

A Morphometric Study of Lumbar Vertebra Pedicles and Its Use in Transpedicular Screw Fixation

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Abstract

Pedicle screws are used with an increasing frequency for fixation in spinal fractures. Thus it is imperative to have adequate knowledge of morphometry of lumbar pedicles. *Aim:* To measure various dimensions of pedicles in lumbar vertebrae and to suggest dimensions for pedicular implants in the Indian population and to improve the pedicular screw placement technique. *Methods and Materials:* Two hundred and ten dry human lumbar vertebrae of unspecified gender and age obtained from Department of Anatomy of Medical colleges. The lumbar vertebrae were divided into two groups typical (L1-4) and atypical (L5) depending on the atypical features of L5. Various parameters of pedicles were measured. *Results and Conclusions:* In typical Lumbar vertebra Pedicle width was almost always less than the pedicle height. In atypical Lumbar vertebra pedicle height is lesser than typical lumbar vertebra. The chord length is more than 35mm in all lumbar vertebrae. The measurement in this study will help in finding the appropriate screw to be implanted in the lumbar region of the spine for spine immobilization and fixation.

Keyword: Lumbar Vertebra; Chord Length; Pedicle.

Introduction

Vertebral pedicles are short, thick rounded dorsal projections from the superior part of the body at the junction of its lateral and dorsal surfaces. It has been proved that the pedicle is the strongest part of the vertebra even in osteoporotic bone [5,8]. Spinal fusion by transpedicular fixation has been in practice for many years so as to treat different painful conditions of the lumbar spine. With increasing popularity, there has been dramatic improvement in the way the spinal fusion operations are performed using fixation devices including the pedicle screws [2]. Pedicular fixation is more stable and versatile because it provides three dimensional fixations. Due to increased use of various pedicle screw instrumentations, there is concern about injuries to the pedicle cortex, nerve root, facet joint, and adjacent vital structures by oversized pedicle screw size. Choice of the screw for the

operation is determined by the minimum diameter of the pedicle [2,4]. Detailed knowledge of pedicle morphometry is critical for proper placement of the transpedicular screw and to avoid inadvertent penetration of the pedicular wall. The purpose of this study was to obtain the anatomic morphometric data of the pedicles so as to provide reference guide to the choice of the size of the pedicular screw for transpedicular screw fixation.

Methods

The present study was carried out on dry human lumbar vertebrae obtained from Department of Anatomy of Medical colleges. Two hundred and ten lumbar vertebrae were selected for study of which 180 was typical lumbar vertebra and 30 were atypical. The vertebrae were of unspecified gender and age. Serial numbers were assigned to lumbar vertebra. Measurements were taken using a vernier caliper (0-300mm with a precision of 0.01 mm). Photographs were taken of lumbar vertebra with a digital camera and the angular measurements were recorded using Markus-Bader (MB) ruler software [7]. MB ruler is software which is free to use for non-commercial purposes. Measurements were taken of right and left

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pedicles. Two authors made all measurements at separate sittings, one measurement serving as a check to the other. The mean was then calculated for that pedicle.

The following parameters were recorded in a proforma:

1. *Pedicle width at the midpoint of the pedicle*: It is the distance between medial and lateral surfaces of pedicle at its midpoint.
2. *Pedicle height at the midpoint of the pedicle*: It is the distance between superior and inferior border of pedicle at its midpoint.
3. *Transverse pedicle angle*: It is the angle between a line passing through the pedicle axis and a line parallel to the vertebral midline.
4. *Sagittal pedicle angle*: It is the angle between a line passing through the pedicle axis and superior vertebral body border in the sagittal plane.
5. *Chord length (Screw path length)*: It is the distance from the most posterior aspect of the junction of the superior process and the transverse process to the anterior cortex of the vertebral body along the pedicle axis.

Results

1. The pedicle width of typical lumbar vertebra at the midpoint of the pedicle on the right side ranged from 4.25 - 16.2 mm with a mean of 8.38 ± 2.13 mm and on the left side ranged from 4.4 – 18.9 mm with a mean of 8.53 ± 2.34 mm
2. The pedicle width of atypical lumbar vertebra at the midpoint of the pedicle on the right side ranged from 10.1 – 20.7 mm with a mean of 15.39 ± 2.81 mm and on the left side ranged from 10.9– 20.4 mm with a mean of 15.62 ± 2.54 mm.
3. The pedicle height of typical lumbar vertebra at the midpoint of the pedicle on the right side ranged from 9.8 -19.5 mm with a mean of 14.01 ± 1.56 mm and on the left side ranged from 9.8 – 16.7 mm with a mean of 13.75 ± 1.49 mm.
4. The pedicle height of atypical lumbar vertebra at the midpoint of the pedicle on the right side ranged from 9.8 -16.7 mm with a mean of 13.23 ± 1.93 mm and on the left side ranged from 9.9 - 18.3 mm with a mean of 12.58 ± 1.90 mm.
5. The transverse pedicle angle of typical lumbar vertebra on the right side ranged from 4.8 - 21.77 degrees with a mean of 10.94 ± 2.98 degrees and on the left side ranged from 4.7 – 22.39 degrees with a mean of 10.87 ± 2.93 degrees.

Table 1: Comparison of pedicle width at the midpoint of the pedicle with other studies

Lumbar vertebra	Study	Year	Country	Material for study	Mean (mm)	Std.Dev	Range (mm)
Typical Lumbar vertebra L1-L4	Alon Wolf et al [10]	2001	Israel	CT scans	L1 -5.6 L2-7.7 L3-8.9 L4-11.4	L1 -1.3 L2 -1.5 L3-1.9 L4-1.8	
	Acharya S et al [1]	2010	India	CT scans	L1 -7.20 L2-7.62 L3-8.97 L4-11.12	L1 -0.93 L2 -0.84 L3-1.09 L4-1.01	6.57–12.2 9.25–14.26
	Aruna N et al [2]	2011	India	Dry bones	L1 -7.39 L2-7.87 L3-9.88 L4-11.42	L1 -0.16 L2 -0.15 L3-0.18 L4-0.13	L1 -4.5-11 L2 -5-11.5 L3-6.5-15 L4-9-20
Atypical Lumbar vertebra L5	Dhawal et al [3]	2014	India	Dry bones	Right: 8.41 Left: 8.57	Right: 1.62 Left: 1.69	Right: 5.02 - 13.02 Left: 4.32 -13.44
	Present study	2016	India	Dry bones	Right:8.38 Left: 8.53	Right: 2.13 Left:2.34	Right :4.25 - 16.2 Left: 4.4 – 18.9
	Alon Wolf et al [10]	2001	Israel	CT scans	13.7	2.2	
	Shiu-Bii Lien et al [6]	2007	Taiwan	Dry bones, cadaveric	Right:17.7 Left: 17.5	Right: 2.7 Left:2.6	
	Acharya S et al [1]	2010	India	CT scans	13.91	1.16	10.65–16.4
Aruna N et al [2]	2011	India	Dry bones	12.33	0.23	13-22	
Present study	2016	India	Dry bones	Right:15.39 Left: 15.62	Right:2.81 Left:2.54	Right: 10.1 – 20.7 Left: 10.9– 20.4	

6. The transverse pedicle angle of atypical lumbar vertebra on the right side ranged from 9.78 - 23.5 degrees with a mean of 17.74 ± 4.09 degrees and on the left side ranged from 9.11 - 23.98 degrees with a mean of 17.64 ± 4.03 degrees.
7. The sagittal pedicle angle of typical lumbar vertebra on the right side ranged from 4.48 - 9.24 degrees with a mean of 6.94 ± 1.15 degrees and on the left side ranged from 4.6 - 9.4 degrees with a mean of 6.84 ± 1.11 degrees.
8. The sagittal pedicle angle of atypical lumbar vertebra on the right side ranged from 7.38 – 11.5 degrees with a mean of 8.33 ± 0.86 degrees and on the left side ranged from 7.1 – 11.3 degrees with a mean of 8.30 ± 0.92 degrees.
9. The chord length of typical lumbar vertebra on the right side ranged from 35.11 – 54.56 mm with a mean of 44.54 ± 4.17 mm and on the left side ranged from 35.61 – 54.12 mm with a mean of 44.65 ± 4.15 mm.
10. The chord length of atypical lumbar vertebra on the right side ranged from 35.89 – 54.33 mm with a mean of 42.33 ± 4.40 mm and on the left side ranged from 35.53 – 54.11 mm with a mean of 42.30 ± 4.37 mm.

Table 2: Comparison of pedicle height at the midpoint of the pedicle with other studies

Lumbar vertebra	Study	Year	Country	Material for study	Mean (mm)	Std.Dev	Range (mm)
Typical Lumbar vertebra L1-L4	Alon Wolf et al [10]	2001	Israel	CT scans	L1 -15.1 L2-14.8 L3-14.5 L4-14.8	L1 -1.9 L2 -1.6 L3-1.9 L4-2.1	
	Aruna N et al [2]	2011	India	Dry bones	L1 -14.81 L2-14.4 L3-14.15 L4-13.85	L1 -0.16 L2 -0.15 L3-0.14 L4-0.16	L1 :11.5-19 L2:12-17 L3:11.5-17 L4:10.5-20
	Dhawal et al [3]	2014	India	Dry bones	Right: 13.96 Left: 13.9	Right: 1.34 Left: 1.39	Right: 10.42-17.42 Left: 10.22-17.54
	Present study	2016	India	Dry bones	Right: 14.01 Left: 13.75	Right: 1.56 Left: 1.49	Right : 9.8 -19.5 Left: 9.8 – 16.7
Atypical Lumbar vertebra L5	Alon Wolf et al [10]	2001	Israel	CT scans	15.6	2.3	
	Singel TC et al [9]	2004	India	Dry bones	Males 13.4 Females 13.25	Males 6 Females 2.5	Males 11-17 Females 12-15
	Aruna N et al [2]	2011	India	Dry bones	17.52	0.14	10-16
Present study	2016	India	Dry bones	Right 13.23 Left: 12.58	Right:1.93 Left: 1.90	Right: 9.8 -16.7 Left: 9.9 - 18.3	

Table 3: Comparison of transverse pedicle angle with other studies

Lumbar vertebra	Study	Year	Country	Material for study	Mean (degree)	Std.Dev	Range (degree)
Typical Lumbar vertebra L1-L4	Alon Wolf et al [10]	2001	Israel	CT scans	L1 -11.8 L2-11 L3-12.8 L4-14.1	L1 -1.3 L2 -1.7 L3-2.2 L4-2.1	
	Acharya S et al [1]	2010	India	CT scans	L1 -10.90 L2-12.12 L3-15.40 L4-18.37	L1 -3.13 L2 -2.89 L3-3.57 L4-4.31	
	Dhawal et al [3]	2014	India	Dry bones	Right: 11.79 Left: 11.67	Right: 4.03 Left: 4.09	Right: 4.44-23.42 Left: 4.02-23.69
	Present study	2016	India	Dry bones	Right 10.94 Left: 10.87	Right: 2.98 Left 2.93	Right : 4.8-21.77 Left: 4.7-22.39
Atypical Lumbar vertebra L5	Alon Wolf et al [10]	2001	Israel	CT scans	18.5	3.9	
	Acharya S et al [1]	2010	India	CT scans	24.75	3.83	16.38–30.16
	Present study	2016	India	Dry bones	Right 17.74 Left: 17.64	Right:4.09 Left: 4.03	Right: 9.78 - 23.5 Left: 9.11 - 23.98

Table 4: Comparison of mean sagittal pedicle angle with other studies

Lumbar vertebra	Study	Year	Country	Material for study	Mean (degree)	Std.Dev	Range (degree)
Typical Lumbar vertebra L1-L4	Dhawal et al [3]	2014	India	Dry bones	Right: 4.78 Left: 4.67	Right: 2.06 Left: 2.04	Right: 1.39-9.88 Left: 1.4-9.31
	Present study	2016	India	Dry bones	Right 6.94 Left: 6.84	Right:1.15 Left 1.11	Right : 4.48 - 9.24 Left: 4.6 - 9.4
Atypical Lumbar vertebra L5	Shiu-Bii Lien et al [6]	2007	Taiwan	Dry bones, cadaveric	Right: 3.0 Left: 2.8	Right: 0.8 Left: 0.7	
	Present study	2016	India	Dry bones	Right : 8.33 Left: 8.30	Right:0.86 Left: 0.92	Right: 7.38 – 11.5 Left: 7.1 – 11.3

Table 5: Comparison of mean chord length with other studies

Lumbar vertebra	Study	Year	Country	Material for study	Mean (mm)	Std.Dev	Range (mm)
Typical Lumbar vertebra L1-L4	Alon Wolf et al [10]	2001	Israel	CT scans	L1 -44.8	L1 -2.8	
					L2 -46.9	L2 -3.6	
					L3 -47.6	L3 -3.7	
					L4 -47.6	L4 -4.4	
Typical Lumbar vertebra L1-L4	Acharya S et al [1]	2010	India	CT scans	L1 -47.00	L1 -3.39	
					L2 -49.03	L2 -2.79	
					L3 -47.21	L3 -3.95	
					L4 -47.48	L4 -5.38	
Typical Lumbar vertebra L1-L4	Dhawal et al [3]	2014	India	Dry bones	Right: 44.78 Left: 44.65	Right: 3.55 Left:3.54	Right: 36.46 -53.48 Left: 36.32 - 53.22
	Present study	2016	India	Dry bones	Right 44.54 Left: 44.65	Right: 4.17 Left 4.15	Right :35.11-54.56 Left: 35.61 – 54.12
Atypical Lumbar vertebra L5	Alon Wolf et al [10]	2001	Israel	CT scans	46.6	5.3	
	Acharya S et al [1]	2010	India	CT scans	48.91	4.42	
	MitraSR et al [8]	2002	India	Cadaveric	Male: 45.87 Female:41.65		
	Present study	2016	India	Dry bones	Right: 42.33 Left: 42.30	Right:4.40 Left: 4.37	Right: 35.89 –54.33 Left: 35.53 – 54.11

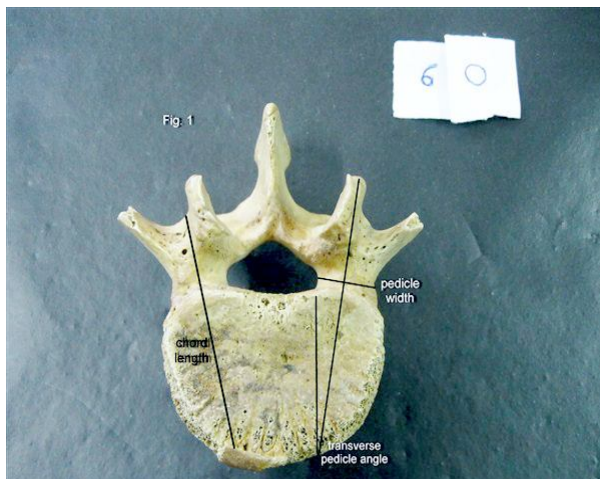


Fig. 1:

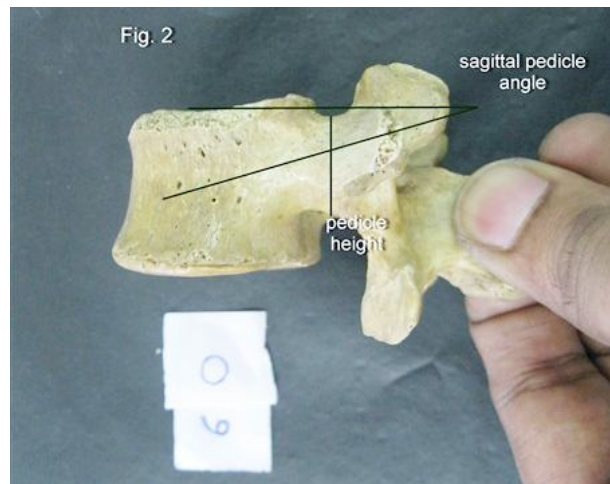


Fig. 2:

Discussion

Many authors have studied the pedicles of vertebrae using different methods such as direct specimen measurements, plain radiographs, computed tomography (CT) scans, Magnetic Resonance Imaging (MRI) scans, and quantitative 3-dimensional anatomic techniques.

Awareness of the racial variations in the size of the pedicles is very important when using international transpedicular screw systems.

In present study it is found that pedicle width of atypical lumbar vertebra is greater than typical lumbar vertebra, similar to findings observed by other studies (Table 1).

The range of pedicle height for typical lumbar vertebrae mentioned by Singel TC et al [9] is 11-17mm.

In present study and in the study conducted by Singel TC et al [9], it is seen that pedicle height of atypical lumbar vertebra is lesser than the typical lumbar vertebra.

However in all studies except present study and study conducted by Singel et al [9], it has been established that the pedicle height of atypical lumbar vertebra is greater than the typical lumbar vertebra (Table 2).

Knowledge of transverse pedicle angle is important while placing screws because any inadvertent medial perforation due to wrong placement of the pedicle screw can put the spinal cord at risk or cause vascular injury.

The result of the present study is in compliance with other studies (Table 3).

Sagittal pedicle angle is important in accurate screw placement as inferior migration of the screw may result in injury to the nerve root (Table 4).

Chord length determines the safest length of any screw that can be used for pedicular fixation. It is important in preventing anterior cortex perforation and therefore consequent injury to vital organs and major blood vessels which lie anterior to the vertebral body. The results of present study are in compliance with other study (Table 5).

Conclusion

Lumbar region is the mobile part of the vertebral column, and is often involved during accidents, degenerative disorders, congenital defects, and neoplastic metastases. With increasing usage of

pedicle screw system, it becomes imperative to understand the vertebral pedicle anatomy better. Therefore, the present study provides a comparison with western studies and other Indian studies to deduce safety parameters based on anatomy for pedicle screw placement. Racial morphometric differences must be taken into account when using international transpedicular screw systems. The dimensions in this study may help in the development of pedicular screws for Indian population.

In typical lumbar vertebra the minimum pedicle width was more than 4.25mm and minimum pedicle height was more than 9.8mm. Thus in typical lumbar vertebra, pedicle width was almost always less than the pedicle height.

In atypical lumbar vertebra minimum pedicle width was more than 10mm and height was above 9.8mm.

It was also found that pedicle height in atypical lumbar vertebra is lesser than typical lumbar vertebra.

The chord length is above 35mm in all lumbar vertebrae.

Detailed knowledge of the pedicle morphometry is critical for proper placement of a transpedicular screw because of the size and shape of the vertebral pedicle. The pedicle dimensions recorded in this study may help in the development of pedicular screws to be implanted in the lumbar region of the spine for spine immobilization and fixation for the population studied.

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