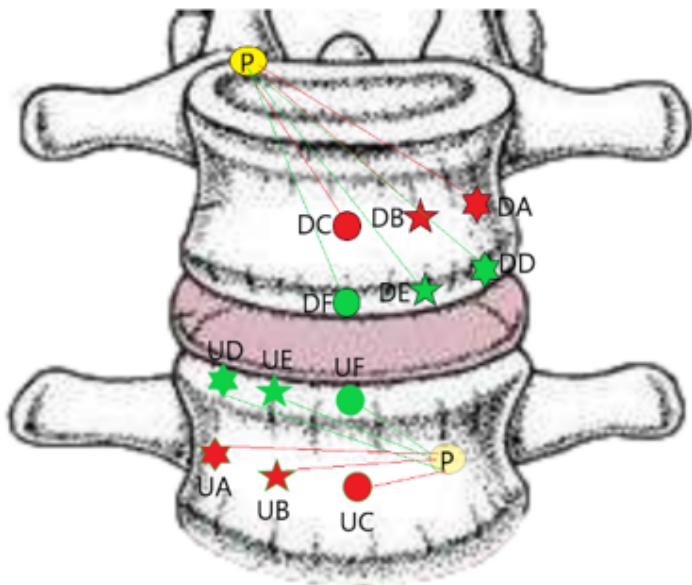


Figure 2

The length of oblique fixation paths from posterior corner in lumbar spine.

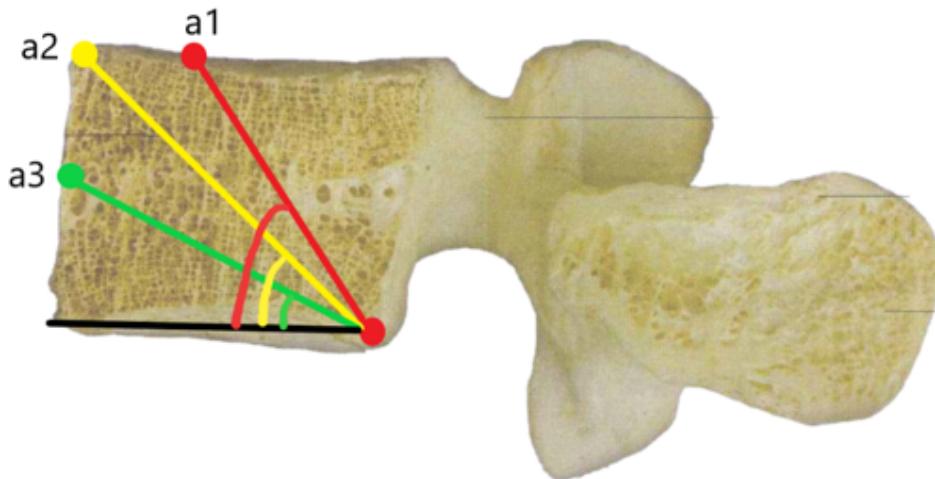


Figure 3

The angle between the oblique fixation path line (upward) from posterior corner in lumbar spine and the parallel line of the corresponding vertebral endplate in sagittal plane.

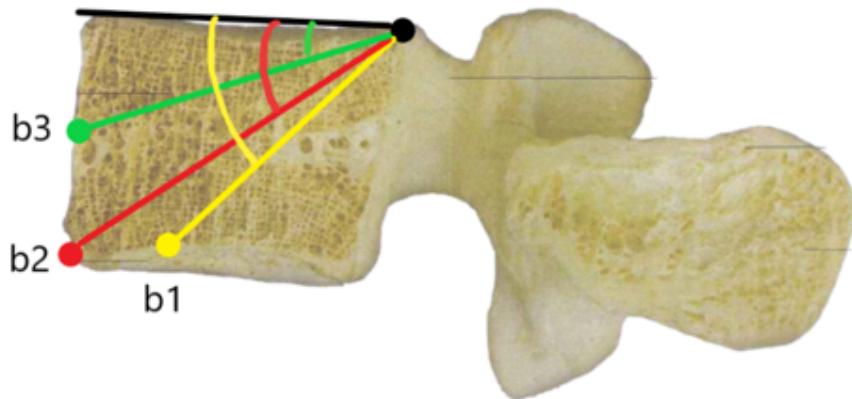


Figure 4

The angle between the oblique fixation path line (downward) from posterior corner in lumbar spine and the parallel line of the corresponding vertebral endplate in sagittal plane.

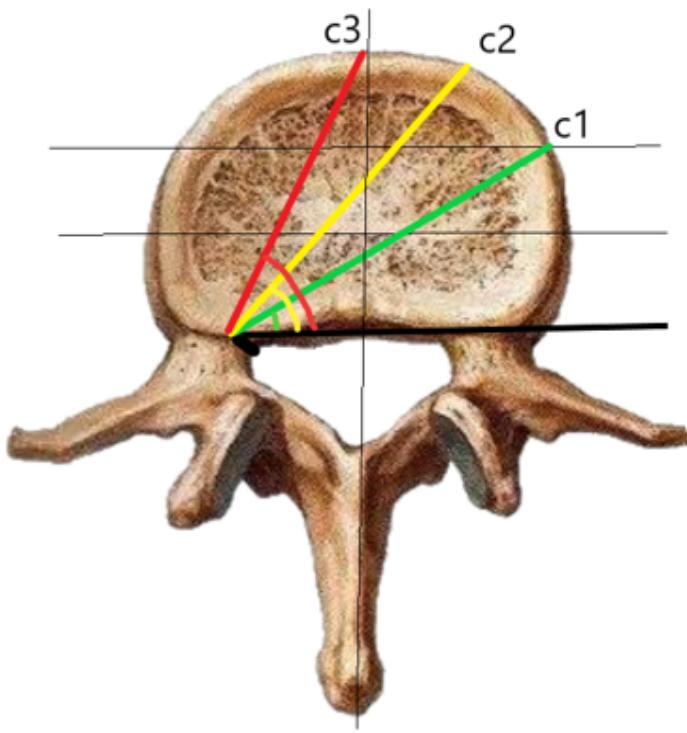


Figure 5

The angle between the oblique fixation path line from posterior corner in lumbar spine and the tangent line to the posterior border of the vertebral body in axial plane.

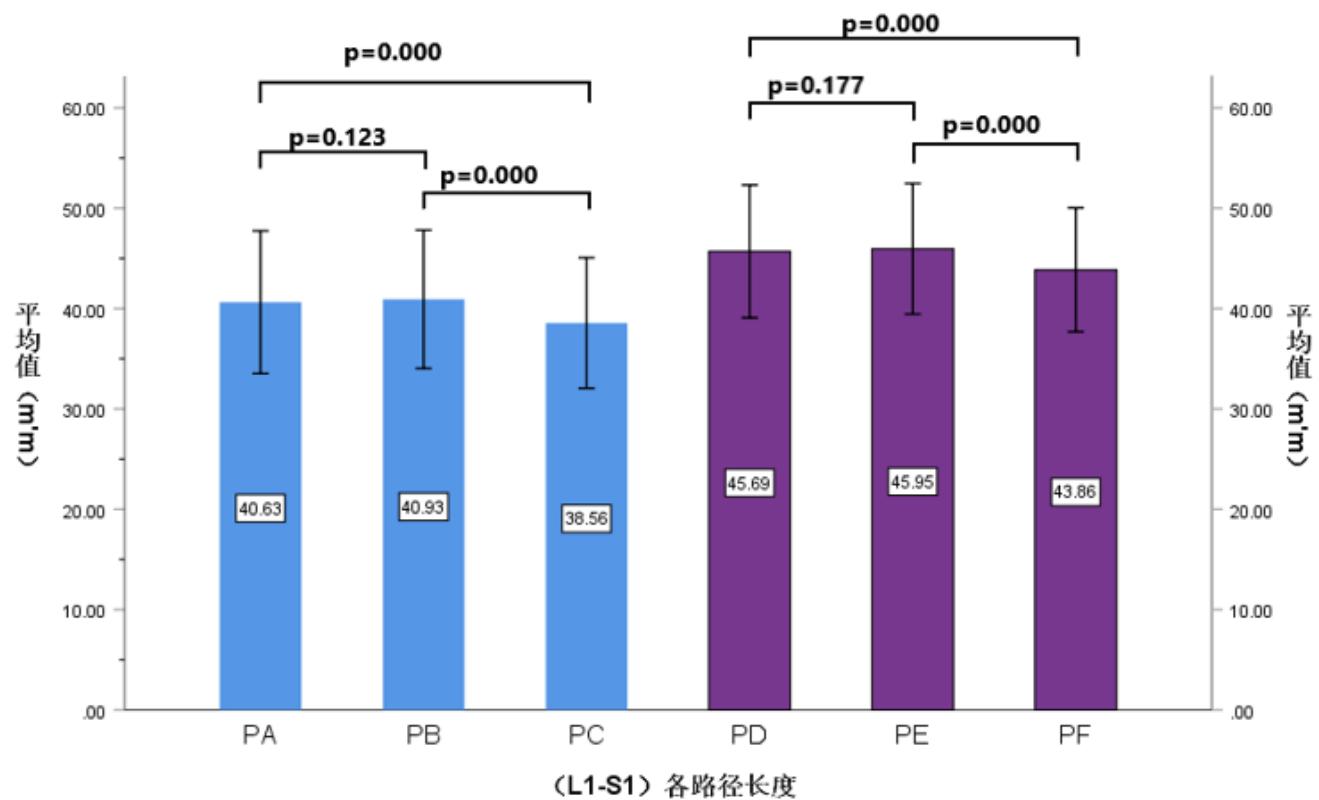


Figure 6

Each path length for oblique fixation from posterior corner in lumbar spine.

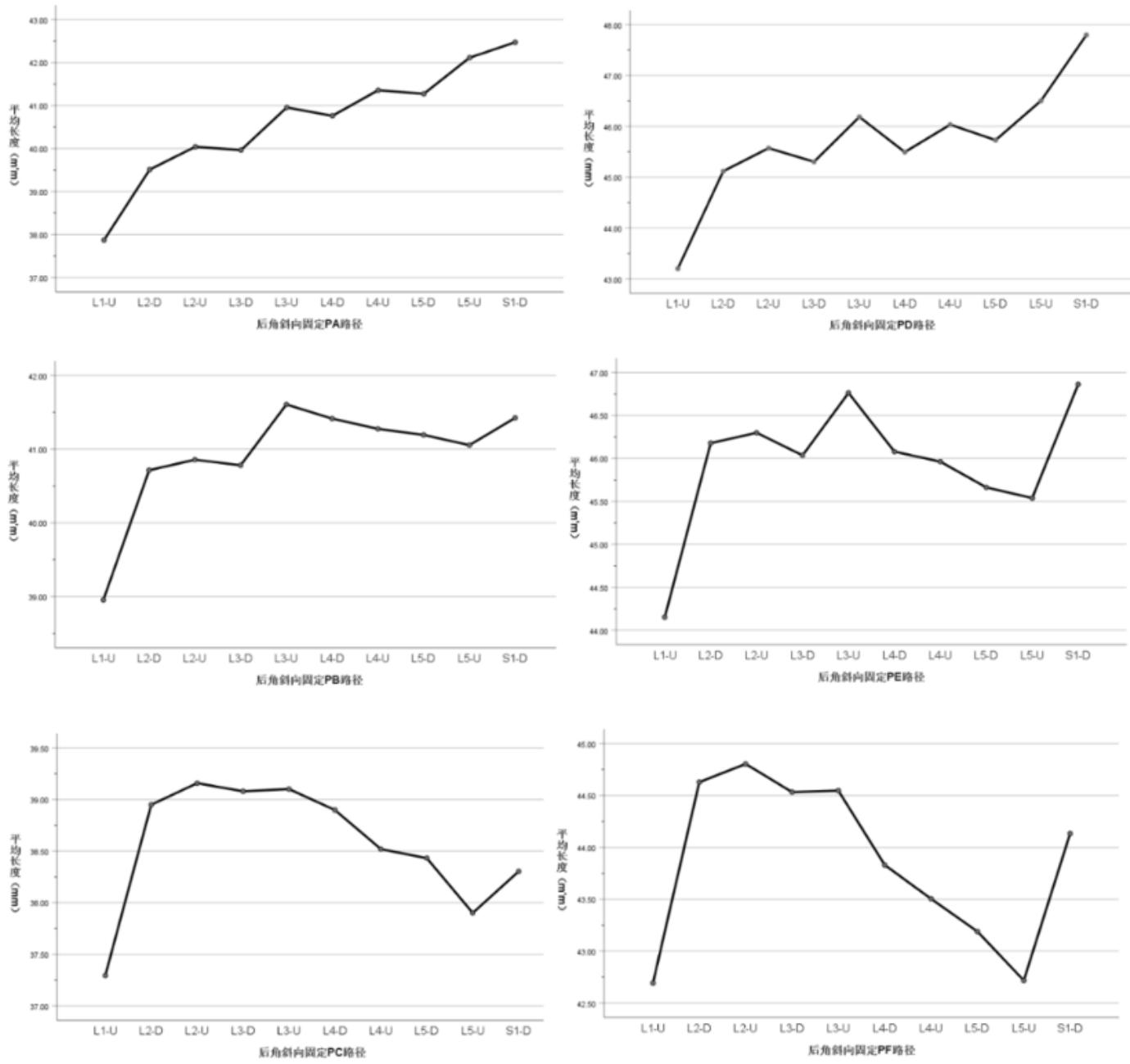


Figure 7

Variation trend of each path length for oblique fixation from posterior corner in lumbar spine (L1-S1).

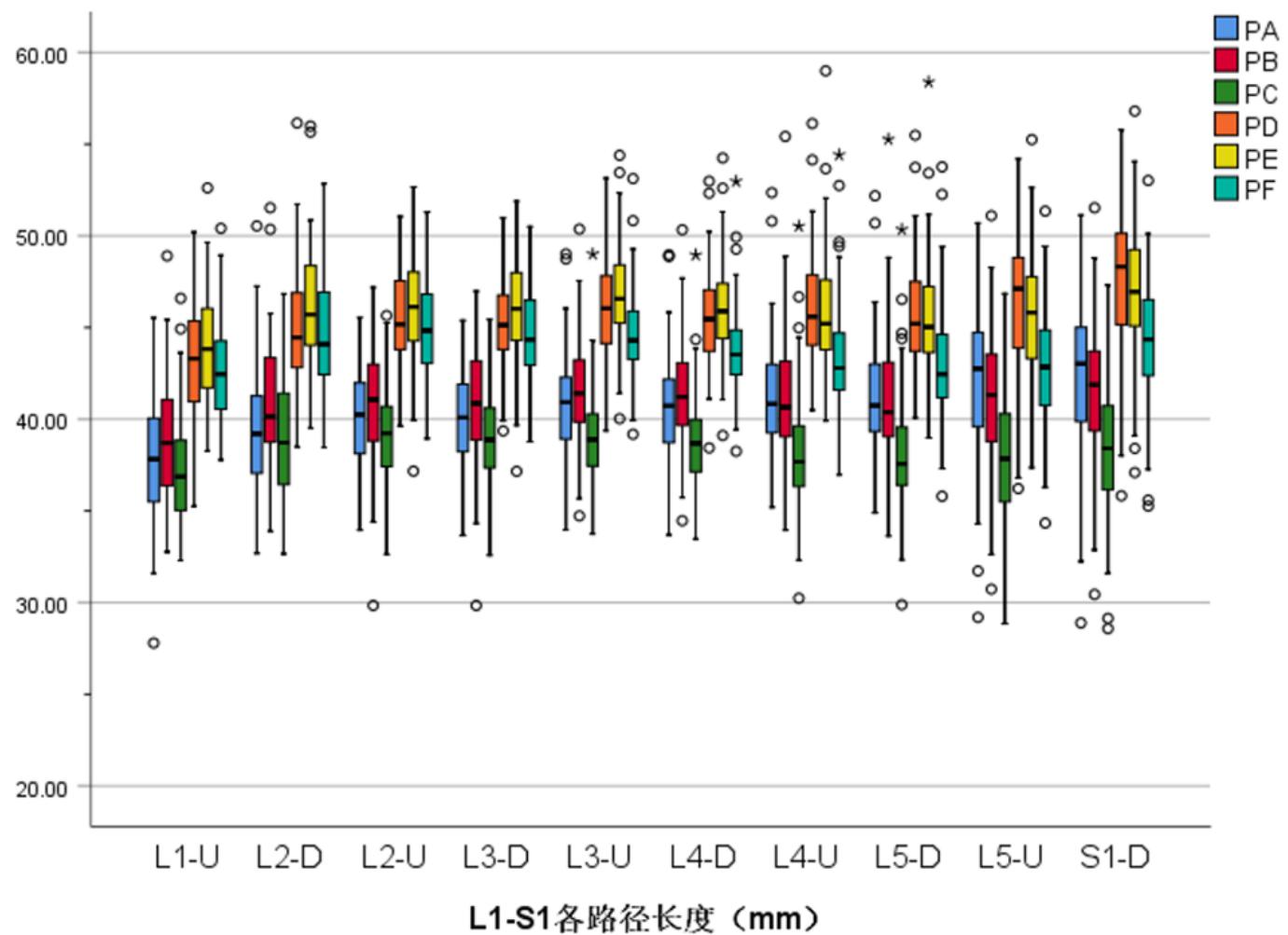


Figure 8

The length of each path for oblique fixation from posterior corner in lumbar spine (L1-S1).

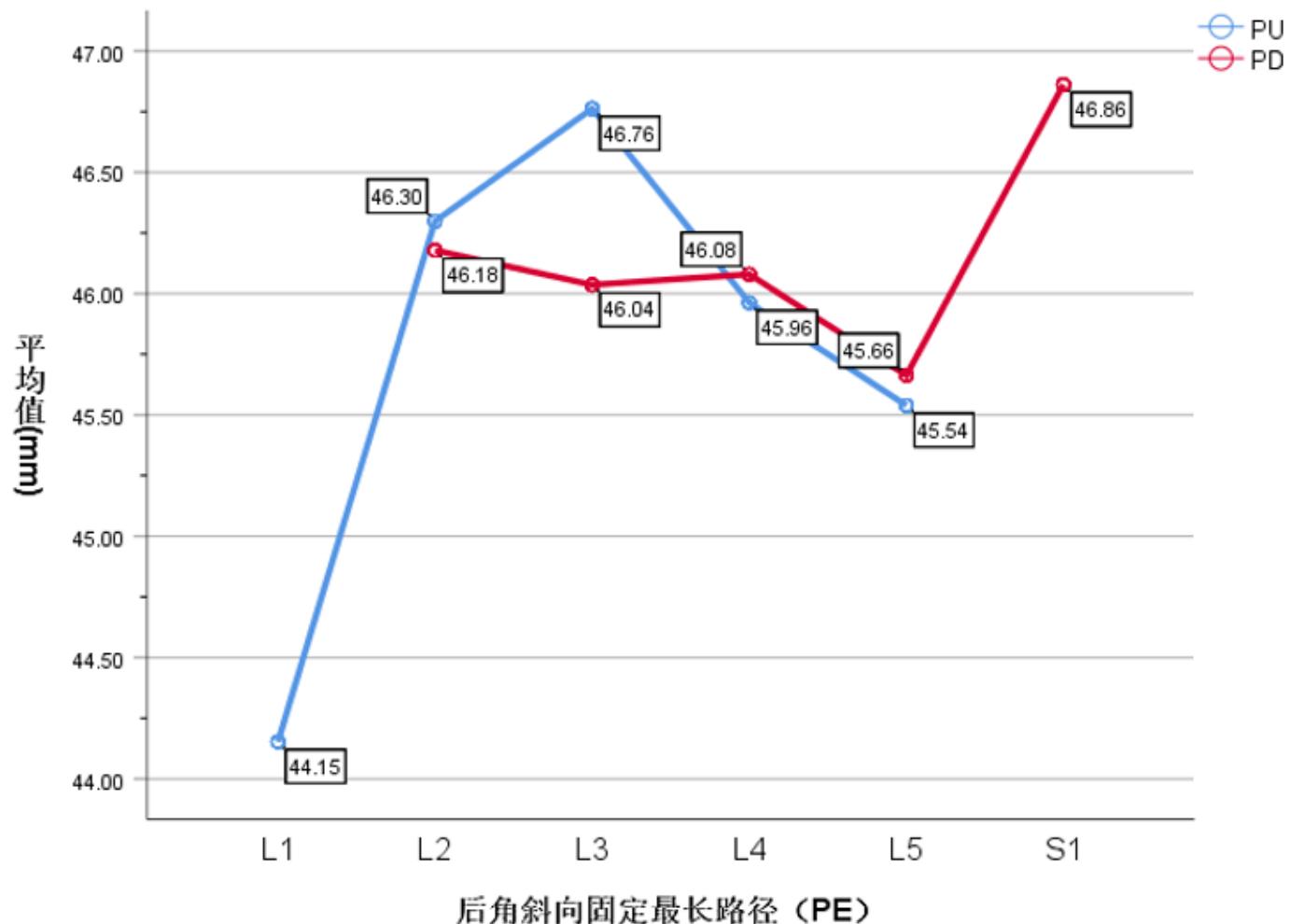


Figure 9

Variation of the longest oblique fixation path (PE)

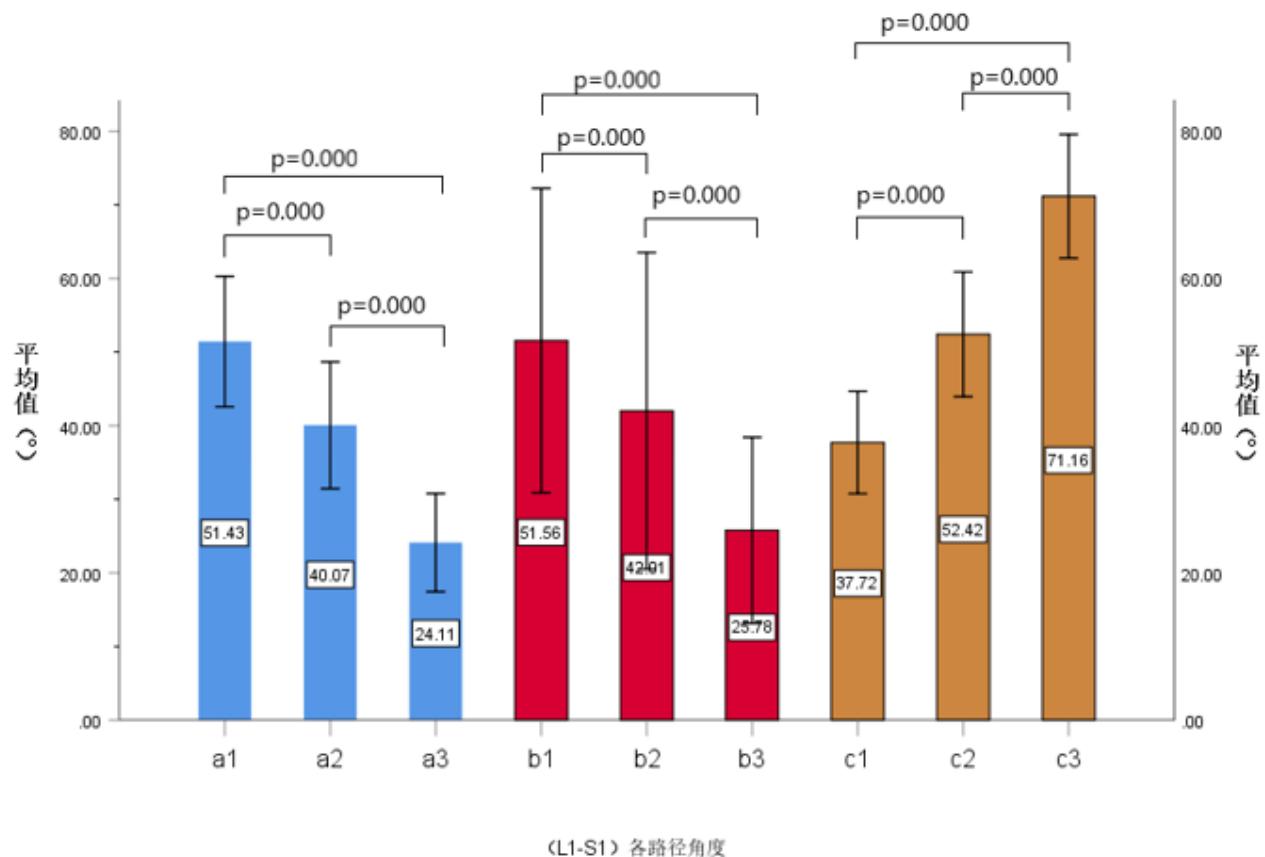


Figure 10

Each path's angle for oblique fixation from posterior corner in lumbar spine (°).

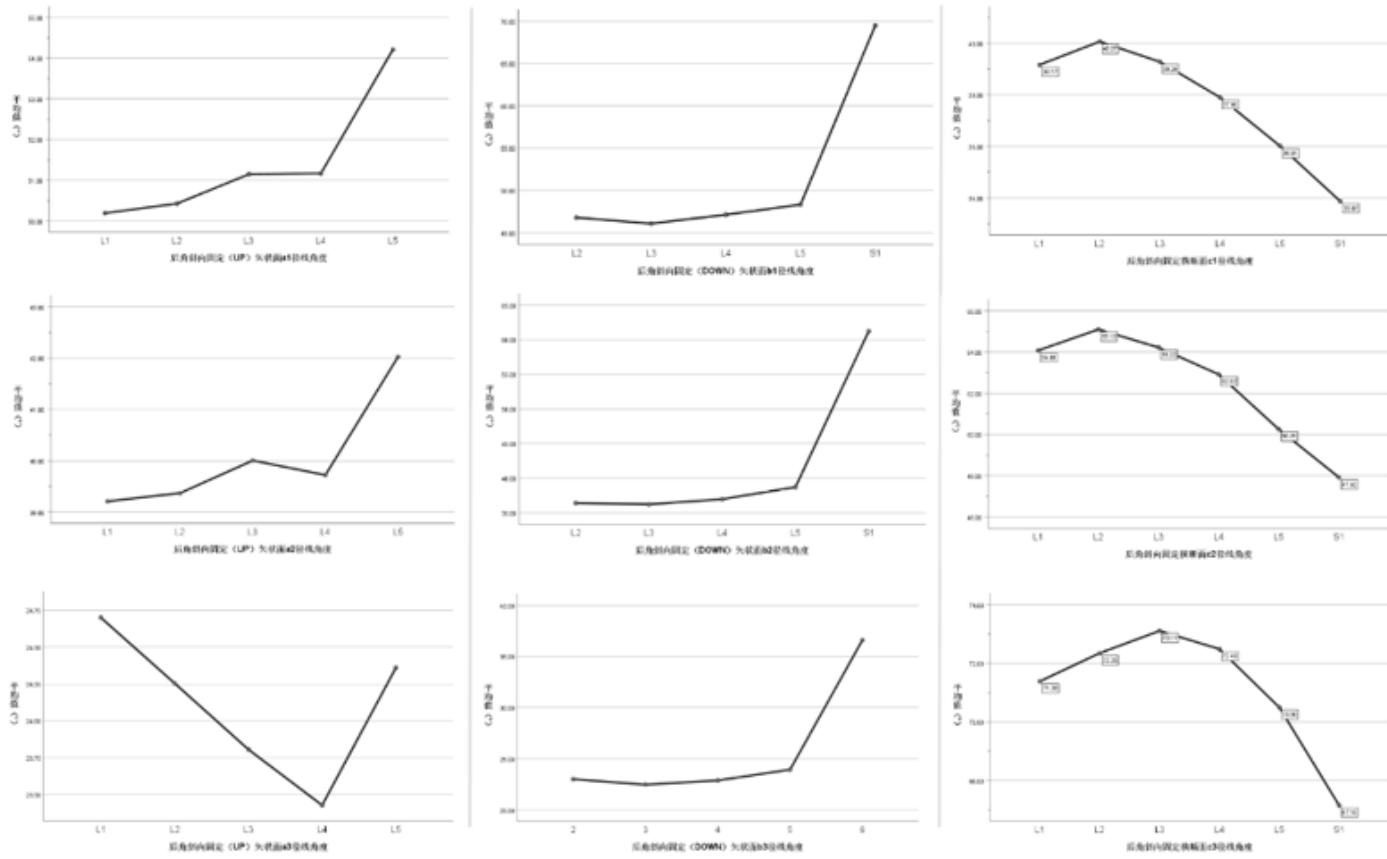


Figure 11

Variation trend of each path angle (L1-S1) for oblique fixation from posterior corner in lumbar spine.

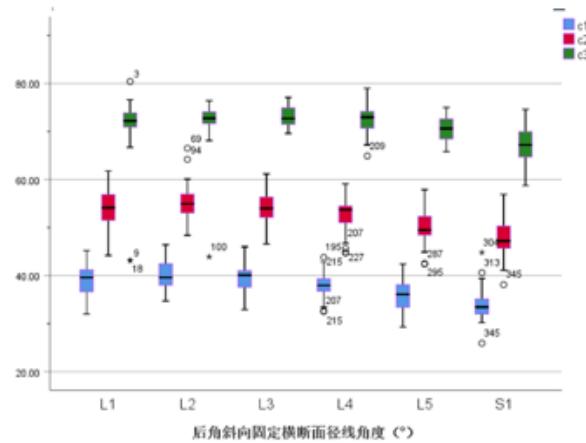
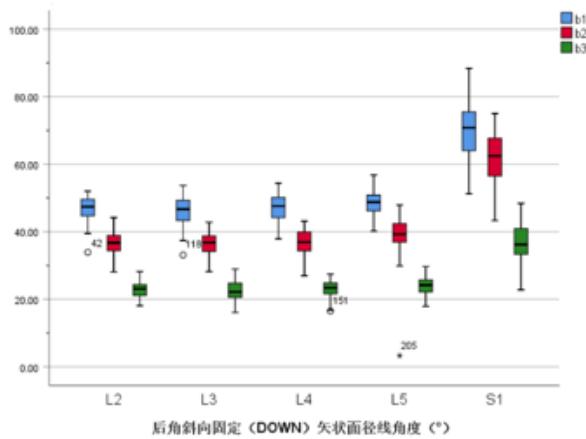
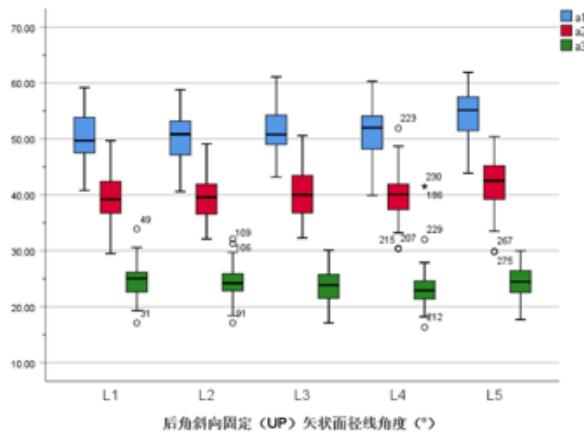


Figure 12

Basic situation of oblique fixation from posterior corner in lumbar spine (L1-S1).

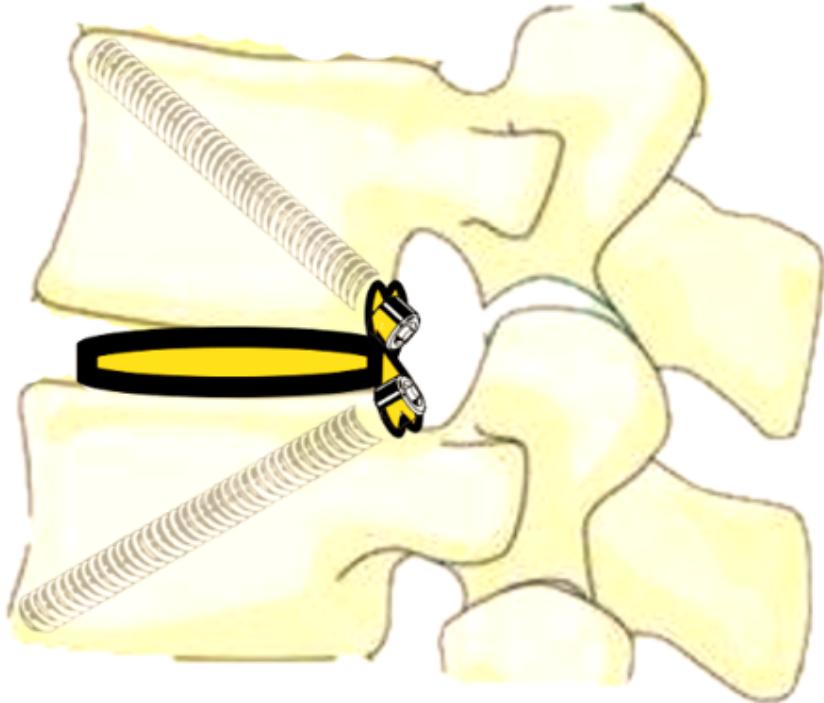


Figure 13

The concept map of percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine.

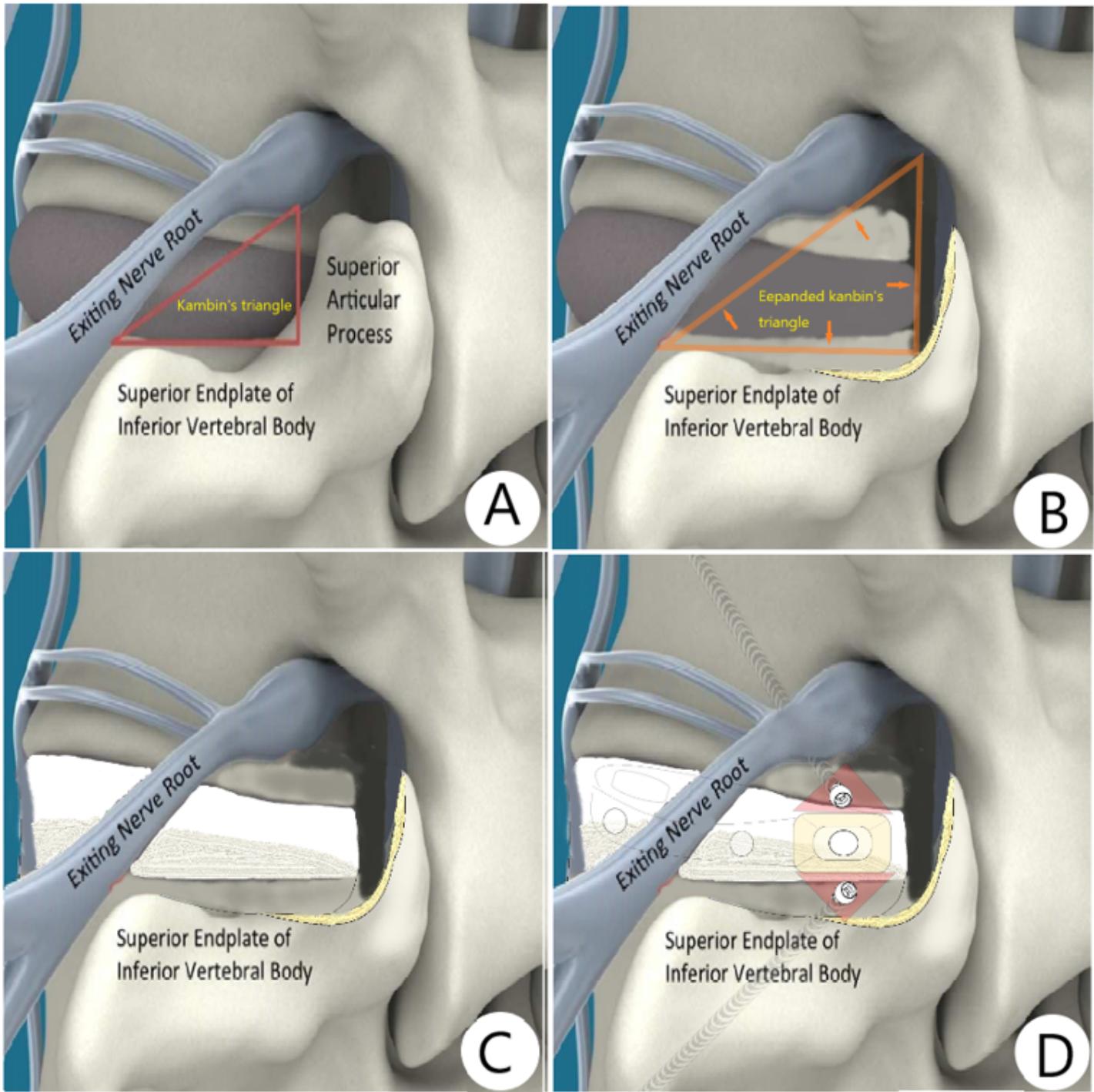


Figure 14

Flow diagram of percutaneous endoscopic transforaminal oblique fixation from posterior corner in lumbar spine. A: Kambin's triangle before Foraminoplasty. B: Kambin's triangle after Foraminoplasty. C: Complete decompression through Kambin's triangle. D: Effect picture of new lumbar interbody fusion cage

Supplementary Files

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