



Morphometric analysis of the lumbar vertebrae in North Indian Population

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ABSTRACT

The lumbar pedicle, a cylinder of cortical bone is the strongest part of the vertebra. The fixation of lumbar spine is needed for various spinal problems. The present study was aimed at measuring the various parameters of lumbar vertebrae from north Indian population with special emphasis on pedicles morphometry. A total 20 dry adult lumbar vertebral sets from unknown age and sex were measured using vernier calipers. There were no significant differences found in right and left side. The Mid-Pedicle width of pedicles increases from L1 to L5. The lowest value for Minimum-Pedicle width was recorded at L1 level (7.1 mm). The mean of Pedicle height was maximum at L1 level (14.6 mm). The minimum Pedicle height was recorded at L4 level (13.4 mm). The Pedicle length was constant throughout the lumbar spine and smallest at L5 pedicle (8.6mm). The vertebral canal observed wider and compressed antero-posterior from L1-L5. The Pedicle angle in transverse plain increase gradually the maximum mean value of Pedicle angle in transverse plain was recorded as 23.7° at L5 and smallest value at L1 level (15.6°). Various parameters of lumbar vertebrae slightly differ from values of other populations thereby knowledge of lumbar pedicle morphology is essential for pedicle screw use.

INTRODUCTION

Vertebral column comprising spine and spinal cord is one of the most complex structures of human body. In recent years there have been considerable developments in instrumentation designed to stabilize and correct the lumbar spine. In order to perform a lumbar fusion by minimally invasive surgery technique is necessary to have precise anatomical knowledge of lumbar pedicles for the safe placement of screws. The fixation of lumbar spine is needed for various spinal problems like fracture in lumbar spine, resection of tumors in vertebral bodies, gross spondylolisthesis and lumbar instabilities. Transpedicular screw fixation of spine has developed as a very successful method of spinal fixation[1]. Pedicle screw fixation is the most common fixation technique employed in the postero-lateral type of spinal fusion. The choice of the screw diameter is determined by the minimum (horizontal) diameter of the pedicle, whereas the pathway of the screw is decided by the transverse (width) and vertical (height) parameters of the pedicle[2]. The horizontal diameter of pedicle decides the screw diameter. The transverse (width) and vertical (height) parameters of pedicle decides the screw path. For this reason, the

detail of pedicle morphometry becomes important as it helps in the selection of most suited pedicle screw [3]. Morphometric measurements of a particular geographical area will help in proper implant selection during spinal surgeries, designing of best suited implant, understanding the biomechanics and patho-anatomy of the spine, precise clinical diagnosis and management for the population under consideration. To our knowledge, however, very few studies have been conducted on North Indian populations to analyzed lumbar pedicle parameters in detail. The parameters measured in the present study were selected considering the growing interest in the lumbar spine instrumentation.

MATERIALS AND METHOD

The Present study was conducted in the Department of Anatomy, S. P. Medical College, Bikaner. The vertebral columns obtained from 20 embalmed dissecting rooms male cadavers of varying unknown ages received at Department. Those cases with remarkable alterations of the vertebral columns or evidencing gross pathological lesions of the spine were excluded from study. The cadaver's dissections were performed through posterior

approach. The vertebrae were prepared by trimming off the soft tissue, leaving only the skeletal remains. The specimens were then buried and retrieved after 3-4 months and vertebrae obtained, washed then air dried and stored. A total 100 vertebrae evaluated, being 20 from each L1 to L5. All the linear measurements were taken using sliding Vernier calipers. Angles were measured by a goniometer. Averages of three readings were taken for each parameter. The mean and standard deviations for each side was calculated through SPSS Software Windows.

Following parameters of Lumbar Vertebrae were measured:-

- Mid-pedicle width : The outer cortical transverse distance of the mid pedicle.
- Pedicle height : The superior inferior outer cortical width of the pedicle
- Minimal pedicle width : It was measured by turning the vernier caliper until the diameter reading was the smallest.
- Pedicle length : Distance from the posterior cortex of pedicle to the junction of pedicle with vertebral body in line with the axis of pedicle.
- Pedicle angle : It is the angulation of pedicle both in sagittal and transverse plane.
- Chord length : Measured from the posterior cortical entry point of the pedicle to the anterior vertebral cortex along the axis of the pedicle.
- Canal dimension : It was measured both in anteroposterior and interpedicular distance.
- Vertebral body height : Distance between superior and inferior surface was measured both anteriorly and posteriorly.
- Vertebral body width : The width of vertebral body at superior, middle and inferior surface was measured.
- Length of transverse process: Measured from base to tip of the transverse process.
- Width of transverse process at the base : Distance between superior and inferior borders of the transverse process at base.
- Spinous process angle : Angulation of the spinous process in the sagittal plane.

RESULTS

The values of the parameters are shown as mean and standard deviation of mean. No significant differences were found ($p < 0.05$) between the right and left sides for any of the evaluated parameters, hence the data were pooled together.

Table-1 shows the mean values and standard deviations of the measurements of pedicles of lumbar vertebrae. We can observe that the minimum Mid-Pedicle width was recorded at L1 level (7.5 mm). The maximum Mid-Pedicle width recorded was at L5 level (17.1 mm). The Mid-Pedicle width of pedicles increases from L1 to L5. The lowest value for Minimum-Pedicle width was recorded at L1 level (7.1 mm). The highest value of Minimum Pedicle width was found at L5 level (11.7 mm). The Minimum-Pedicle width of pedicles increases from L1 to L5; but not that steeply as of the Mid-Pedicle width. The Pedicle height remains relatively same from L1 to L5. As seen in the Table-1, the mean of Pedicle height was maximum at L1 level (14.6 mm). The minimum Pedicle height was recorded at L4 level (13.4 mm). The

range of minimum-Pedicle width at L1 was 5.1 to 10.8 mm; and the range of Pedicle height at L4 was 10.8 to 18.7 mm. The pedicle height is consistently larger than the width. The greatest Pedicle length was found at the L3 pedicle (9.3 mm) and the smallest at the L5 pedicle (8.6 mm). As evidenced by these results the Pedicle length was relatively constant throughout the lumbar spine. The L5 pedicles are thicker in all dimensions except for length. The Chord length being remained relatively same from L1 to L5, with only slight increase in mean value at L3 level (39.8 mm) and minimum being at L1 (37.6 mm). Both the Pedicle length and Chord length showed the same trend being highest at L3 level. As seen the dimensions of the vertebral canal from L1-L5 the canal becoming wider and compressed antero-posterior, because the antero-posterior (AP) dimension of the vertebral canal constantly decreasing though slightly, values start at L1 (15.9 mm) L4 (14.0 mm), but only to be slightly increased at L5 level (15.2 mm). The gradual increase in dimensions occurs for the vertebral canal interpedicular distance (IP) from L1 to L5, smallest being at L1 (21.3 mm) and largest values at L5 (26.3 mm) this is because of pedicles diverge increasingly from L1 to L5.

Anterior Vertebral Height shows constant increase from L1 to L5. Smallest value obtains at L1 (23.3 mm) and largest value at L5 (26.1 mm). Vertebral Height posterior remain almost same up to L3 level (26.5 mm) than gradually decreases up to L5 level being lowest as (23.1 mm). The Vertebral Height posterior is higher than the Vertebral Height Anterior, except at L5. This is due to the wedge shape of the L5 vertebra, which defines the spinal curvature in the lumbar region. Vertebral body width taken at three places of body at superior surface at mid of body and at inferior surface of body, the maximum dimensions were taken. Vertebral width Superior shows constant increase from L1 to L5. Smallest value obtained at L1 (41.4 mm) and largest value at L5 (50.3 mm). Likewise vertebral width middle shows constant increase from L1 to L5, but dimensions are less because body of the lumbar vertebrae compressed at middle level. The Smallest value obtained at L1 (36.2 mm) and largest value at L5 (44.4 mm). Vertebral width inferior increases also from L1 (44.6 mm) to L5 (50.6 mm) except only being dip at L3 Level to smallest (41.3 mm). The Transverse process length exhibits an increase up to L3 level being largest (20.7 mm) and their after decreases to L5 (16.8 mm). The mean of Transverse process of L1 was found smallest (15.2 mm). Transverse process width increases from L1 (9.1 mm) to L5 (11.7 mm) except only being dip at L4 Level being found as (41.3 mm). The Transverse process of L1 was found thinnest and shortest.

The Pedicle angle in transverse plain increase gradually because pedicles diverge increasingly from L1 to L5, with the maximum mean value of Pedicle angle in transverse plain was recorded as 23.7° at L5 and smallest value at L1 level (15.6°). Pedicle angle in sagittal plain of the lumbar vertebra was almost parallel to the horizontal plane. Pedicle angle in sagittal plain shows reducing trend caudally, firstly the pedicles were found directed upwards and then being found slightly directed downwards that's why the angle at L5 was most reduced and recorded with negative mean angle value as -0.5° . Largest Pedicle angle in sagittal plain was observed at L1 level (8.95°).

Spine Angle in sagittal plain was recorded from superior surface of vertebral body to the tip of the lumbar spine. Spine Angle becomes slightly straight cranio-caudally as being most oblique at L1 level (32.6°) and 30° at L5 level.

Table 1: Mean and SD values of all the parameters measured

Parameters	L ₁		L ₂		L ₃		L ₄		L ₅	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mid-Pedicle Width	7.5	1.54	7.8	1.75	9.7	2.03	12.1	2.24	17.1	2.9
Minimum Pedicle Width	7.1	1.41	7.4	1.67	9.2	2.48	9.9	1.33	11.7	2.18
Pedicle Height	14.6	1.41	14.3	1.45	14.4	1.43	13.4	1.61	14.4	1.91
Pedicle Length	9.4	2.89	9.2	3.05	9.5	3.23	9.0	3.08	8.6	2.89
Chord Length	37.6	4.90	38.6	4.41	39.8	4.76	38.9	4.57	38.4	4.77
Vertebral Canal (AP)	15.9	1.47	15.2	1.92	14.3	1.87	14.0	2.09	15.2	1.99
Vertebral Canal (IP)	21.3	1.64	22.1	2.15	22.1	1.47	22.4	2.91	26.3	2.59
Vertebral Height Anterior	23.3	2.41	24.7	2.31	25.7	2.16	25.4	2.39	26.1	2.10
Vertebral Height Posterior	26.4	1.77	26.5	2.35	26.5	2.03	25.5	2.22	23.1	4.72
Vertebral Width Superior	41.4	2.83	44.0	3.23	46.2	3.95	48.3	3.17	50.3	4.64
Vertebral Width Middle	36.2	3.05	38.2	3.20	40.3	3.27	42.3	3.61	44.4	4.46
Vertebral Width Inferior	44.6	3.25	46.8	3.41	41.3	3.34	50.9	3.06	50.6	4.62
Transverse process length	15.2	3.84	18.0	3.69	20.7	3.61	18.3	4.04	16.8	2.42
Transverse process width	9.1	1.57	9.9	2.11	10.5	2.15	9.4	1.27	11.7	2.22
Pedicle Angle Transverse Plain	15.6	3.48	15.4	5.64	16.4	6.01	18.8	5.8	23.7	4.83
Pedicle Angle Sagittal Plain	8.95	4.33	6.02	4.05	2.75	3.28	1.5	3.41	-0.5	2.6
Spine Angle	32.6	4.99	31.0	3.94	31.4	6.34	30.3	5.77	30	6.45

DISCUSSION

The present study was undertaken to gain a detailed knowledge of the vertebral morphology of lumbar spine in North India and the observations from the present study were compared with the previous published studies from India, Asia, and western world. The findings of the present study are quite similar to those reported in a previous reports stating that the values for the left and right pedicles of the lumbar vertebrae were nearly the same. Since there was no significant statistical difference between right and left side these values were pooled together for comparison³. In the present study Mid-Pedicle width of pedicles increases from L1 to L5. The minimum Mid-Pedicle width was

recorded at L1 level (7.5 mm). The maximum Mid-Pedicle width recorded was at L5 level (17.1 mm). The lowest value for Minimum-Pedicle width was recorded at L1 level (7.1 mm). The highest value of minimum Pedicle width was found at L5 level (11.7 mm). The Minimum-Pedicle width of pedicles increases from L1 to L5; but not that steeply as of the Mid-Pedicle width.

Vinay K V et.al 2012 studied the mid pedical width on X-ray studies and found the same results as of ours, they reported the minimum mid pedicle width at L1 level (7.4 mm) and values increase cranio-caudally being maximum at L5 level (11.65 mm). However the values are slight lower that may be they have measured the pedicle width on X-rays⁴. The Same results were

recorded by the Prakash et al 2007 8.2 mm being lowest mean value at L1 level and it increased to L5 level being highest as 16.2 mm. they conducted the study on dry bones so their results came very similar to the present study.

Aruna N et al 2011 and Ajay S C et al 2009 in two different studies which were conducted on dry bones from central and south Indian region have observed the same trend of the increase of mid pedicle width from cranio-caudally but their mean values range from 14.2 mm smallest to 19.2 mm largest at L5 level^{5,6}. Singel T C in their study on dry lumbar vertebrae in Saurashtra region population have reported a decrease in mid pedicle width but the mean values were same ranging from 13.3 mm at L5 level to 15.1 mm at L1 level³. Amonoo-Kuofi studied the pedicle dimensions on X-rays and found the mid pedicle width being increasing from L1 to L5 level with the mean values higher as 17.8 mm to 19.1 mm for L1 to L5 respectively². Islam, C. found that there was a real minimal diameter which was different from the vertical and transverse diameters of pedicles⁷. This is the smallest diameter which cannot be definitely determined by the imaging methods currently in use, such as anteroposterior and lateral radiographs, and computed tomography. The mean Pedicle height was maximum at L1 level (14.6 mm). The minimum Pedicle height was recorded at L4 level (13.4 mm). The Pedicle height remains relatively same from L1 to L5. For the pedicle height in two different studies performed by Prakash et al 2007 and Vinay K V et al 2012 on dry bones and X-rays respectively the mean values were close to the findings of present study, but Vinay K V have shown a gradually decrease pattern from L1 to L5 (14.7 mm to 11.7 mm). Aruna N et al 2011, Ajay S C et al 2009 and Singel T C 2004 all they have taken measurements on dry bones from Indian population in their three different studies and have reported trends of increase in pedicle height cranio-caudally but the mean values were significantly low as compare to the present study ranging from lowest at L1(7.24mm) to largest at L5 (12.0 mm)¹⁻⁸. The Pedicle length from body of the vertebra to the transverse process along the long axis of pedicle was not included in majority of the previous works, although it is important for screw fixation techniques. Prakash et al 2007 reported that these values were maximum at L2 level (8.3 mm) and minimum at L5 level(6.1 mm) in both left and right pedicle in both the sexes and the pedicle length decreases from L1 to L5 level Short stature of average Indian population compared to the western world can be correlated for the decreased value of all the parameters bilaterally from L1 to L5 in both the sexes⁸. Our findings were same as above but pedicle length mean values were slightly higher at all levels. The greatest Pedicle length was found at the L3 pedicle (9.3 mm) and the smallest at the L5 pedicle (8.6 mm). Pedicle length was relatively constant throughout the lumbar spine for present study.

No any previous study have reported the Chord length which remain relatively same from L1 to L5, with only slight increase at L3 level (39.8 mm) minimum being at L1(37.6 mm). Both the Pedicle length and Chord length have the same trend being highest at L3 level. Data on the chord length will be help for determination on pedicle fixation screw length. In the present study a gradual increase in dimensions occurs for the vertebral canal Inter-pedicle distance (IP) from L1 to L5, smallest at L1 (21.3 mm) and largest values at L5 (26.3 mm) was found. This is because of pedicles diverge increasingly from L1 toL5. According to Urrutia V E 2009 the inter-pedicle distance was reported as smallest at L1 level (22.4 mm) and largest at L5 level (29.7 mm)⁹. In an another study conducted by Tan S H et al 2004 the inter-pedicle distance increases from 19.4 mm at L1 level to

23.4 mm at L5 level¹⁰. These findings are close to the present study. Antero-posterior (AP) dimension of the vertebral canal constantly decreasing though slightly, start at L1 (15.9 mm) to L4(14.0 mm), but only to be slightly increased at L5 level(15.2 mm), these mean values of Antero-posterior (AP) dimension of the vertebral canal were found very close to the findings of Tan S H et al 2004.

We found the posterior Vertebral Height is higher than the Anterior Vertebral Height, except at L5 level. Anterior Vertebral Height shows constant increase from L1 to L5. Smallest value obtained at L1 (23.3 mm) and largest value at L5 (26.1 mm). Vertebral Height posterior remain almost same up to L3 level (26.5 mm) than gradually decreases up to L5 level being lowest as (23.1 mm). Gocmen-mas N et al 2010 have reported the same pattern of anterior vertebrae height ranging from 22.9 mm to 25.9 mm¹¹. the results of Tan S H et al 2004 shows same trend but the mean values are slightly lower than found in present study. Vertebral width Superior shows constant increase from L1 to L5. Smallest value obtained at L1(41.4 mm) and largest value at L5(50.3 mm). In the observations of Tan S H et al 2004 the vertebral superior width increases from L1 to L5 levels and the mean values were found as 36.3 mm to 41.6 mm. the same increasing order was found in the vertebral inferior width for which mean values were 39.2 mm at L1 level and 43.2 mm at L5 level. The width of the inferior surface is greater than the superior surface because the overall body size increases from L1 to L5 level.

No previous studies have reported the Transverse process dimensions. The Transverse process length exhibits an increase up to L3 level being largest (20.7 mm) and their after decreases to L5 (16.8 mm). The mean of Transverse process of L1 was found smallest (15.2 mm). Transverse process width increases from L1 (9.1 mm) to L5 (11.7 mm) except only being dip at L4 Level being found as (41.3 mm). The Transverse process of L1 was found thinnest and shortest.

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CONCLUSION

The present study shows that there is ethnic as well as racial variation in the size of lumbar pedicle and other parameters, thus emphasizing the need to have normal values for the lumbar vertebrae for different populations. These morphometric findings on lumbar vertebrae could be of some use possibly in designing pedicle screws. The result of the present study can help in understanding the spine pathologies and management of the spinal disorders.

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