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Morphometric Analysis of Lumbar Vertebrae in Tertiary Care Institutions in Telangana.

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ABSTRACT

Background: Pedicle screw fixation has become an increasingly popular technique of instrumentation to treat spinal disorders by providing stable fixation in the treatment for degenerative diseases, trauma, deformities, and tumours of the spine. This method provides rigid support that allows surgeons to limit instrumentation to one or two motion segments, thus preserving maximum motion. This study was conducted to record the surgically relevant parameters of transverse pedicle isthmus width, transverse pedicle angle, spinal canal diameters and the approximate screw path length and to compare the results between male and female vertebrae and with those of similar studies in literature. **Methods:** 295 lumbar vertebrae in 61patients were analyzed based on transverse pedicle isthmus width, transverse pedicle angles, AP and transverse spinal canal diameters and approximate screw path length. The screw path length was measured in 184 vertebrae from 37 patients. The measurements were processed using SPSS v.15 software and analysed. **Results:** The mean transverse pedicle isthmus width was the least at L1 level (8.1 mm) and highest at L5 level (16.5mm). There was a significant difference between male and female vertebral diameters. Of the pedicles at L1, over 9% had a diameter of less than or equal to 5 mm, 15% had a diameter of less than or equal to 6 mm. The mean transverse pedicle angle was maximum at L5 level (26.8^0). The canal diameters are significantly lower than that of the western population. There was a change in pedicle angle and diameter in the same vertebra between right and left pedicles. Female vertebrae had a smaller pedicle diameter and screw path length but had a similar spinal canal diameter as compared to a male vertebrae. **Conclusions:** Significant differences in the morphometric parameters existed between genders and even between individuals of same gender. It is suggested that preoperative computed tomography scans of the patients must be evaluated to choose the appropriately sized implant and avoid inadvertent complications.

Keywords: Lumbar vertebrae, Morphometric analysis, Spinal fixation

INTRODUCTION

In 1963, Roy-Camille first applied the pedicle screw plating system for the lumbar spine. Since then, pedicle screw fixation has become an increasingly popular technique of instrumentation to treat spinal disorders by providing stable fixation in the treatment for degenerative diseases, trauma, deformities, and tumours of the spine. The trans-pedicular segmental method of fixation provides rigid support that allows surgeons to limit instrumentation to one or two motion segments, thus preserving maximum motion.

A thorough understanding of the anatomy and orientation of the posterior elements of the spine is essential for safe and accurate surgical procedures. The complications associated with misplaced pedicle screws include neurologic, vascular, and visceral injury.[1-3] Knowledge of the morphometric characteristics of the pedicle is essential to prevent such complications from occurring.[4-10]

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Numerous studies have described the anatomy of the posterior elements of the spine, but most have used Western population for reference which may be different from other ethnic groups.[4-15]. Differences have been reported between Indian and the Western population by Chadha et al[16] and Acharya et al[17] on the lower skeletal size and body proportions in Indians as compared with their western counterparts. But these studies did not mention the difference between male and female vertebral parameters. Moreover, many of these studies have limitations such as a small sample size and lack of demographic data including race, age and sex.

The accuracy of computed tomography (CT) measurements of the pedicle diameter, pedicle axis, and “screw path length” has established the CT scan as the best means of evaluating pedicle radiographic morphology.[13,18,19] In this study, we have tried to conduct a morphometric analysis of the posterior elements of the spine in a relatively large number of subjects by using CT Scan.. These morphometric data should contribute to better results in posterior spinal surgeries, especially in those involving posterior spinal instrumentation and may also serve as a basis for the development of new spinal implants.

MATERIALS AND METHODS

CT scans of lumbar spine in 61 adult patients (>18yrs) was done in the Departments of Orthopaedics, Chalmeda Anandrao Institute of Medical Sciences, Karimnagar and Malla Reddy Institute of Medical Sciences, Hyderabad between from March 2012 to Dec 2014. Vertebrae with obvious pathology like fractures and tumours have been excluded from the study. Computed tomography scans of the lumbar spine using a Siemens Somatom 4 Plus (Erlangen, Germany) scanner with 2-mm cuts were reviewed. We selected 295 vertebrae from 61 patients for analysis. Patient's ages ranged from 18 to 70 years. 29 patients were males and 32 were females. In 40 patients, CT scan was done for reasons other than back pain.

The criteria for recording measurements were similar to those described by Marchesi et al[14] [Figure 1]. Using the bone window, the transverse section on which the left and right pedicle appeared largest was selected for measuring on a Dicom image using the Magicview software. This image was referred to as the mid pedicle cut. All measurements are taken on this mid pedicle cut. All scan cuts used for measurements done or reconstructed are perpendicular to the above disc space.

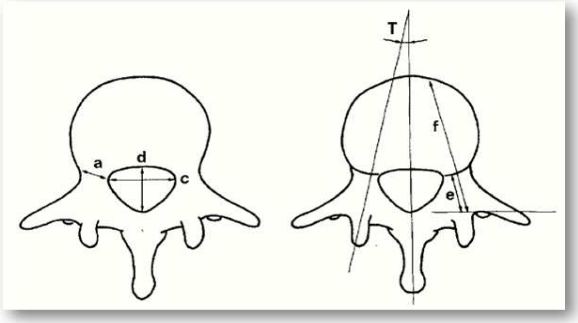

Figure 1: Measurement criteria

Marchesi et al Method: Measurements are based on Marchesi et al method Where A stand for pedicle diameter, d for AP diameter of spinal canal, c for transverse diameter of spinal canal, T for pedicle angle, f for Screw path length. But in our study we measured up to facet.

The narrowest possible distance between two outer cortices of a pedicle on the mid pedicle cut was drawn and measured as pedicle isthmus width. The antero-posterior (AP) midline axis was defined by visual inspection, the orientation of which was adjusted as closely as possible, so that a single line fell transversely along both transverse processes perpendicular to this AP midline. The pedicle longitudinal axis was drawn perpendicular to pedicle isthmus width line. The angle made by pedicle longitudinal axis with AP midline axis is measured as transverse pedicle angle. Measurement of the screw path length is defined as the distance from a line drawn along the flat portion of the posterior cortex of the lamina or from posterior aspect of facet to the anterior cortex of the vertebra. Sagittal reconstruction of the pedicle is done to measure vertical pedicle diameter and pedicle angle.

All measurements are made in SI system of units, distance in millimetres and angles in degrees; distances were read to the nearest 0.1 mm. Angular measurements were made with magic view software and adjusted to the nearest 0.1°. SPSS software v 15 is used for statistical analysis of the generated data.

RESULTS

Our study evaluated pedicle morphometry of 295 vertebrae from lumbar vertebrae (L1–L5) in 61 persons. The results for various parameters are depicted in [Table 1]. The study population consisted of 29 men and 32 women.

The widest pedicle diameter was seen at L5, with a mean of 16.5±2.33 mm and the narrowest pedicle isthmus diameter was seen at L1, with a mean of 8.1±1.88 mm. Pedicle isthmus diameter of less than or equal to 5 mm was seen at L1 in 10 cases (9%) of patients [Figure 2] while that of diameter less than or equal to 6 mm was seen in 17 of the cases (15%) at L1. There was a variation in right and left pedicle diameters in nearly all vertebrae, but the mean diameter was almost the same

Table 1: Results of pedicle morphometry

Level	Pedicle Diameter (in mm)						Pedicle Angle (in Degree)		
	Right	S.D.	Range	Left	S.D.	Range	Angle	S.D.	Range
L1	8.1	±1.88	4-12.1	8.4	±1.94	4-12	10.49	±2.99	4.5-18
L2	8.6	±1.54	6-12.9	8.6	±1.54	5-12.4	11.84	±3.37	6.3-18.79
L3	10.3	±1.64	7.7-15.6	10.4	±1.61	7-15.6	14.46	±4.01	6-21
L4	12.1	±1.78	8.4-16.2	12.0	±1.77	9-16.3	18.40	±4.20	8.28-28
L5	16.5	±2.33	11.8-22.7	16.6	±2.43	11-23.4	26.88	±5.79	9.57-42

In 20 (6.77%) vertebrae, the difference between the right and left pedicles was more than 2mm [Figure 3]. The female average pedicle width was significantly narrower than the males at all levels.
The vertical pedicle diameter or height of the pedicle is consistently more than 10mm in all the levels, hence further statistical analysis was not performed.
The transverse pedicle angle was least at L1 vertebra with a mean of $10.5^{o}\pm3^{0.}$ The maximum transverse pedicle angle was found at L5 with an average angle of $26.88^{0}\pm5.79^{0}$. The sagittal pedicle angles varied between $3\text{-}6^{o}$. There was no difference in pedicle angles between males and females in all the lumbar vertebrae [Table 2].

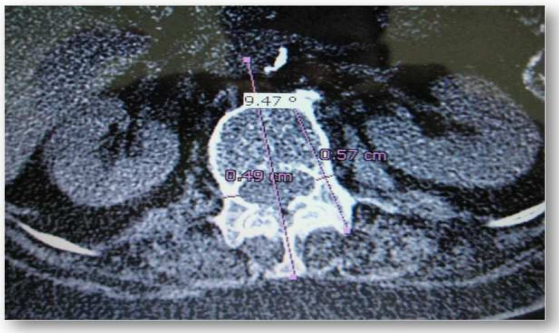

Figure-2: shows pedicle diameter less than 5 mm at L1

Table 2: Spinal canal diameters and screw path length.

Level	Pedicle angle (degrees)		Pedicle Diameter (mm)		Spinal Canal Diameters (in mm)				Screw Path Length (mm)	
	M	F	M	F	Trans (M)	A.P (M)	Trans (F)	A.P (F)	M	F
L1	10.55	10.38	8.845	7.1	19.0	16.35	19.2	16.7	51.3	49.1
L2	11.53	12.32	9.05	7.9	19.6	15.2	19.5	16.6	53.2	50.6
L3	14.12	15.02	10.85	9.55	20.2	14.8	19.9	15.9	54	50.1
L4	18.26	18.63	12.6	11.3	20.2	13.8	21.2	14.5	52	46.9
L5	27.39	26.91	17.1	15.6	25.0	15.4	25.1	14.25	50.2	45.7

Transverse Pedicle angles were found to be nearly same between right and left pedicles, but there was a change in transverse pedicle angle between right and left pedicle of more than 5 degrees in nearly 20% cases [Figure 4].
In 26 patients, we found the transverse angle to be less than 5^{0} at L1 [Figure 5]. There was also a change in the transverse pedicle angle in the same vertebra from above downwards.
The shortest distance to Screw path was found in L5 vertebra with a distance of 4.85±0.53cm.and the longest distance for screw path was found in L3 vertebra with mean of 5.24±0.33cm. The female vertebrae were shorter in all lumbar segments compared to male vertebrae and the difference was seen more in L5 region [Table 3].
The diameters of spinal canal were found to change both transversely and antero-posteriorly from L1 to L5. The transverse diameters were gradually increasing from L1 to L5 [Table 2] while AP diameters are gradually decreasing from L1 to L5, thus the shape of spinal canal was changing from circular to oval. There is not much difference in spinal canal diameters between male and female vertebrae [Table 3].

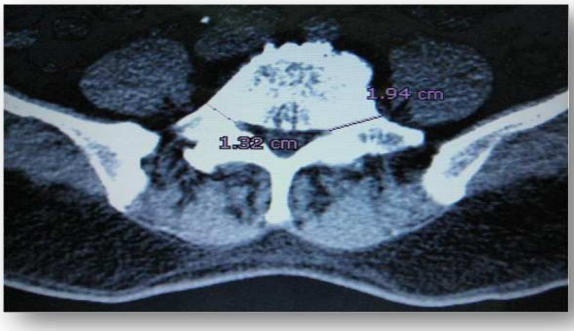

Figure 3: More than 2mm difference in pedicle diameters

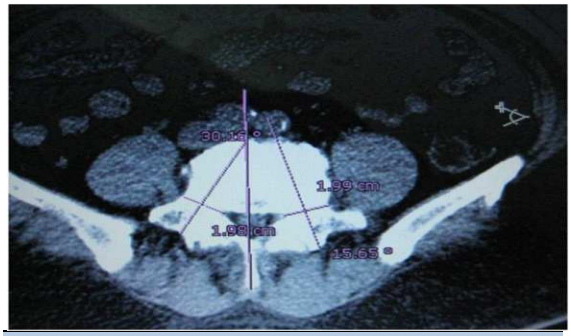

Figure 4: $>10^{0}$ difference in pedicle angle between pedicles

Table 3: Spinal Canal diameters – difference in males and females

Vertebra	Spinal Canal Diameters						Screw path Length (in mm)		
	Females			Males			Combined		
	A.P.	S.D.	Range	Trans	S.D.	Range	Mean	S.D.	Range
L1	16.32	±2.33	11.3-21.3	19.1	±2.2	12-25	50.4	±3.04	43.5-57.8
L2	16.2	±2.95	8.2-21.8	20.1	±1.71	15.2-22.9	52.2	±3.06	43.8-57.8
L3	15.3	±3.31	9.8-23.4	20.1	±1.99	15.2-25	52.4	±3.34	43.6-56.4
L4	14.3	±3.44	9.5-28	21	±2.98	11-26.4	49.9	±4.78	38-60.7
L5	15.2	±4.09	9.2-28.0	25.5	±4.31	15-36	48.5	±5.35	40.8-62.2

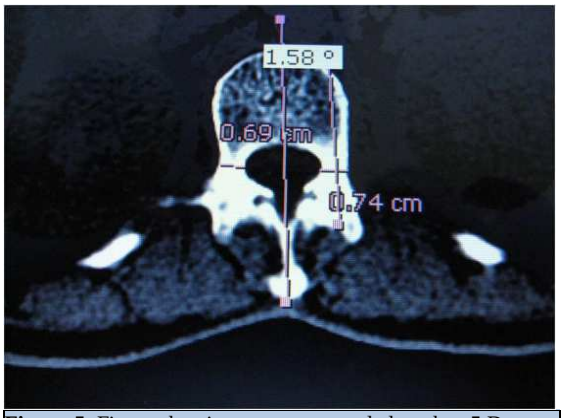

Figure-5: Figure showing transverse angle less than 5 Degrees

DISCUSSION

There were multiple studies across the world on the anatomic and radiographic morphometry of lumbar spine. However, the values varied significantly across the races, genders and study groups. We ventured to develop our own database to help us prevent instrumentation errors and failures. The outer diameters of the most commonly used pedicle screws range from 5 to 7mm. Various authors have documented that the cross-section of the pedicles is oval; hence, the sagittal pedicle isthmus width is always greater than the transverse pedicle isthmus width, which is the limiting factor in choosing the diameter of the pedicle screws. Our results confirmed the same. Use of a larger size screw will lead to the violation of the medial or lateral cortex of the pedicle and may lead to neurologic deficit. In such situations, if cement is used to enhance the pullout strength in osteoporotic bone, the cement can leak through the damaged wall and cause further injury. Although some surgeons may believe in the "in-out-in" technique, our view is that screws that fit within the pedicle are the safest.

The transverse pedicle isthmus width varied significantly between genders and across vertebral levels. There is a gradual increase in pedicle diameter from L1 to L5 and the same trend was observed in other studies. The pedicle diameters in female are smaller than male at all levels i.e. from L1 to L5 [Table 3]. The male TPW values were nearly same as the data quoted by Zindricket al[19], and the values were slightly higher in comparison with other Indian studies of Chadha et al[16], and Acharya et al[17] with similar trends. However, the female TPW values are smaller than the male counter parts of our study, and the studies of various authors like Zindrick et al[19], Kenya Nojori et al[6], and Acharya et al[17]. This shows that there is significant difference between pedicle diameters between male and female vertebra. It is always advisable to use smaller size screws in females.

There was a variation in right and left pedicle diameters in nearly all vertebrae, but the mean diameter was nearly same. Differences from side to side on the same axial slice may be due to slightly off-axis cut catching one pedicle dead centre and the other a bit cephalad or caudad. But in nearly 7% of cases, the pedicle isthmus diameter difference was more than 2 mm; this shows that there is considerable variation between both pedicles.

Pedicle isthmus diameter of less than or equal to 5 mm was seen at L1 in (10 out of 116) 9% of patients [Figure 6] and less than or equal to 6 mm was 15% (17 of 116). These results were much less compared western patients. This shows the importance of measurement of pedicle diameter especially at L1 even for 5 mm screw.

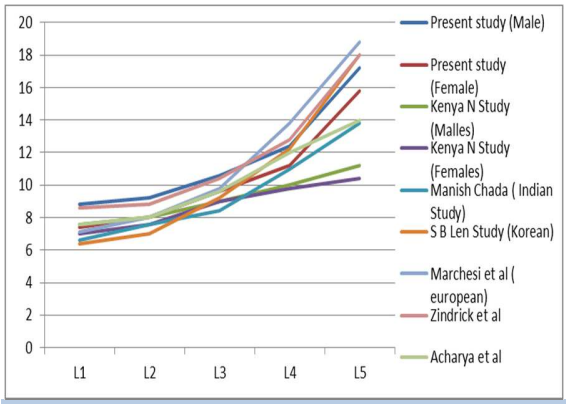

Figure 6: Comparison of pedicle diameters with Indian and international studies

TPA followed the trend of other previous studies. The angle is gradually increased as we moved caudal, with the maximum angulation is at L5 vertebrae. This trend is similar to Indian and western studies noted above but with slight difference in values [Figure 7]. There was no change in transverse pedicle angle in male and female vertebra in our study. There was a change in transverse pedicle angle between right and left pedicle in nearly 20% (n=54) cases, which will not be visible on X rays.

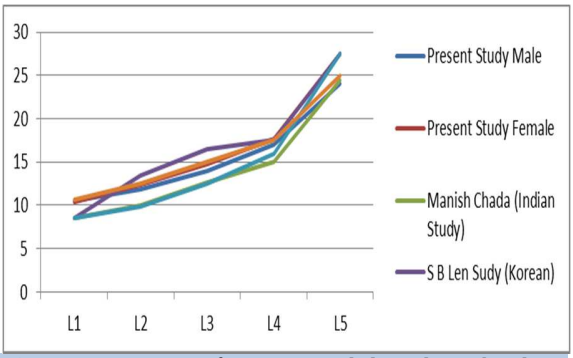

Figure-7 Comparison of transverse pedicle angles with Indian and international studies

In nearly 9% of cases (n=26), the pedicle angle was less than 5^0 and all the cases were noted in L1 vertebrae only. This shows the need for preoperative CT scan before surgery. There was also a change in transverse pedicle angle in the same vertebra from above downwards and it was observed in L5 vertebra. The transverse pedicle angle was gradually increased on coming down in the same vertebra, this gives an imagination that pedicle in L5 vertebra is not tubular as with other vertebra, but is twisted and outwardly rotated.

The antero-posterior diameters of spinal canal were gradually decreasing from L1 to L5, while the transverse diameters of spinal canal were gradually increasing. This denotes that the shape of spinal canal is changing from circular to oval. The largest spinal canal diameters were found in L5. There was no change in spinal canal diameters between male and female gender.

As compared to the other Indian studies like Chadha et al[16], the screw path lengths were higher in all vertebrae, but the trend was same [Figure 8]. The reason for larger screw path length is measurement up to facet. The screw path length was increasing from L1 to L3 and thereafter decreasing and the least screw path length was seen in L5, which should be kept in mind when placing the screw. The females were having shorter vertebrae, but the pattern was the same.

The relation between superior articular facet and pedicle axis was gradually changing from L1 to L5. In L1, the pedicle axis was in line with the superior articular facet and in L2, the pedicle axis was at the outer margin of the facet. As we were moving to L5, the pedicle axis was completely out of the facet. This finding is similar to the previous studies by Houet al[20] in which the entry point to centre of lumbar pedicle migrates laterally from L1 to L5. The study by Mitra and Datir[21] supports the previous studies and proposes that no one single universal starting point is appropriate for all levels.

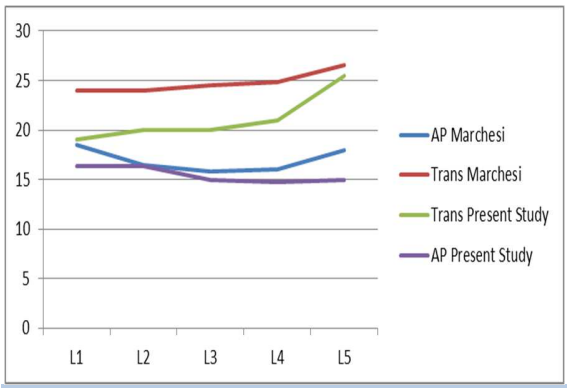

Figure-8 Comparison of screw path lengths with Indian and international studies

The results approve that females have smaller vertebrae than male at the same level. They are having small pedicle diameters, same canal diameters and shorter screw path lengths indicating slender vertebrae. Thus we should be careful while inserting pedicle screws and it is advisable to use thinner screw than male at the same level.

CONCLUSION

Significant differences in the pedicle width, transverse pedicle angles, canal diameters and screw path length exist between genders and among different races, and even between individuals. One should beware of routinely using 5 mm screws in L1 because; nearly 10% pedicles at L1 have ≤ 5mm isthmus width. Significantly wider Transverse pedicle angles are seen at L4 and L5 (Mean of 26^0 at L5 level) levels in our native population as compared to any other series across the world. Pre operative CT should be considered when contemplating L1 level instrumentation. Females are having less pedicle diameters same spinal canal diameters thus implicating slender and delicate vertebrae than male.

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