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Importance of transverse pedicle angle & chord length of lumbar pedicle in screw placement: a CT scan study on North West Indian population

Kunal Chawla[1], Mahesh Sharma[2], Suman Kochhar[2], Avinash Abhaya[2], Daisy Sahni[1] and Richa Gupta[1]

[1]Department of Anatomy, Post Graduate Institute of Medical Education & Research, Chandigarh, India
[2]Department of Anatomy, Government Medical College & Hospital, Chandigarh, India

SUMMARY

The aim of this study was to measure the lumbar pedicle dimensions and its angulations for the development of techniques and devices for spinal instrumentation on computed tomography (CT) scan. Fifty CT scans of lumbar vertebral column of patients belonging to North West Indian population was randomly selected. Various morphometric parameters were recorded using software.

The transverse pedicle angle increased from L1 to L5 in both males and females. In males it was maximum at L5 (25.7°) and minimum at L1 (7.5°). In females it was maximum at L5 (24.0°) and minimum at L1 (7.4°). The chord length in males was maximum at L5 (51.3 mm) and minimum at L1 (48.1 mm). In female chord length was maximum at L2 (51.1 mm) and minimum at L4 (47.6) on right side and on left side it was maximum at L3 (50.9 mm) and minimum at L1 (46.7 mm). A screw of 40 mm length appeared to be safe at all lumbar levels as all the vertebrae studied had a chord length well in excess of 40 mm.

The length of the pedicular screw needs to be substantially smaller for Indian population than those mentioned in Western literature. At the lower lumber levels, greater lateral inclination of the pedicle should be kept in mind. Otherwise it may lead to the breach of the medial cortex of the pedicle with resultant risk to the neural tissues.

Key words: Chord length – CT scan – Lumbar – Pedicle – Spine – Transverse pedicle angle – Vertebra

INTRODUCTION

The lumbar region, being the mobile part of vertebral column, is subjected to instability following trauma particularly related to road traffic accidents, use of heavy mechanical devices and adventure sports besides surgical laminectomies, degenerative conditions, congenital defects and metastasizing malignant tumors of the prostate and other pelvic organs (Inceoglu et al., 2005).

Various devices like rods, plates or wires can be fixed to the spinal column by the screws for immobilization (Amonoo-Kuofi, 1995). The factors to achieve stability using implants include accurate screw for fixation and the good quality of bone for the proper screw path (Zindrick et al., 1986). In the recent past, transpedicular screw implantation techniques have gained popularity (Zindrick et al., 1987) over anterior instrumenta-

Corresponding author: Kunal Chawla. Department of Anatomy, Postgraduate Institute of Medical Education & Research, Chandigarh. Pin code 160012, India. Tel: 9914113291.
E-mail: drkunalchawla@gmail.com

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tion and hook-rod devices as the mean of spinal fixation. The unique anatomy of the pedicles provides an excellent implantation site for screw fixation in reconstructive spinal surgeries to maintain and restore stability in such patients (Roy-Camille et al., 1986).

The morphology of vertebral pedicle and angular alignment is difficult to estimate by plain x-ray or at surgery. A mismatched size of pedicle and screw may result in loosening of the screw and fracture of the pedicle, tearing of duramater, leakage of CSF and nerve-root injuries (Matsuzaki et al., 1990; Masferrer et al., 1998; Ofiram et al., 2007).The horizontal diameter of pedicle decides the screw diameter. The transverse (width) and vertical (height) parameters of pedicle decide the screw path.

The accuracy of measurements of the pedicle diameter, pedicle axis and depth to the anterior cortex along the pedicle axis has established the CT scan as the best means of evaluating pedicle radiographic morphology. However, no significant statistical difference exists between the data obtained from CT scan and direct cadaveric measurements as detailed by various authors (Zindrick et al., 1987; Olsewski et al., 1990; Ebraheim et al., 1996; Robertson and Stewart, 2000).

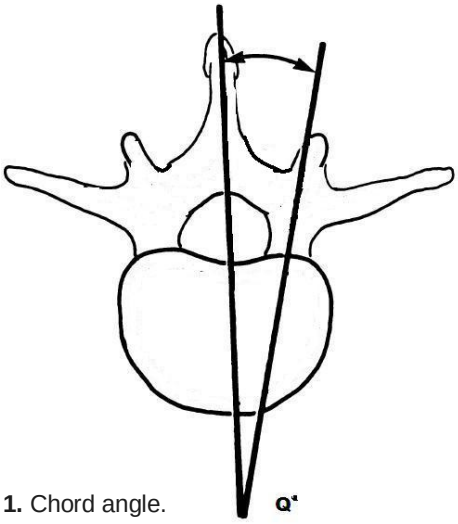

Fig. 1. Chord angle.

MATERIALS AND METHODS

Fifty CT scans (25 male and 25 female) of lumbar vertebral column of randomly selected patients fulfilling the inclusion criteria (age above 25 years) and exclusion criteria (Patients with certain degree of skeletal pathology which was assessed by their history of Chronic back pain, Acute episode of back pain within one year, Inflammatory arthritis, Prior back surgery & Pregnancy) were studied for various morphometric parameters. It is a retrospective study in collected images from previous admitted patients suspected of other

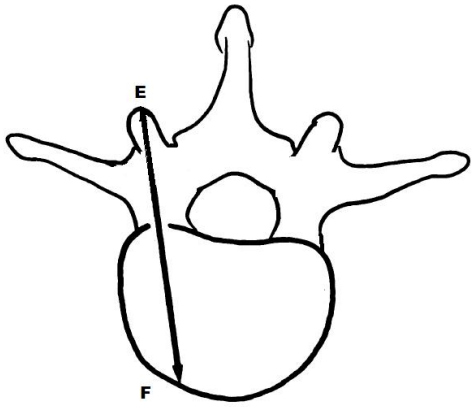

Fig. 2. Chord length.

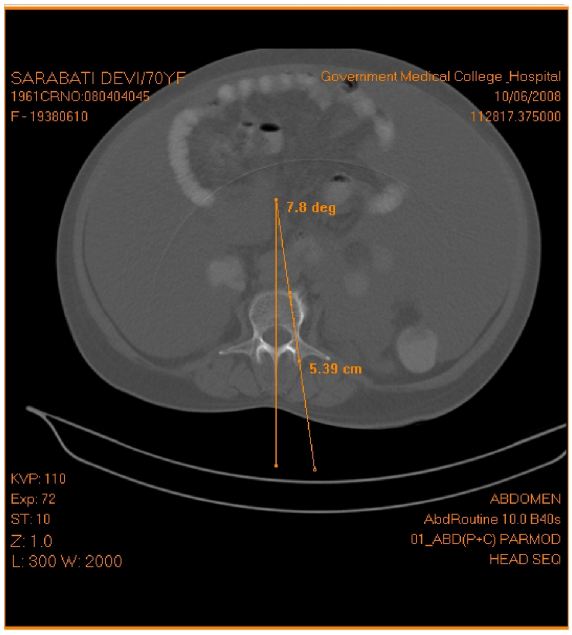

Fig. 3. Transverse pedicle angle.

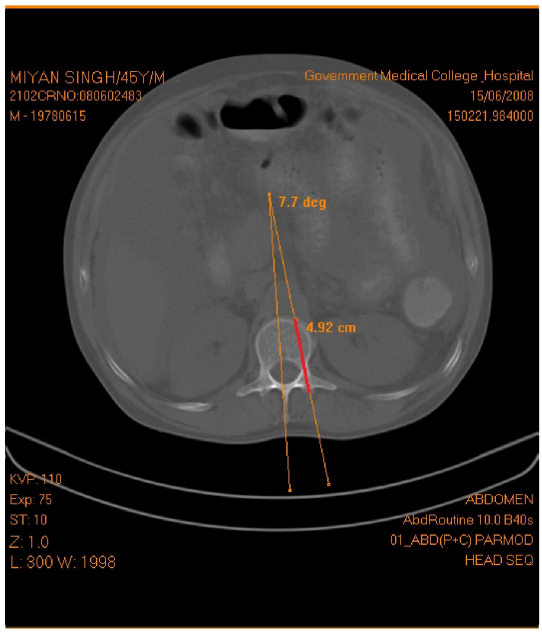

Fig. 4. Chord length.

pathologies reported to the Department of Radiodiagnosis, Government Medical College & Hospital, Chandigarh for conditions not related to any skeletal pathology of vertebral column.

Contiguous axial sections of 5-10 mm of the vertebral column were taken with patient in supine position on which right and left pedicle appeared largest using Siemens Somatomemotion spiral CT scanner. Later the images were printed on bone window settings, and the measurements of the various morphometric parameters were recorded using cursor of the Dicom Works software and a standard computer grid. The findings were recorded on the proforma.

1) Transverse pedicle angle (QO): It was defined as the angle formed between midsagittal plane and plane bisecting the pedicle, as described by Berry et al. (1986) (Fig. 1).

2) Chord length (EF): The pedicle transverse angle or screw convergence angle was measured between a line along the long axis of the pedicle and the median vertebral plane, as described by Olsewski et al. (1990) (Fig. 2).

The accuracy for various parameters like chord length and transverse pedicle angle on Dicom Works software was 0.1 mm and 0.1 degree.

RESULTS

Fifty CT scans (25 males and 25 females) of lumbar vertebral columns of patients above the age of 25 years were studied using student's t-test under the following headings:

Transverse pedicle angle (QO) (Figs. 1, 3, 5; Tables 1, 2): In Males on right side it was maximum at L5 (25.7°) and minimum at L1 (7.5°) and on left side it was maximum at L5 (25.6°) and minimum at L1 (7.5°). The difference of measurements between right and left side was statistically insignificant ($p > 0.05$). It was observed that the transverse pedicle angle gradually increases from L1 to L5 on both sides. In females, on right side it was maximum at L5 (24.0°) and minimum at L1 (7.4°) and on left side it was maximum at L5 (23.8°) and minimum at L1 (7.3°). The difference of measurements between right and left side was statistically insignificant ($p > 0.05$). It was observed that the transverse pedicle angle gradually increases from L1 to L5 on both right and left side. Student's t-test was applied to compare measurements between males and females. However the transverse pedicle angle showed highly significant difference at L4 and L5 level ($p < 0.05$).

Chord length (EF) (Figs. 2, 4, 6; Tables 3, 4): In males, on right side it was maximum at L5 (51.3 mm) and minimum at L1 (48.1 mm) and on left side it was maximum at L2 (51.4 mm) and minimum at L1 (48.6 mm). The difference of measurements between right and left side was statistically insignificant ($p > 0.05$). In females on right side it was maximum at L2 (51.1 mm) and minimum at L4 (47.6) and on left side it was maximum at L3 (50.9 mm) and minimum at L1 (46.7 mm). The difference of measurements between right and left side was statistically insignificant ($p > 0.05$). Student's t-test was applied to compare the chord length between males and females and it showed statistically significant difference at L5 level ($p < 0.05$).

DISCUSSION

Any structural deviation of the pedicle may result in interference of the weight transmission mechanism and compression of neural structures, as it forms one of the components of weight transmission and boundaries of vertebral as well as intervertebral foramina.

The lumbar region being the mobile part of the vertebral column is frequently involved during accidents, degenerative conditions, congenital defects, or metastasis of the neoplasm. Thus it may require instrumentation to regain activity.

Surgical intervention in this region requires thorough knowledge of the anatomy to identify a suitable site for instrumentation for fixation of spine.

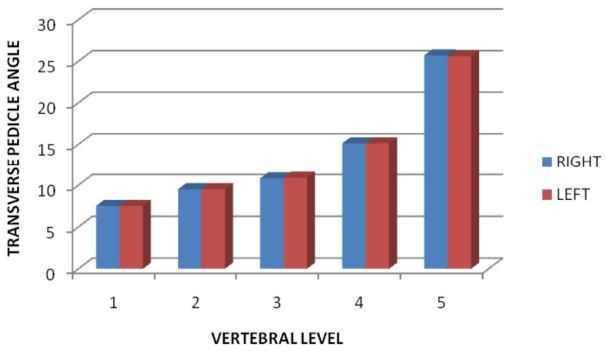

Fig. 5. Transverse pedicle angle of males.

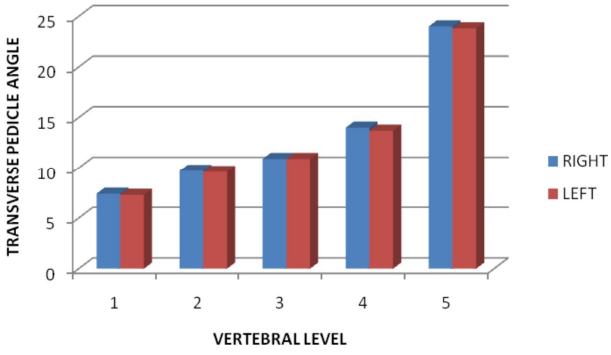

Fig. 6. Transverse pedicle angle of females.

Table 1. Transverse pedicle angle (QO) in males

		RIGHT	LEFT	p-value
L 1	Mean	7.5	7.5	0.710
	S.D.	0.64	0.64	
	Range	6.5 – 8.9	6.3 – 8.7	
L 2	Mean	9.5	9.5	0.451
	S.D.	0.73	0.77	
	Range	7.8 – 10.5	7.7 – 10.7	
L 3	Mean	10.8	10.9	0.121
	S.D.	0.48	0.55	
	Range	10.2 – 11.6	10.1 – 11.7	
L 4	Mean	15.1	15.1	0.922
	S.D.	1.15	1.03	
	Range	13.3 – 16.8	13.3 – 16.7	
L 5	Mean	25.7	25.6	0.646
	S.D.	1.87	1.84	
	Range	20.0 – 27.7	20.3 – 27.9	

Table 2. Transverse pedicle angle (QO) in females

		RIGHT	LEFT	p-value
L 1	Mean	7.4	7.3	0.054
	S.D.	0.57	0.61	
	Range	6.2 – 8.2	6.0 – 8.1	
L 2	Mean	9.7	9.6	0.055
	S.D.	0.48	0.56	
	Range	8.8 – 10.5	8.6 – 10.6	
L 3	Mean	10.9	10.9	0.902
	S.D.	0.47	0.54	
	Range	10.1 – 11.6	10.0 – 11.8	
L 4	Mean	14.0	13.7	0.051
	S.D.	1.15	1.17	
	Range	11.7 – 16.0	11.4 – 15.6	
L 5	Mean	24.0	23.8	0.059
	S.D.	2.78	2.73	
	Range	20.0 – 28.5	19.8 – 28.1	

Table 3. Chord length (EF) in males

		RIGHT	LEFT	p-value
L 1	Mean	48.1	48.6	0.392
	S.D.	0.43	0.45	
	Range	39.0 – 57.8	40.1 – 59.8	
L 2	Mean	51.2	51.4	0.643
	S.D.	0.44	0.40	
	Range	43.2 – 59.1	44.0 – 56.9	
L 3	Mean	51.0	51.3	0.651
	S.D.	0.27	0.27	
	Range	44.4 – 55.0	48.1 – 57.1	
L 4	Mean	49.8	49.0	0.180
	S.D.	0.45	0.35	
	Range	41.3 – 59.2	42.5 – 54.9	
L 5	Mean	51.3	50.7	0.054
	S.D.	0.42	0.40	
	Range	44.3 – 58.8	43.0 – 57.4	

Table 4. Chord length (EF) in females

		RIGHT	LEFT	p-value
L 1	Mean	47.7	46.7	0.92
	S.D.	0.41	0.43	
	Range	42.3 – 55.6	41.1 – 54.9	
L 2	Mean	51.1	50.2	0.108
	S.D.	0.50	0.46	
	Range	43.4 – 62.1	41.2 – 59.0	
L 3	Mean	50.2	50.9	0.210
	S.D.	0.40	0.41	
	Range	43.7 – 57.1	45.0 – 56.8	
L 4	Mean	47.6	49.1	0.124
	S.D.	0.45	0.54	
	Range	41.7 – 57.4	41.4 – 59.8	
L 5	Mean	48.8	48.1	0.180
	S.D.	0.27	0.34	
	Range	44.9 – 55.8	43.1 – 53.2	

The vertebral pedicles are used for placement of screws through them for the management of the unstable lumbar spine and offer potential advantages over anterior instrumentation and hook-rod devices (Matsuzaki et al., 1990), and with the help of screws, various devices such as rods, plates or wires can be applied to spine for immobilization or fixation (Amonoo-Kuofi (1995).

A misplaced or misdirected pedicle screw may cause injuries to the pedicle cortex, nerve root, facet joint and adjacent vital structures (Weinstein et al., 1988; Misenheimer et al., 1989). Therefore, for safer pedicle screw placement, it is important to understand pedicle dimensions and its angula-

Table 5. Transverse pedicle angle data available in literature

Authors	L1	L2	L3	L4	L5
Zindrick et al. (1986) North America)	10.9	12	14.4	17.7	29.8
Olsewski-Olsewski et al. (1990) North America	6	8	13	16	29
Mitra et al. (2002) West India	9	10.05	12.33	14.72	29.33
Chadha et al. (2003) North India	8.78	10.03	12.25	15.39	24.33
Wolf et al. (2001) Israel	11.8	11.0	12.8	14.1	18.5

tions for the development of techniques and devices for spinal instrumentation.

In pedicle screw insertion, the screw is passed through the posterior aspect of the pedicle into the body of the vertebra anteriorly. As the success of this technique depends upon the ability of the screw to obtain strength within the vertebral body, the choice of the screw is determined by the minimum diameter of the pedicle. Therefore the morphometric data of the pedicles is useful in preoperative planning and also in designing pedicle screws and other implantable devices.

In previous studies (Chawla et al., 2011, 2012) by the same authors it was found out that for the Indian population Steffee pedicle screws of 5.5 mm diameter can be used safely in lumbar vertebrae since the diameter of the pedicular screw is governed by the minimum diameter of the pedicle, which in the present study was across the width (8.7 mm). Section of pedicle resembled a shell with outer cortex surrounding inner cancellous bone.

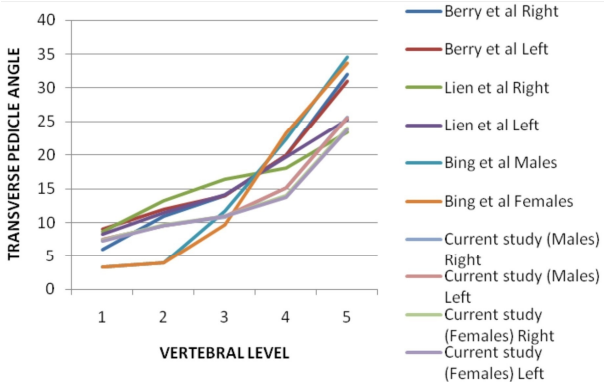

Fig. 7. Comparison of transverse pedicle angle.

Transverse pedicle angles of lumbar vertebrae were studied in CT scans. It was maximum at L5 (25.7°) and minimum (7.5°) at L1 on right side. On the left side too it was maximum at L5 (25.6°) and minimum at L1 (7.5°). In females too it was maximum at L5 (24.0°) and minimum at L1 (7.4°) and on left side it was maximum at L5 (23.8°) and minimum at L1 (7.3°). The pattern of gradual increase from L1 to L5 observed in the current study was in accordance with the findings of previous studies except Wolf et al. (2001) who reported that mean transverse pedicular angle decreased from L1 to L2 and then gradually increased from L2 - L5 (Fig. 7; Table 5).

The value for L5 was 24.8° in the current study, as compared to other authors who found a 27° inclination at L5. The pedicle lay in horizontal plane with an anteroposterior axis at L1 vertebra whereas at L5 vertebral axis moved slightly laterally so that posterior end becomes laterally placed at L5 level as compared to the anterior end. The oblique orientation of the pedicle axis allows oblique screw placement, and thus produces an interlocking or toe-nailing effect between the right and left screws in each vertebra. While operating, any inadvertent medial angulation of the screw may lead to the breach of the medial cortex of the pedicle with resultant risk to the neural tissues. Preoperative CT scan can give morphometric details regarding transverse pedicle angle, which would be critical while deciding

Table 6. Comparison of transverse pedicle angle values observed in current study with previous studies

Authors			L1	L2	L3	L4	L5
Li et al. (2004) China	Males		3.3	4.0	11.7	22.4	34.5
	Females		3.3	4.0	9.7	23.3	33.7
Current Study	Males	Rt.	7.5	9.5	10.8	15.1	25.7
		Lt.	7.5	9.5	10.9	15.1	25.6
	Females	Rt.	7.4	9.7	10.9	14.0	24.0
		Lt.	7.3	9.6	10.9	13.7	23.8

Table 7. Chord length data available in literature

Authors	L1	L2	L3	L4	L5
Zindrick et al. (1986) North America	44.7	45.5	44.4	40.7	33.7
Olsewski et al. (1990) North America	45.8	49.2	51.7	55.3	49.2
Mitra et al. (2002) West India	46.8	49.7	49.35	49.83	46.87
Chadha et al. (2003) North Indiaa	47.49	49.09	46.25	46.27	49.45
Wolf et al. (2001) Israel	44.8	46.9	47.6	47.6	46.6

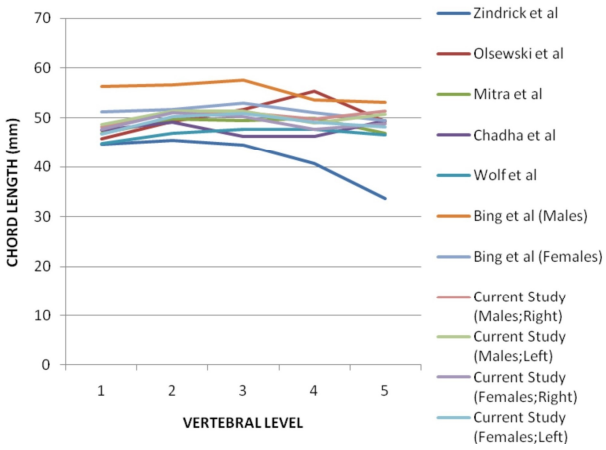

Fig. 8. Comparison of cord length.

entry point of pedicle screw.

There was a significant difference in mean transverse pedicle angle at all lumbar levels between the current study and that of Li et al. (2004) who studied the Chinese population. The difference may be due to racial variation.

In males the chord length in the present study was maximum at L5 (51.3 mm) and minimum at L1 (48.1 mm) on right side, while on left side it was maximum at L2 (51.4 mm) and minimum at L1 (48.6 mm). In females it was maximum at L2 (51.1 mm) and minimum at L4 (47.6 mm) on right side and on left side it was maximum at L3 (50.9 mm) and minimum at L1 (46.7 mm).

In all the studies, chord length at L5 consistently measured less than at other lumbar vertebral levels. However, in the present study L1 had minimum chord length followed by L4. The difference was not significant.

Olsewski et al. (1990) reported the greatest chord length at L4, as compared with L2 reported by Zindrick et al. (1986) (Table 7). In the current study, the chord length was greatest at L2 for the males and females. Chord length was fairly constant amongst individuals and as well as L1-L5 levels.

In previous studies (Fig. 8; Table 8) chord lengths of the right and left pedicles were nearly same and similar trend was seen in the present study except at L5 level. Mean chord length in females was lower than in males at all levels in current study and the trend corresponds to findings of Li et al. (2004) though his readings were higher than the current study. In a study on Korean population authors observed no significant difference between males and females in case of pedicle angle and chord length whereas in the current study statically significant gender difference were observed for both chord length and transverse pedicle angle (Kim et al., 2009).

Some of the differences may be due to factors such as race, stature, build and in CT scans due to observer's bias, slice thickness, and scan diameter, calibration standards, and orientation of the scanning plane relative to the anatomic structure of interest. The pedicle anatomy in scoliosis patients shows very high individual variations and a careful study of pre- operative CT scans is essential for planning proper pedicle screw placement (Upendra et al., 2010). Pedicle screw fixation did not appear to depend on bone quality (DXA) (Santoni et al., 2009).

To summarize, for the Indian population: Steffee pedicle screws of 5.5 mm diameter can be safely

Table 8. Comparison of chord length values observed in current study with previous studies

Authors			L1	L2	L3	L4	L5
Li et al. (2004) China	Males		56.3	56.6	57.5	53.5	53.1
	Females		51.2	51.7	52.9	51.0	49.5
Current Study	Males	Rt.	48.1	51.2	51.0	49.8	51.3
		Lt.	48.6	51.4	51.3	49.0	50.7
	Females	Rt.	47.7	51.1	50.2	47.6	48.8
		Lt.	46.7	50.2	50.9	49.1	48.1

used in lumbar vertebrae, as the diameter of the pedicular screw is decided by the minimum diameter of the pedicle which in the present study was across the width (8.7 mm). Screws of 40 mm length appeared to be safe at all lumbar levels as the minimum mean chord length was 46.1 mm. At the lower lumbar levels, higher lateral inclination of the pedicle should be kept in mind, as it may lead to the breach of the medial cortex of the pedicle with resultant risk to the neural tissues.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest. There is no financial help from the organizing research committee.

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