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Safety and feasibility of lumbar spine for intralaminar screw fixation: a computed tomography-based morphometric study

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Objective: The use of intralaminar screws (ILS) in spinal surgery has experienced a recent increase in popularity. The aim of this study is to define the morphological parameters of the lumbar laminas so that guidance may be defined for ILS placement.

Methods: The study involved the evaluation of lumbar computed tomography (CT) images of patients. Two hundred thirty-five patients (127 male, 108 female) were included in the study. The mean patient age was 44.2 years (19–78 years). The measured parameters of the lamina were the transverse inner diameter, transverse outer diameter (lamina width), lamina length, subdural space (safe zone), and spinolaminar angle for each lumbar level (L1–L5).

Results: The mean transverse outer diameter (L1–L5) ranged from 7.2–7.8 mm, and mean transverse inner diameter ranged from 2.5–3.0 mm. The lamina of L3 had the largest width and the lamina of L1 and L5 the smallest. The mean lamina length was 26.6 mm, ranging from 21.0–34.0 mm, and the mean spinolaminar angle was 124.7°, ranging from 111–135°. The L1 level had the shortest mean lamina length and L4 the lowest spinolaminar angle. Mean subdural space (safe zone), which was narrowest at the L5 level, was 2.4 mm, ranging from 1.3–3.6 mm.

Conclusion: ILS of the appropriate size (3.5–4.5 mm) and length (20 and 25 mm) can be used safely in the lumbar spine. However, further biomechanical studies should be performed to measure strength of the fixation.

Keywords: Computed tomography; intralaminar screw; lamina; lumbar vertebrae; morphology; salvage procedure.

Level of Evidence: Level IV Diagnostic Study

The use of intralaminar screws (ILS) as a salvage stabilization technique for posterior spinal surgery has become increasingly popular among spinal surgeons. Rigid segmental fixation with or without arthrodesis is offered for spinal disorders such as idiopathic scoliosis, adult degenerative scoliosis, spondylolisthesis, fractures, tumors, and other forms of spinal instability.

Anatomical changes in advanced spinal deformities make rigid fixation difficult. Due to the lack of epidural space and the increased rotation of the vertebra, pedicle

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screw insertion may be difficult and sometimes impossible; thus, rigid posterior instrumentation with pedicle screws may be insufficient. ILS has recently been proposed as an alternative to pedicle screw fixation in spinal surgery, especially for cases in which pedicle screw insertion is impossible or difficult.[1,2]

A successful ILS placement in spinal surgery requires sufficient understanding of the morphology of the lamina. To our knowledge, there is little in the existing literature reporting on the morphology of the lumbar spine lamina and no guide for assisting surgeons in correct ILS placement.[2–4] We believe that the data from this study will fundamentally boost the spinal surgeon's complete understanding of the lamina morphology and will help the surgeon's ILS placement practice in the lumbar spine.

Patients and methods

Prior to the beginning the cross–sectional study, we obtained approval and a study dispensation from the Ethical Committee of Çanakkale Onsekiz Mart University (050.99-214).

This study involved the evaluation of lumbar computed tomography (CT) scans of patients admitted to our institution between January 2012–June 2013 for lumbar spine assessment. The patients were selected randomly from the radiology department registry. The lamina parameters were measured from the CT images utilizing a Toshiba Asteion (Toshiba America Medical Systems, Tustin, CA, USA; rotation time 0.75 s) CT scanner with an axial slice at a 1 mm interval (Rapidia version 2.8, INFINITT, Seoul, Korea). Patients with bony and ligamentous injury, intraosseous pathology (primary or secondary tumor and infection), congenital or acquired deformity, advanced degenerative changes, and patients <18 years of age (not skeletally mature) were excluded.

Two hundred and thirty-five patients (127 male, 108 female) met the criteria and were included in the study. The measurements were done on axial sections of L1–L5 vertebrate bilaterally. The measured parameters of the lamina were the transverse inner diameter, transverse outer diameter (lamina width), lamina length, subdural space (safe zone), and spinolaminar angle. The measurements were made at the narrowest portion of the lamina. The transverse inner and outer lamina diameters were defined as the innermost or outermost diameter of the lamina, measured perpendicular to the axis of the lamina. The lamina length was measured between the outer cortex of the lamina (entry point) and the level where the medial cortex of the pedicle was seen, subdural space was between the inner cortex of the lamina and the dura, and spinolaminar angle was measured from straight lines bisecting the spinous process and the axis of the lamina. The measurements were made in millimeters up to 0.1 mm by the same radiologist to ensure consistency (Figure 1).

A statistical analysis of all results was conducted, and the mean values, standard deviation, and range values were calculated for each parameter. Data were analyzed

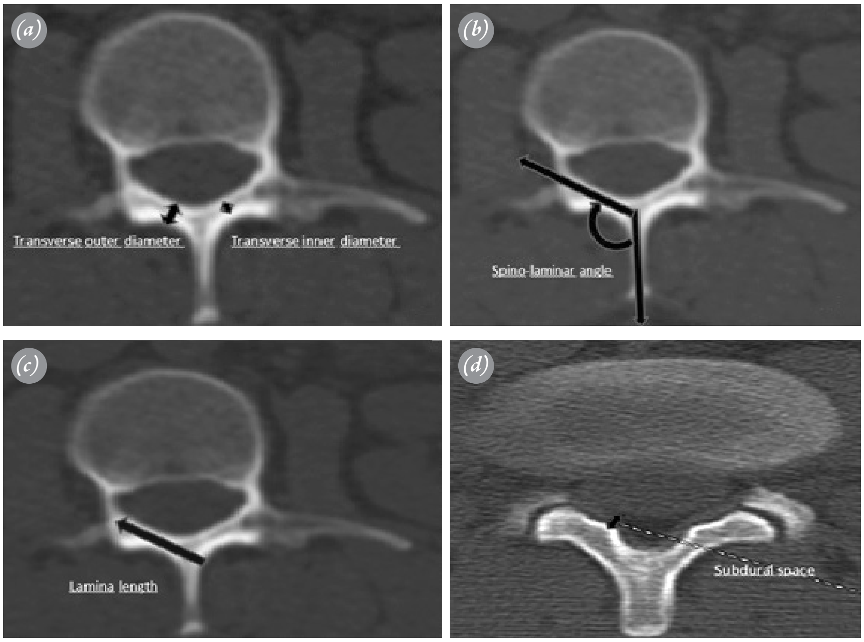

Fig. 1. Illustrations showing measurements of the transverse inner and outer diameter **(a)**, spinolaminar angle **(b)**, laminar length **(c)**, and subdural space **(d)**.

Table 1. Morphology of the lumbar laminas based on CT measurements.

	Transverse outer diameter	Transverse inner diameter	Lamina length	Subdural space	Spinolaminar angle
L1	7.2 (0.8)	3.0 (0.3)	25.5 (2.6)	2.6 (0.2)	126.3 (3.4)
L2	7.6 (0.4)	2.8 (0.2)	27.5 (2.5)	3.0 (0.2)	125.7 (2.6)
L3	7.8 (0.3)	3.0 (0.2)	26.8 (0.9)	2.8 (0.2)	126.4 (3.6)
L4	7.4 (0.5)	2.7 (0.2)	26.8 (1.7)	2.1 (0.2)	117.6 (3.7)
L5	7.4 (0.7)	2.5 (0.2)	26.8 (1.0)	1.8 (0.3)	127.8 (2.8)

CT: Computed tomography; Mean values [mm] with standard deviations [SD]; n=235.

using the Statistical Package for Social Sciences version 19.0 (SPSS, Inc., Chicago, IL, USA). Normality of distribution was evaluated by Kolmogorov-Smirnov test. Statistical differences of each parameter were compared between right and left laminas and between male and female patients at every level using Mann-Whitney U test, and a p value <0.05 was considered statistically significant. The measurements were also grouped into different age groups (19–39, 40–59, 60–78 years), and all parameters were analyzed using Kruskal-Wallis H test, and a p value <0.05 was considered statistically significant. Bonferroni Corrected Mann-Whitney U test was applied to define the difference between the groups, and a p value <0.017 was considered statistically significant.

Results

Two hundred and thirty-five patients (127 male and 108 female) were included in the study. The mean patient age was 44.2 years (range: 19–78 years).

There was no significant difference in all measurements between the right and left laminas, and mean values of right and left laminas for each measurement were calculated (Table 1).

The total number of laminas measured was 2,350 (470 lamina for each level), and 11,750 measurements were recorded. The mean transverse outer diameter of the lamina of L1, L2, L3, L4, and L5 was 7.2, 7.6, 7.8, 7.4, and 7.4 mm, respectively. The mean transverse outer diameter

Table 2. Distribution of patients according to transverse outer diameter measurements (TOD), transverse inner diameter (TID), and lamina length measurements of L1–L5 laminas.

TOD	**<6 mm**		**6–7 mm**		**>7 mm**	
	n	**%**	**n**	**%**	**n**	**%**
L1	18	8	71	30	146	62
L2	0	0	18	8	217	92
L3	0	0	6	2	229	98
L4	0	0	57	24	178	76
L5	0	0	59	25	176	75
L1–L5 (mean)	3.6	2	42.2	18	189.2	80
TID	**<2 mm**		**2–3 mm**		**>3 mm**	
L1	0	0	98	42	137	58
L2	0	0	136	58	99	42
L3	0	0	89	38	146	62
L4	0	0	181	77	54	23
L5	0	0	229	97	6	3
L1–L5 (mean)	0	0	142.6	62	88.4	38
Lamina length	**20–25 mm**		**25–30 mm**		**>30 mm**	
L1	93	40	127	54	15	6
L2	30	12	163	70	42	18
L3	9	4	226	96	0	0
L4	23	10	209	89	3	1
L5	3	1	232	99	0	0
L1–L5 (mean)	31.6	13	191.4	82	12	5

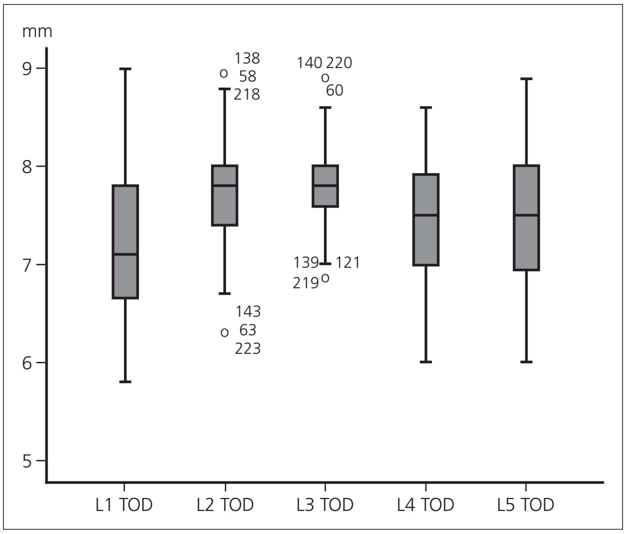

Fig. 2. Box plot showing the transverse outer diameter measurements of the L1–L5 laminas (TOD: Transverse outer diameter, mm: millimeter).

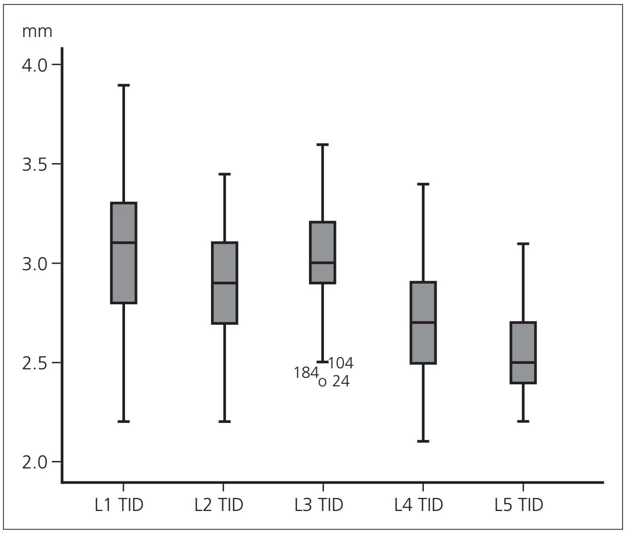

Fig. 3. Box plot showing the transverse inner diameter measurements of the L1–L5 laminas (TID: Transverse inner diameter, mm: millimeter).

of the lamina ranged between 7.2–7.8 mm. The mean transverse inner diameter of the lamina of L1, L2, L3, L4, and L5 was 3.0, 2.8, 3.0, 2.7, and 2.5 mm, respectively (range: 2.5–3.0 mm). The lamina of L3 had the largest transverse inner and outer diameter and the lamina of L1 and L5 the smallest (Tables 1, 2; Figures 2, 3).

The mean lamina length was 26.6 mm, ranging 21.0–34.0 mm (Table 4), and the mean spinolaminar angle was 124.7°, ranging 111–135°. The L1 level had the shortest mean lamina length (25.5 2.6 mm), and L4 had the lowest spinolaminar angle. Mean subdural space (safe zone) was 2.4 mm, ranging 1.3– 3.6 mm, and it was narrowest at the L5 level (1.8 0.3 mm).

Furthermore, the lamina measurements of the patients were analyzed by age group (19–39, 40–59, and >60 years) and gender (male and female) separately, and statistically significant differences between age groups and genders were recorded (Tables 3, 4).

Discussion

Spinal instrumentation with pedicle screws is the most popular method of internal fixation of the spine. While the use of pedicle screws as fixation devices for spinal fusion surgery has become progressively popular, the use of ILS remains quite rare worldwide.[5–7] ILS is useful when alternative spinal fixation techniques (pedicle screws, cables, hooks) have failed or the bony anatomy is not suitable for hook or screw placement.[8] The deformed spine may have bony anomalies as well as rotation which may complicate the instrumentation procedure. In that scenario, ILS can be used as a salvage technique by the spinal surgeon. As a rarely used instrumentation technique, ILS instrumentation requires extensive feasibility and safety assessment before it can be accepted as a standard practice. Radiological studies with sufficient number of patients may provide important detailed morphometric data. Even though cadaveric studies may provide more accurate data, they may be limited due to the availability of cadavers and the strict ethical procedures that govern such studies. Accordingly, advanced radiological imaging techniques would be ideal, as they would result in better anatomical feasibility and safety assessment.[6]

One of the oldest spinal hardware placement techniques, facet fixation was first described by Boucher in 1959;[4] the strategy behind this technique is to block movement at the facet joints with screws that perforate and penetrate the joint. The technique was revised, and translaminar screw fixation was introduced by Magerl in 1984.[9] The translaminar screw technique has since been used over the past 2 decades for short segment fusion for spinal stenosis and degenerative diseases in the lumbar spine. The principle of this technique involves screw fixation of the facet joints in order to facilitate calcification of the bone graft.[3,9] The ILS technique was first described by Wright[10] in the cervical spine for a different purpose. In this technique, the screw is inserted in the lamina but does not penetrate the facet joint. Thus, ILS is unique from translaminar facet screws.[2,11–13] Most of the reports in the literature about ILS fixation address the cervical and uppermost region of the thoracic spine.[2,14,15] To our knowledge, there are few reports regarding the use of laminar screws in the lumbar spine,[2–4] most of which studied not ILS but translaminar facet screws.

Table 3. Measurements of the lumbar laminas in female and male patients.

	Males			Females			
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**	**p**
L1							
TOD	7.2	0.8	5.8–8.9	7.1	0.8	5.8–9.0	0.294
TID	3.1	0.4	2.2–3.9	3.0	0.4	2.4–3.8	0.823
SD	2.6	0.3	2.0–3.2	2.6	0.3	2.1–3.3	0.472
LL	25.7	2.6	21.4–32.0	25.2	2.5	21.0–32.0	0.126
SLA	126.0	3.6	117–132	126.6	3.2	119–135	0.418
L2							
TOD	7.6	0.4	6.7–8.9	7.7	0.5	6.3–8.8	0.095
TID	2.8	0.3	2.5–3.5	2.8	0.3	2.2–3.4	0.146
SD	3.1	0.2	2.5–3.5	3.0	0.2	2.2–3.6	0.995
LL	27.5	2.5	22–34	27.4	2.5	22–33	0.949
SLA*	125.3	2.6	119–130	126.1	2.5	121–131	0.012
L3							
TOD	7.8	0.3	7.0–8.6	7.8	0.4	6.9–8.9	0.669
TID*	3.0	0.2	2.4–3.5	3.0	0.2	2.5–3.6	0.038
SD	2.8	0.2	2.4–3.2	2.8	0.3	2.5–3.5	0.199
LL	26.9	0.9	24.2–28.1	26.8	0.9	24.7–29.0	0.071
SLA*	125.9	3.8	115–132	127.1	3.2	118–134	0.045
L4							
TOD	7.4	0.5	6.1–8.6	7.4	0.6	6.0–8.5	0.903
TID	2.7	0.2	2.2–3.2	2.7	0.3	2.1–3.4	0.415
SD	2.2	0.3	1.5–2.6	2.1	0.3	1.5–2.8	0.066
LL	26.7	1.9	21–29	27.0	1.4	23–30	0.747
SLA*	117.0	3.6	111–125	118.3	3.7	112–126	0.012
L5							
TOD	7.3	0.7	6.0–8.5	7.5	0.7	6.0–8.9	0.052
TID	2.6	0.2	2.3–3.0	2.5	0.2	2.2–3.0	0.113
SD	1.8	0.3	1.3–2.5	1.7	0.3	1.3–2.5	0.216
LL*	26.9	0.9	23.6–28.7	26.6	1.0	25.0–28.7	0.004
SLA	127.7	2.5	122–132	127.9	3.2	122–133	0.457

*Significant difference; SD: Standard deviations; TOD: Transverse outer diameter; TID: Transverse inner diameter; SD: Subdural space; LL: Lamina lengths; SLA: Spinolaminar angle.

Although ILS may be a salvage technique to prevent the structural extension to an additional level when transpedicular fixation fails, it is not commonly used, which may be attributed to a lack of knowledge of ILS placement. Use of ILS requires a through understanding of the pedicle, lamina, and nervous anatomy. Although ILS may provide a more reliable profile for direct visualization of the lamina at the time of screw insertion as well as screw position posterior to the thecal sac and exiting nerve roots, the surgeon's choice of technique depends largely on his/her knowledge of morphology.[16] The feasibility of this practice in the subaxial cervical, thoracic, and lumbar spine has been demonstrated.[1,3,11,13] Lewis et al. presented ILS as an easy procedure with little risk of injury to the vascular and neural structures. Additionally, with no need for intraoperative fluoroscopy to guide screw placement, radiation exposure and operation time are reduced.[15] However, the surgeon must have a comprehensive understanding of the anatomic morphology of the lamina and the limitations of ILS in thoracic and lumbar vertebrae. In cases where the laminas are too thin, small, or short to accommodate ILS, another fixation technique should be utilized. The spinal cord may potentially be at risk if a ventrally placed screw is used, making neurologic sequela probable. Kretzer et al.[5] and Lewis et al.[15] proposed that adequate preoperative imaging is required to determine the feasibility of this technique at various thoracic levels. In contrast, Kose et al.[2] reported that, as these screws are generally used as salvage screws, unless a certain decision is made to use laminar screws, patients should not be exposed to unnecessary doses of radiation.

Table 4. Measurements of the lumbar laminas in different age groups.

	Age 19–39 years (n=103)			Age 40–60 years (n=75)			Age >60 years (n=57)			
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**p**
L1										
TOD	7.2	0.8	5.8–9.0	7.1	0.8	5.8–8.9	7.2	0.8	5.9–8.5	0.429
TID*	3.0	0.4	2.4–3.9	3.1	0.3	2.2–3.8	3.0	0.3	2.5–3.7	0.007
SD*	2.6	0.3	2.0–3.2	2.6	0.3	2.0–3.3	2.6	0.3	2.2–3.2	0.013
LL	25.7	3.0	21.0–32.0	25.6	2.3	21.4–29.0	24.8	2.0	21.0–8.0	0.077
SLA	126.3	3.0	120–132	125.8	3.4	117–131	126.8	3.5	119–135	0.386
L2										
TOD	7.6	0.5	6.7–8.9	7.7	0.4	7.0–8.8	7.7	0.5	6.3–8.3	0.261
TID*	2.8	0.2	2.5–3.4	2.8	0.3	2.2–3.4	2.9	0.3	2.3–3.3	0.001
SD	3.0	0.2	2.2–3.5	3.1	0.2	2.5–3.6	3.0	0.2	2.7–3.4	0.221
LL*	27.7	2.0	22.0–33.0	27.6	2.8	22–34	26.6	2.5	22–31	0.04
SLA*	125.3	2.6	119–131	125.0	2.5	121–129	127.2	1.9	124–130	0.001
L3										
TOD*	7.8	0.3	6.9–8.6	7.9	0.4	7.0–8.9	7.7	0.3	6.9–8.2	0.038
TID*	3.0	0.2	2.4–3.5	3.1	0.2	2.7–3.6	3.1	0.3	2.5–3.5	0.01
SD	2.8	0.3	2.4–3.2	2.8	0.3	2.5–3.2	2.8	0.3	2.5–3.5	0.531
LL	26.9	0.8	25.0–29.0	27.0	0.8	24.7–28.1	26.5	1.1	24.2–8.0	0.123
SLA	126.9	3.2	118–134	126.4	3.6	115–131	125.6	4.0	119–132	0.111
L4										
TOD	7.4	0.5	6.1–8.2	7.4	0.6	6.1–8.6	7.4	0.6	6.0–8.5	0.964
TID*	2.8	0.2	2.2–3.2	2.7	0.3	2.2–3.2	2.5	0.3	2.1–3.4	0.001
SD*	2.1	0.3	1.5–2.8	2.2	0.3	1.5–2.6	2.0	0.3	1.6–2.5	0.004
LL	26.8	2.0	21–30	26.7	1.7	23–29	27.0	1.4	24–29	0.54
SLA	117.2	3.4	112–126	118.0	3.8	111–126	117.8	3.9	112–124	0.379
L5										
TOD*	7.3	0.7	6.0–8.5	7.4	0.7	6.0–8.9	7.6	0.8	6.0–8.5	0.027
TID*	2.5	0.2	2.2–3.0	2.6	0.2	2.3–2.9	2.5	0.2	2.2–2.8	0.003
SD*	1.9	0.3	1.3–2.5	1.8	0.3	1.3–2.2	2.5	0.3	1.3–2.1	0.028
LL*	27.2	0.6	26.0–29.0	26.5	1.2	23.6–28.7	26.5	1.0	25.0–8.0	0.001
SLA	127.9	2.5	123–132	127.3	2.9	122–133	128.2	3.3	122–132	0.128

*Significant difference; SD: Standard deviations; TOD: Transverse outer diameter; TID: Transverse inner diameter; SD: Subdural space; LL: Lamina lengths; SLA: Spinolaminar angle.

The use of pedicle screws for posterior spinal fusion surgery has gradually become accepted worldwide. Until this point, many studies have been performed on pedicle morphology for the success of the pedicle screw technique.[17–21] This knowledge base and the guides that direct the surgeon how to perform correct pedicle screw placement, which is superior to biomechanical tests, are the major reasons for the worldwide usage of pedicle screws. Similarly, research has been conducted regarding lamina and pedicle measurement for ILS usage. However, these similar studies focus specifically on the cervical spine.[11,15,22–28] These authors recommend that if measurement and anatomy of the lamina and pedicle is well known, then ILS is a safe surgical method for spinal fusion in the cervical spine.

In this study, the safety and feasibility of ILS in the lumbar spine was investigated, with the aim of producing a guide for ILS usage in the lumbar spine to better aid the surgeon. Based on our measurements, the widths of the lumbar laminas (transverse outer diameter) are >6 mm in 98% and >7 mm in 80% of cases. Transverse inner diameters are >3 mm in 38% and between 2–3 mm in 62% of cases (Table 2). Although inner diameters are quite narrow, total width (transverse outer diameter) is sufficient for the safe placement of 3.5, 4, and 4.5 mm ILS. This discrepancy in size between inner and outer diameters is resultant from cortical thickness of the lumbar lamina, which may be a biomechanical advantage of ILS usage in the lumbar spine.

The lengths of the laminas range between 25–30 mm in 82% of cases, with no lamina lengths <20 mm. Consequently, 20, 25, and 30 mm screws are safe for use in some patients; however, the L1 lamina is the shortest in length, so it is advisable not to use a screw more than 25 mm long for this segment (Table 1, 2).

Spinolaminar angles are similar, between 125–127° in all levels, with the exception of the L4, which is 117°. Thus, the surgeon should pay extra attention for correct screw trajectory in the L4 level (Table 1). Subdural space (safe zone) is another crucial measurement; it has been found that the L5 level has the narrowest safe zone (Table 1).

In terms of limitations, the current study is a CT-based morphometric study; consequently, measurement errors are possible. However, as all the measurements were performed by the same radiologist in the same manner on slices ≤0.1 mm, we believe any such errors to be minimized and negligible. While it is possible to obtain more accurate data with anatomical studies, the availability of an adequate number of cadavers and the strict ethical procedures governing such studies limits this approach. Additionally, all measurements were performed on the CT scans of spine disease-free patients. Therefore, measurements may not always simulate the true diameters and lengths found in deformed spines. The deformed spine may have bony anomalies as well as rotation, which may complicate the instrumentation. One possible remedy to this limitation would be to take CT scans of these patients and perform the measurements presurgery. Another issue to consider with ILS placement is the limitation of putting both screws in similar directions due to screw shaft contact, creating the necessity to use different trajectories for the right and left screws (i.e., cranially and caudally). Measurements in the current study did not take this situation into consideration.

In conclusion, ILS with the appropriate size and lengths can be used safely in lumbar spine surgery as a salvage technique. However, further biomechanical studies should be conducted before this method is considered for primary fixation.

Conflics of Interest: No conflicts declared.

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