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COMPUTERIZED TOMOGRAPHIC MORPHOMETRIC STUDY OF LAST THORACIC AND ALL LUMBAR PEDICLES IN THE INDIAN POPULATION RELATED TO PEDICLE SCREW FIXATION

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Abstract:

Transpedicular fixation of the spine with pedicular screws is becoming increasingly popular being more stable and versatile as it provides three dimensional fixations. Several systems of internal fixation that uses the pedicle as a source of purchase for bone screws from posterior approach into the vertebral body are currently available. A data was collected by CT scan measurement of the pedicles along with 8 of its parameters and were compare with other associated studies with a collection of a mixed group of 80 patients. This data were then used to verify the accuracy of the technique that radiologist and surgeons must used for preoperative of evolution. This study indicates that computer software were aided pedicular morphometric data are reliable and comparable to other published study with other methods. For the Indian population the diameter and length of the pedicle screw need to be smaller than those mentioned in western studies. Therefore the need of CT morphometric data assessment preoperative planning of spinal surgery at different spinal level is important in account of large variation so that intra and postoperative complication can be avoided.

Key-words: *pedicle morphometry, CT morphometric axis length, sagittal angulation, transverse angulation, medial offset, sagittal offset*

Introduction:

Measurement of bone or any part of human body provides accurate knowledge about morphology of the structure which helps the clinicians in diagnosing and treating various diseases. Due to present lifestyle and with its speed, it has resulted in increase in the incidence of assaults on the vertebral column in the form of different spinal pathologies such as prolapsed inter vertebral discs, spondylolisthesis, spondylosis & fracture. The growing need of various orthopaedic procedure as a part of treatment of above pathologies demand accurate knowledge of measurements of the vertebra. The present study was undertaken with the view to study dorsal and lumbar region pedicles. posterior spinal instrumentation is a time honored method of spinal fixation.

Transpedicular fixation of the spine with pedicular screws is becoming increasingly popular as it is more stable and versatile because it provides three dimensional fixations.In several studies,researcher demonstrated fusion rates of 90% or greater with pedicle screw fixations,however along with this benefits a number of complication associated with pedicle screw fixation were reported.The most divesting complication related to pedicle screw is neurological injury.Secondary to misplaced screw abutting or transecting a nerve.So with the use of pedicle screw system it become imperative that a casual relationship between the screw and neurological complication be ruled out.Morphometric study of pedicles of spine of dorsal and lumbar region is thus relevant and critical for proper placement of the Transpedicular screw to avoid inadvertent penetration of pedicular wall.Accurate anatomical description of the shape and orientation of dorsal and lumbar pedicle are necessary for the use of implantable devises and spinal instrumentation technique.It is important to distinguish differences in morphometric pedicles. Studies were conducted were data have been obtained from computerized tomography (CT) of spines.The knowledge of pedicle morphology is essential for proper placement of the screw.

Methodology:

This was an observational study of 80 patients (55 males and 25 female),ranging from 25 to 59 years selected from the dept of orthopaedics of D.Y.Patil medical college and hospital and study carried out in the department of orthopedics. Postopertive spine patients and patients with malignancy involving spine were excluded from this study while all patients with or without spine pathology were included in this study. Helical computerized tomography was made from twelfth thoracic to fifth lumbar vertebra in eighty patients. Morphologic characterstic were obtained from the thoracolumbar junction to 5th lumbar vertebra(T 12 to L5) using CT scan reformatting and reconstruction of slice thickness taken at 3mm using osirix software (figure 1)

Results:

The computerized tomographic scan of 480 vertebraes from T12 to L5 in 80 pateints were analysed.6 linear and 2 angular parameters were measured for 480 pedicles. Significant levels related difference ($p<0.05$) were observed in association with seven parameters, with the pedicle saggital offset

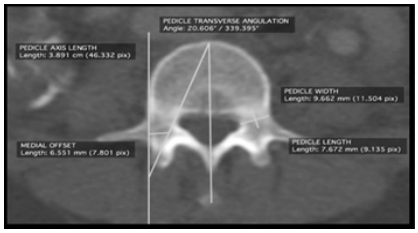

Fig 1: Pedicle transverse angulation, width, axis length, pedicle length and medial offset

Fig 1: Pedicle transverse angula

Table 1 :
Measurements in males and females of pedicle height, width, length and axis length

Pedicle	Height (mm)		Width (mm)		Length (mm)		Axis Length (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female
T12	13.6±2.0	13.2±1.6	7.4± 1.9	7.4±1.3	8.6±1.4	8.6±0.7	37.8±4.3	36.0±3.6
L1	13.5±1.1	12.4±1.7	6. 9±1.3	6.1±1.0	7.6±1.1	7.6±1.0	41.3±4.0	38.6±4.2
L2	12.4±2.4	11.5±2.08	7.0±1.4	6.1±1.2	7.7±1.3	7.6±1.1	41.2±3.5	39.9±3.9
L3	12.4±2.2	12.1±2.1	7.8±1.6	7.7±2.3	8.2±1.3	7.9±1.1	40.3±4.0	38.5±3.3
L4	11.2±2.16	11.1±2.7	9.3±1.7	9.0±2.4	8.4±1.4	8.1±1.2	39.5±3.5	37.8±4.1
L5	12.4±2.29	12.1±2.7	11.0±1.7	10.6±1.9	9.3±1.7	9.0±1.3	38.9±3.9	38.4±5.4

*The values are given as the mean and standard deviation. †Each of the four parameter was found to be significantly dependent on the spinal level as determined with use of analysis variance ($p<0.05$).

Table 2 :
Measurements in males and females showing Transverse angulation, sagittal angulation, medial offset and sagittal offset

Pedicle	Transverse Angulation (deg)		Sagittal Angulation (deg)		Medial Offset (mm)		Sagittal Offset (mm)	
	Male	Female	Male	Female	Male	Female	Male	Female
T12	- 14.03±2.63	- 13.30±2.48	6.13±1.04	5.52±1.02	5.9±1.3	5.5±0.11	10.9±1.8	9.5±2.2
L1	13.52±2.01	13.59±2.45	6.08±0.91	5.72±0.97	5.5±1.0	4.9±0.10	10.7±2.8	10.0±2.2
L2	13.97±2.40	13.57±2.10	6.29±0.97	5.69±1.10	5.8±1.4	5.3±0.10	10.7±2.0	9.9±2.0
L3	14.45±2.50	14.12±2.40	6.24±1.04	5.62±0.99	6.4±1.4	5.6±0.11	10.8±2.3	9.9±2.4
L4	15.55±2.36	14.87±3.36	6.05±0.97	5.75±1.36	7.0±1.4	6.8±0.13	10.7±2.6	9.5±1.8
L5	18.15±2.85	17.87±3.55	6.92±1.17	4.53±4.31	8.4±1.8	8.3±0.14	10.6±0.25	10.3±2.6

*The values are given as the mean and standard deviation. †All of the parameters were found to be significantly dependent on the spinal level except sagittal offset as determined with use of analysis variance ($p<0.05$).

Pedicle width (range, 4.66 to 17.08mm) was significantly dependent ($p<0.05$) on spinal level. The mean width increase from 7.4mm at T-12 to 10.9 at L-5. Post-hoc analysis revealed that pedicle width at each level was significantly different from that at all other level($p<0.005$). themean pedicle width was greater in men then in women at all level. The width was <5.00mm ten pedicles in 9 patients(5men 4 women) including 3 pedicles at T-12, 3 at L-1, 3 at L-2 and 1 at L-3.

Pedicle height (range, 7.33 to 19.2mm) was significantly dependent ($p<0.05$) on spinal level.The mean height decreased from 13.2 at T-12 to 12.3mm at L-5. Post-hoc analysis revealed that T-12 pedicle height was significantly greater ($p<0.005$) then the pedicle height at all other level. The mean pedicle height was greater in men then in women at all level. Pedicle height was more then 7mm at all levels. Pedicle height less then8.5mm in 11 pedicles, 6 at L-2, 4 at L-4, 1 at L-5. Pedicle axis length (range, 29.6 to 50.4) was significantly dependent($p<0.05$)on spinal level. The mean axis length was longest at L-2(40.6mm)at shortest at T-12 (36.9mm). Post-hoc analysis revealed that the axis length was significantly shorter at T-12 then at all other levels ($p<0.005$). The mean pedicle axis length was greater in men than in women at all level.

Medial offset (range, 2.2 to 12.4mm) was significantly dependent ($p<0.05$) on spinal level. The mean medial offset was 5.7 at L-1 and increased to 8.41 at L-5. Post-hoc analysis revealed that medial offset at each level was significantly different from that at all other level ($p<0.005$). The mean medial offset was lower in women than in men at all level.

Pedicle length (range,5.28 to 11.74mm) was significantly dependent($p<0.05$) on spinal level.

The mean pedicle length was shortest at L-1(7.6mm) and longest at L-5. Post-hoc analysis revealed that pedicle length significantly smaller at L-1 and L-2 than it was at T-12, L-3, L-4, L-5 ($p<0.005$). The mean pedicle length was greater in men than in women at all level.

Pedicle transverse angulation T-12 (range, -20.31 to -8.99 deg.) L1-L5(range, 8.87 to 23.9 deg) was significantly dependent ($p<0.05$) on spinal level. The mean pedicle transverse angulation was largest at L5(18.15 degree). Post-hoc analysis revealed that pedicle transverse angulation value at each level were significantly different at all other level($p<0.005$). Transverse pedicle angle most medially directed at L5 vertebrae with mean 18.15. whereas on other hand T-12 vertebrae transverse angle laterally deviated from midline with mean -13.66 degree. The mean transverse angulation was lower in women at all levels.

Pedicles sagittal angulation (range, -6.35 to 9.59) was significantly dependent($p<0.05$) on spinal level. Pedicles were directed cranially in all vertebrae except in 4 pedicles(only in female) at L-5 shows caudal angulation. Post-hoc analysis revealed that pedicle sagittal angulation value at each level was significantly different from those at all levels. The mean sagittal angulation was higher in men than in woman at all levels.

Sagittal offset (range 5.1 to 15.3mm) was statistically no significant difference was observed in sagittal offset at different level ($p>0.05$). The mean sagittal offset was lower in women at all levels.

Discussion:

The biomechanical superiority of pedicle screw over other methods of spinal fixation [1,2] along with increasing surgeon comfort with pedicle screw techniques, has driving the popularity of this technique. However, anatomy variations can make screw placement challenging. The knowledge of pedicle morphometry is helpful in the selection of most suited pedicle screw in Transpedicular fixation. Transpedicular screw fixation of spine is very successful method of spinal fixation. If the size of screw and pedicle mismatch may lead to instrumentation fail. This may result in cortex perforation of pedicle or fracture of pedicle. Sometimes pedicle screw may loosen. The complication associated with oversize pedicle screw are dural tear, leakage of cerebrospinal fluid and injuries to nerve root.[3] According to Krogman (1978)[4]; as the racial variations in skeleton are well known, hence morphometry of pedicle may vary from population to population.

Computed tomography (CT) scan provides an accurate way of obtaining this dimension. Biomechanical invitro studies of axial pullout strength and load to failure have helped in determining the optimum depth of pedicle screw penetration.[5,6,7] Our study provide morphometric data from thoracolumbar junction to fifth lumbar vertebrae(T12 to L5) in Maharashtra state of India by computer software aided by osirixCt based measurement which is more accurate comparatively to cadaveric data.

Pedicle height and width is important as it determine the diameter of screw that safely accommodated by pedicle. The outer diameter of most commonly used pedicle screw range from 5 to 7 mm.[8] Use of larger size screw will lead to breach medial or lateral cortex of pedicle. The pedicle height at all level was more then 7mm in the present study. Pedicle height and width value were lower than values given by Zindricket al[9]. And Krag et al[10]. On western population. The mean pedicle width was lower for L1 as comparatively

T12. This difference also noted by Shankar Acharya et al[11]. And M.Chadha et al[12]. for Indian pedicles (fig2,3).

	Our Study	Shankaracharya et al	Manish Chadha et al	Zindrick et al
T12	7.4	7.34	7.33	7.1
L1	6.5	7.2	6.69	8.7
L2	6.6	7.62	7.26	8.9
L3	7.8	8.97	8.43	10.3
L4	9.2	11.12	10.81	12.9
L5	10.8	13.91	13.47	18

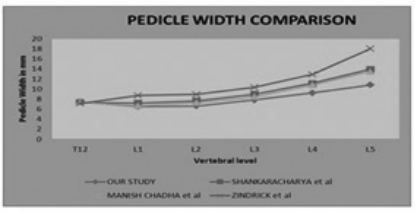

Fig 2: Pedicle width comparison

	Our Study	Sandeep and Mitra et al	Olsewski et al	Zindrick et al
T12	13.4			15.8
L1	12.95	15.69	16.15	15.4
L2	11.95	15.48	15.35	15
L3	12.25	15.22	14.8	14.9
L4	11.15	14.75	14.9	14.8
L5	12.25	16.35	19.6	14

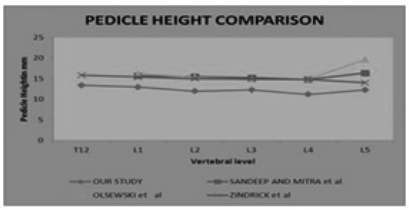

Fig 3: Pedicle height comparison

The result of our study shows that 5mm screw is much safer at upper lumbar level (L1 and L2). During using 6mm screw at upper lumbar level one needs to be extremely cautious because 24.61% pedicles are smaller then 6mm. the mean pedicle width decrease from T-12 to L-1 and increase L2 to L5.

Transverse pedicle angle were medially angulated at all lumbar levels. The angle increase medially as we move caudal. The degree of lateral angulations at T-12 level in our

study was higher in comparison to S.Acharya et al. study (fig 4).

	Our Study	Shankaracharya et al	Manish Chadha et al	Zindrick et al
T12	-13.66	-10.69	-3	-4.2
L1	13.55	10.9	8.78	10.9
L2	13.77	12.12	10.03	12
L3	14.28	15.4	12.25	14.4
L4	15.21	18.37	15.39	17.7
L5	18.01	24.75	24.33	29.8

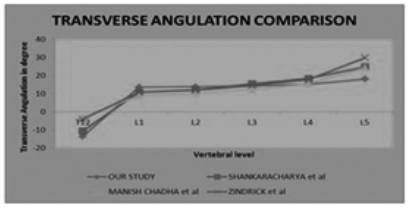

Fig 4: Pedicle transverse angulations comparison

Angular measurement of pedicle axis in the transverse and sagittal planes provide a quantitative description of pedicle screw insertion. Saggital angulations shows approximately 6 degree value in present study. Similar pattern shown by Olsewski et al[13]. The variations at L5 from -10 to 8 degree in the Olsewski et al study and from -6.35 to 9.59 in present study.

Pedicle axis length is important to prevent anterior cortex perforation and injury to vital organ. Pedicle axis length is minimum at T12 that is also showed by Indian and western studies(fig.5)

	Our Study	Shankaracharya et al	Manish Chadha et al	Zindrick et al
T12	36.9	34.43	34.73	38.6
L1	39.95	47	47.49	50.7
L2	40.55	49	49.09	51.9
L3	39.4	47.21	46.25	51.9
L4	38.65	47.48	46.27	49.7
L5	38.65	48.91	49.45	51

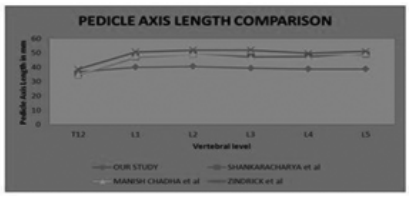

Fig 5: Pedicle axis length comparison

The result of the present study indicated that although transverse offset (medial) were significantly different at each level, there was a consistent trend from T12 to L5 vertebrae. The pedicle entry point location in the axial plane, defined by medial offset, was approximately 5.5mm medial to lateral margin of L1 lateral mass and moved medially at caudal levels. Vertical screw location, defined by sagittal offset, was approximately 10.7mm inferior to superior L1 articular process. To our knowledge, the present study is the first to quantify the ideal pedicle screw entry points in terms of lateral mass geometry.

Conclusion

This study indicates that the computer software aided pedicular morphometric data are reliable and comparable to other published studies with other methods. The recommended screw diameter of various vertebrae in our study came as: T12-6mm,L1-5mm, L2-5mm,L3-6mm,L4-8mm,L5-9mm. the differences in values may be on related morphologic differences as Indians have noticeably smaller build than western population, which was suggested also by Shankar Acharya et al[11]. However, no analysis is concluded in this study between patient height, weight and pedicle morphology.

It can be concluded from the above study that during placing pedicle screw at lumbar level, screws have to be medially directed and along the pedicular axis for reaching upto the anterior cortex of vertebral body without breaching it. Similarly during placing pedicle screw at T12 screw should be directed laterally and short pedicle axis length also keep in mind during placing pedicle screw at T12 comparatively to lumbar vertebrae.

Pedicle axis length needs to be carefully accessed during pre and intra operative period as it is significantly smaller at T12, L4 and L5 level(less then 40mm). the pedicle entry point moves medially and superiorly at caudal level. For the Indian population, the diameter and length of pedicular screw needs to be smaller than those mentioned in western study. The point of entry should be modified as mentioned in this study. Therefore, the need of CT based morphometric data assessment and preoperative planning of spinal surgery at different spinal level is important in accout of large variations, so that the intra and post operative complication can be avoided.

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