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Anatomy

MORPHOMETRY OF CERVICAL, THORACIC AND LUMBAR VERTEBRAE IN RELATION TO THE PEDICLE AND ITS CLINICAL IMPLICATIONS IN NORTH INDIA

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ABSTRACT

Introduction: A morphometric study of the cervical, thoracic, and lumbar vertebrae giving emphasis on the pedicular parameters was conducted on 28 sets of dried vertebrae. The study of pedicle dimensions is important to determine the size of pedicle screws to be used in surgeries, aiming to stabilize the vertebrae.

Methods: 28 sets of adult dried vertebral bones were used, and the listed measurements were taken- pedicle height, midpedicle width, pedicle length, transverse pedicle angle and inter pedicular distance. The transverse pedicle angle was measured with a goniometer while all other measurements were made using a digital vernier caliper.

Observations: In this study, we observed that the average midpedicle width of cervical vertebrae (5.47mm) and thoracic vertebrae (5.89mm) does not differ significantly. On the other hand, the average midpedicle width of the lumbar vertebrae (9.46mm) varies significantly from these values.

Conclusion: Midpedicle width is the primary determinant of the diameter of screw that can be used during pedicle screw placement. Therefore, due to significant difference in the pedicle size, even within an individual, the choice of the pedicle screw must be made carefully to avoid post-surgical complications.

KEYWORDS : Vertebrae, pedicle, Indian population, pedicle screw

1. INTRODUCTION

The pedicle is a stout, thick, backward protuberance from the superior part of the body at the assembly point of its lateral and posterior surfaces. The pedicle is the most durable component of the vertebrae and is made entirely out of cortical bone with a core consisting of cancellous bone.[27] Along with the laminae, it forms the vertebral arch. As reported by Pal and Routal, weight is transferred through three columns in the cervical region- an anterior column comprised of the bodies and intervertebral discs, and two posterior columns formed by the articular pillars.[16,23] As regards the thoracic (upper and lower) and lumbar regions, Pal and Routal concluded that the weight is transmitted through two columns- anterior column consisting of the centrum and the intervertebral disc, and the posterior column consisting of the consecutive laminae.[23,24] Thus, any structural deviation in the pedicle may lead to disturbance in weight transmission and compression of neural structures in the spinal cord.

This study is important as recently, the pedicle screw fixation has emerged as a successful method of spinal fixation. This procedure is implemented in case of spinal problems such as fractures in the vertebrae, resection of tumors in vertebral bodies. Screw fixation can also be performed for gross spondylolisthesis, lumbar instabilities and even in laminectomies patients. [9,14,28] The procedure of spinal screw fixation involves passing the screw through the dorsal aspect of the pedicle into the body of the vertebrae. The stability of the pedicle screw fixation techniques is ascertained by the pullout strength and extent of insertion in the vertebral body; 70% of the pedicle diameter should be occupied by the screw, wider screw provides more stability.[7,34] In contrast with other fixation methods, posterior transpedicular screw fixation provides very strong resistance to pullout forces.[1,5,11,12] The competence of the screw to obtain strength within the vertebral body is the primary determinant of the success of this procedure. Various equipments like rods, plates and wires can be secured to the spinal column by screws to achieve immobilization. However, the pedicle screw has some disadvantages. This technique may turn out badly in case of mismatched size of the screw and pedicle and may result in cortex perforation of pedicle or even a fracture. Sometimes pedicle screws may loosen. Other obstacles associated with disproportionate size of the screws are dural tears, leakage of cerebrospinal fluid and damage to neurovascular structures. [1,8,14,22,33,35,37] Therefore, the size of the screws to be placed in the vertebral pedicles need to be chosen conscientiously to minimize chances of complications.

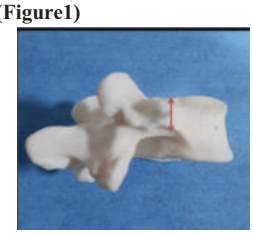
Racial as well as gender-based differences in the pedicle have been reported by some studies. [3,6,15,20] A few related studies have been conducted in India so far but there is scarce data for North India. [6,34] This study aims to highlight the need to use different sizes of screws for cervical, thoracic, and lumbar pedicle screw fixation even within the same individual. This information would be beneficial to neurosurgeons for selecting screw size for pedicle screw fixation.

2. MATERIALS AND METHODS

Direct morphometry of 28 sets of fully ossified dried adult human cervical (C3 to C7), thoracic (T1 to T12) and lumbar (L1 to L5) vertebrae was performed. All the measurements were taken in 9 different sittings. The readings were recorded with the help of a digital vernier caliper, and the angles were measured by the means of a goniometer and the readings rounded off to the nearest angle. Deformed and broken bones were omitted from the study.

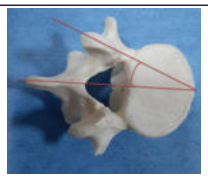
The measurements mentioned below were taken for both sides of the vertebrae:

a) Midpedicle width (MPW): It is the outer cortical transverse distance of the mid pedicle. **(Figure1)**



b) Pedicle height (PH): The measure of the closest points in upper and lower points of the pedicle vertically on its lateral aspect is termed as PH.**(Figure2)**

c) Pedicle length (PL): It is the length between the posterior cortex of pedicle to the junction of pedicle with vertebral body in line with the axis of the pedicle. **(Figure3)**



d) Transverse pedicle angle (TPA): It is the angle between the pedicle axis and a line parallel to the vertebral axis in a transverse plane. **(Figure4)**

e) Inter pedicular distance (IPD): The maximum distance between the medial surfaces of the left and the right pedicles of the same vertebra. **(Figure5)**

3.RESULTS

The data of the measurements was recorded in Microsoft Excel and was analyzed. The mean values and standard deviation of 28 sets of vertebrae are shown in Table 1 for cervical vertebrae, Table 2 for thoracic vertebrae and Table 3 for lumbar vertebrae.

In cervical vertebrae **(Table 1)**, midpedicular width increases from C3 to C7 with C7 having the most width (6.54±0.94mm on the right side and 0.54±0.84mm on the left). The pedicle height has no pattern in its measurements. Pedicle length, on the other hand, initially decreases from C3 to C5 after which there is an increase till C7. C7 has the most extensive mean pedicle length of 7.43±1.39mm on the right and 7.7±1.32mm on the left. The transverse pedicle angle shows a gradual increase from C3 to C7. Inter pedicular distance also shows a gradual increase from C3 to C6 with a slight decrease in C7. Thus, C6 has the highest inter pedicular distance of 23.51±1.82mm.

In thoracic vertebrae **(Table 2)**, the midpedicle width increases on average from T1 to T12 while showing a drop in the values in the middle thoracic vertebrae. T12 has the greatest mid-pedicular width of 8.24±1.81mm (right) and 8.48±1.67mm (left). Pedicle height increases from T1 to T12 with negligible variations in the middle. Similarly, the pedicle length also has an overall increase from T1 to T12 with T12 having the maximum values of 12.16±1.76mm on the right and 11.99±2.04mm on the left. The transverse pedicular angle of thoracic vertebrae initially decreases and then increases with minor variations. T1 has the highest inter pedicular distance of 18.88±2.01mm. The inter pedicular distance decreases gradually as we go down and starts increasing again in the lower thoracic vertebrae.

In lumbar vertebrae **(Table 3)**, the mid pedicular width is least for L1 (7.35±1.54mm on the right and 7.55±1.65mm on the left) and maximum for L5 (12.69±3.26mm on the right and 12.60±3.32mm on the left) with a gradual increase from L1 to L5. No noteworthy pattern was observed for the pedicle height and its value was maximum for L3 (14.47±1.62 mm on the right and 14.48±1.65mm on the left). The pedicle length showed no specific pattern in its values. There was an increase in the transverse pedicle angle from L1 to L5 with L5 having the maximum value of 17.96±4.73mm on the right side and 17.73±5.20mm on the left side. The inter pedicular distance also showed an increase from L1 to L5.

Table 1: Direct Measurement of Cervical Pedicles (Mean Values)

No. of Cervical Vertebra	Mid-pedicle Width (in mm)		Pedicle Height (in mm)		Pedicle Length (in mm)		Transverse Pedicle Angle (in degrees)		Inter pedicular Distance
	R	L	R	L	R	L	R	L	
C3	4.96±0.92	4.83±1.05	6.94±0.97	6.90±1.15	7.12±1.64	7.13±1.58	21.04±2.96	20.62±2.59	21.67±1.16
C4	5.22±1.29	5.32±1.41	7.01±0.76	7.01±1.01	6.98±1.76	6.92±1.72	21.56±3.57	20.84±2.66	22.28±1.24
C5	5.28±0.86	5.18±1.08	6.56±0.93	6.77±1.01	6.47±1.40	6.71±1.36	21.68±2.54	21.04±2.13	23.17±1.65
C6	5.57±0.88	5.16±1.04	6.46±0.86	6.58±0.99	7.05±1.41	7.17±1.53	21.67±2.13	21.22±2.03	23.51±1.82
C7	6.54±0.94	6.54±0.84	7.03±0.86	6.96±0.84	7.43±1.39	7.7±1.32	22±1.88	22.31±1.72	23.00±1.98

*Data is given as mean with standard deviation

Table 2: Direct Measurement of Thoracic Pedicles (Mean Values)

No. of Lumbar Vertebra	Mid-pedicle Width (in mm)		Pedicle Height (in mm)		Pedicle Length (in mm)		Transverse Pedicle Angle (in degrees)		Inter pedicular Distance
	R	L	R	L	R	L	R	L	
T1	7.52±1.27	7.62±1.52	9.34±1.17	9.25±0.96	8.44±1.13	8.42±1.26	19.14±2.90	19.5±3.06	18.88±2.01
T2	6.03±1.46	5.96±1.52	10.35±1.29	10±1.32	8.76±1.35	8.99±1.47	17.54±2.73	16.79±2.60	16.68±2.25
T3	5.22±1.45	4.87±1.32	10.76±1.23	10.41±1.39	9.24±1.87	9.24±1.90	15.21±2.27	14.64±2.78	15.91±1.37
T4	4.69±1.20	4.55±0.97	10.61±1.17	10.53±1.16	9.41±1.68	9.72±1.77	13.64±1.68	13.18±1.68	15.22±1.38
T5	4.73±1.21	4.51±1.43	10.39±1.11	10.18±0.88	10.48±1.97	10.53±1.98	13.57±1.79	12.75±1.96	15.42±1.60
T6	5.09±1.11	4.62±1.11	10.66±1.17	10.52±1.13	11.01±1.60	11.00±1.83	13.32±1.98	12.68±1.81	15.30±1.13
T7	5.18±1.05	5.32±1.40	10.9±1.19	10.84±1.10	11.00±1.83	11.43±1.73	12.82±1.93	12.46±1.91	15.43±1.29
T8	5.50±1.31	5.44±1.56	11.27±2.14	11.65±1.68	11.00±1.90	11.18±1.97	12.59±1.99	11.89±1.74	15.76±1.27
T9	5.99±1.43	5.85±1.61	12.14±1.44	12.37±1.65	11.34±1.50	11.86±1.41	13.36±2.84	12.82±2.44	15.70±1.31
T10	6.33±1.25	6.51±1.40	13.25±1.83	13.34±1.73	11.23±1.59	11.18±1.22	12.78±2.10	12.74±2.18	15.67±1.40
T11	8.04±1.72	8.15±1.81	15.21±1.40	15.45±1.25	11.11±2.27	10.99±1.49	14.15±2.28	14±2.42	16.93±1.83
T12	8.24±1.81	8.48±1.67	15.29±1.61	15.41±1.62	12.16±1.76	11.99±2.04	14±2	13.91±2.09	18.55±2.35

*Data is given as mean with standard deviation

Table 3: Direct Measurement of Lumbar Pedicles (Mean Values)

No. of Lumbar Vertebra	Mid-pedicle Width (in mm)		Pedicle Height (in mm)		Pedicle Length (in mm)		Transverse Pedicle Angle (in degrees)		Inter pedicular Distance
	R	L	R	L	R	L	R	L	
L1	7.35±1.54	7.55±1.65	14.47±1.38	14.07±1.38	15.69±3.21	15.59±2.79	15.27±3.38	14.58±2.93	20.39±1.82
L2	8.05±2.22	8.10±2.00	14.33±1.42	14.21±1.59	15.63±3.24	16.37±3.01	15.48±2.95	15.04±3.02	20.99±1.92
L3	8.60±1.51	8.79±1.53	14.47±1.62	14.48±1.65	15.89±3.29	15.83±2.94	15.73±3.52	16.08±3.55	20.89±1.95
L4	10.60±1.72	10.37±1.50	13.66±1.64	13.76±1.60	14.76±3.05	14.66±2.67	17.19±4.01	16.77±4.13	21.39±2.08
L5	12.69±3.26	12.60±3.32	13.06±1.52	13.15±1.77	15.68±3.29	15.1±3.60	17.96±4.73	17.73±5.20	23.22±2.51

*Data is given as mean with standard deviation

4. DISCUSSION

Recently, transpedicular screw fixation techniques have become more acceptable than other vertebral instruments and hook-rod devices as a technique of spinal fixation. [10,32] It amplifies fusion rate and also does not require extensive post-surgical immobilization. [32] The exceptional structure of pedicles provides a desirable site for the implantation of screw in reconstructive spinal surgeries.[27] King was one of the first to tackle screw fixation parallel to the inferior border of the lamina, while Boucher victoriously introduced passing a long screw through the lamina and pedicle into the vertebral body below to perform spinal fusion, with internal splinting by screw fixation, thereby momentarily stabilizing L4 to L5 and L5 to Sl.[4,13] According to King, pedicle screws has shown positive results in reducing and stabilizing spondylolisthesis.[13] Magerel developed adjustable external spinal skeletal fixation to stabilize the lower thoracic and lumbar spine in patients with acute spinal trauma.[19] The groundwork for pedicle screws and posterior plates was laid by Roy-Camille et al.[27] In 1948,King built new segmental instrumentation for pedicle screw fixation with spinal plates modeled for anatomic positioning for disorders of thoracic and lumbar vertebrae. This enhanced graft consolidation and fusion. Luque introduced yet another approach of inter pedicular segmental fixation using pedicle screws wired to Luque rods.[17] Further enrichment of pedicle screw fixation techniques is being investigated to increase the accuracy of pedicle screw placement. [18,21,29,31,36].

The main determinant of the screw diameter is midpedicle width as it usually has a value less than that of pedicle height of the same vertebra. Pedicle length gives an idea about the length of screw that can be used for pedicle screw fixation. The transverse pedicular angle and the inter pedicular distance contribute to determine the orientation of screw placement. The inter pedicular distance also helps in establishing the length of the transfixator.

On comparison with other studies, we have found a similar trend in the midpedicle width of cervical vertebrae, with C7 having the maximum mid pedicular width. [25,26,30] Tan et al. found that midpedicle width decreases from T1to T3 and from T3 to T7, the midpedicle width remains consistent and then increases till T12.[30] This study also shows a similar pattern in the midpedicle width of thoracic vertebrae. As for the midpedicle width of lumbar vertebrae, other studies also show an increase from L1 to L5. [2,30]

The average midpedicle width of cervical vertebrae is 5.47mm, for thoracic vertebrae, it is 5.89mm and that for lumbar vertebrae is 9.46mm. Thus, the diameters of pedicle screws required for cervical and thoracic vertebrae do not have significant difference, but lumbar vertebrae require a greater diameter of pedicle screw for better stability.

5. CONCLUSION

With the aim of enhancing the stability in pedicle screw fixation, about 70% of the cross-sectional area of pedicle must be occupied by the screw. This implies that the size of screws must be selected according to the dimensions of the pedicle to prevent post-surgical complications. This study establishes that the choice of pedicle screws depends not only on the ethnicity and gender, but also on the level of the vertebrae within the same individual due to some significant variations in (and even within) the different groups of vertebrae.

Conflict Of Interest

No potential conflict of interest.

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