MORPHOMETRIC STUDY OF PEDICLES OF LUMBAR VERTEBRAE IN SOUTHERN INDIA
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ABSTRACT: INTRODUCTION: The growing interest in transpedicular screw fixation in the present time has warranted improved knowledge in morphometric details of the pedicles. The key to successful surgery is a clear knowledge of intracanal anatomy and the location of the pedicle. OBJECTIVES: To estimate and compare width and Height of pedicles of typical and atypical lumbar vertebra. To estimate and compare interpedicular distance of typical and atypical lumbar vertebra. MATERIAL AND METHODS: 119 dry human lumbar vertebrae of undetermined gender and age were selected for the study. The various parameters of pedicles were measured. RESULTS: The pedicle width at the midpoint of the pedicle on the right side ranged from 4.2-15.6 mm with a mean of 8.63±2.18 mm and on the left side ranged from 4.1-15.2 mm with a mean of 8.93±2.27 mm in typical vertebrae. The pedicle height at the midpoint of the pedicle on the right side ranged from 9.96-17.4 mm with a mean of 13.95±1.46 mm and on the left side ranged from 9.98–18.9 mm with a mean of 13.93±1.59 mm in typical vertebra. The interpedicular distance ranged from 9.9mm to 25.4mm with a mean of 20.41±2.32 in typical vertebra. The pedicle width at the midpoint of the pedicle on the right side ranged from 10.8-21.5 mm with a mean of 17.69±2.57 mm and on the left side ranged from 14.4-20.9mm with a mean of 17.68±2.02 mm in Atypical vertebrae. The pedicle height at the midpoint of the pedicle on the right side ranged from 11.9-17.6 mm with a mean of 14.7±1.69 mm and on the left side ranged from 12.1–17.2 mm with a mean of 14.48±1.73mm in typical vertebrae. The interpedicular distance ranged from 23.4mm to 28mm with a mean of 25.37±1.58 in Atypical vertebra. CONCLUSION: There is significant correlation between height and width of right and left side of typical and atypical vertebrae. KEYWORDS: Pedicle, Pedicle screw, Vernier caliper.

INTRODUCTION: The growing interest in transpedicular screw fixation in the present time has warranted improved knowledge in morphometric details of the pedicles.¹ With advances in the pre and intraoperative imaging techniques, transpedicular screw fixation is mostly indicated in unstable spine conditions like traumatic listhesis, wedge compression fractures, primary and secondary tumours, infections like tuberculosis.

The pedicle is the sole bridge between the posterior column and the middle and anterior columns. Hence pedicle screws traverse all three columns and as such can rigidly stabilize both the ventral and dorsal aspects of the spine. Performing pedicular screw fixation is technically challenging.² The key to successful surgery is a clear knowledge of intracanal anatomy and the location of the pedicle.³ A detailed knowledge of pedicle size and dimensions is crucial while using the pedicle to gain hold and strength of the vertebra. The sizes of the screws used in surgery must take pedicle dimensions into consideration.⁴
A break in the cortex of the pedicle can result from the misplaced screw. Intraoperative complications for the pedicle screw fixation include screw maldirection and pedicle fracture. The stability of the pedicle screw and its pullout strength depend on the integrity of the pedicle and the vertebral body even though larger screw sizes are preferred as they are stronger and give better results. The minimum width of the pedicle is the deciding factor in screw selection.

Screw design, details, biomechanics and implantation safety depend upon anatomic constraints, especially from the pedicle and the body. A number of implants have been devised and are being reviewed extensively elsewhere. To minimize the length of spinal segment involved, a three dimensionally rigid grip on each vertebra is needed. Placement of the screw through the pedicle into vertebral body appears to be a very good way to accomplish this. For this reason, the details of pedicle morphometry become important in defining anatomic design constraints. Some data exist on this subject, but these got limitations. The current study has been undertaken to define certain important morphometric details relative to the human vertebral pedicle.

One of the most important and pertinent causes of chronic low backache especially in elder age group could be lumbar canal stenosis. Many cases of spinal canal stenosis are related to the anatomical variants with varying degrees of reduction of vertebral foramen particularly in sagittal diameters to which are added degenerative lesions of vertebral arches, facet joints and flaval ligaments. Due to common occurrence of low backache (thoracic and lumbar spines being the prime targets resulting into this symptom) workers over the world have tried to concentrate on this region for their exhaustive study.

As regards to the morphometrical data, it is well established that the same varies within different sex, race, ethnic and regional groups. Even though the problem of low backache is equally prevalent all over the Universe, we see little studies being done in Indian context. Hence there is a need for our own metrical data specifically relevant to this region, which may if found appropriate fill up a big void. This data generated will be relevant and come handy to the clinicians dealing with the problem of low backache, particularly due to bony abnormalities or deformities. The role of narrow lumbar spinal canal is well established in back and sciatic pain.

OBJECTIVES:
1. To estimate width and Height of pedicles of typical lumbar vertebra.
2. To estimate width and Height of pedicles Atypical lumbar vertebra.
3. Comparison of width and height of typical and atypical lumbar vertebra.
4. To estimate and compare interpedicular distance of typical and atypical lumbar vertebra.

MATERIAL AND METHODS: The study was conducted on 119 Adult dry human lumbar vertebrae of which 104 were Typical and 15 were Atypical. Undamaged vertebrae of unknown age & sex were obtained from the department of Anatomy Amala Medical College, Trissur and department of anatomy Azeezia Medical College, Kollam. Each vertebra was assigned a serial number. Measurements were taken using a digital vernier caliper (0-150mm with a precision of 0.02 mm).
The following parameters were recorded,

1. **Pedicle width at the midpoint of the pedicle:** It is the distance between medial and lateral surfaces of pedicle at its midpoint, measured at right angles to the long axis of the pedicle. Fig. 1.

2. **Pedicle height at the midpoint of the pedicle:** It is the vertical distance between superior and inferior border of pedicle at its midpoint. Fig. 2.

3. **Interpedicular distance:** This is the maximum distance between the medial surfaces of the right and left pedicles of the same vertebra. This was recorded as the transverse diameter of the vertebral canal. Fig. 3.

OBSERVATIONS AND RESULTS:

1. The pedicle width at the midpoint of the pedicle on the right side ranged from 4.2–15.6mm with a mean of 8.63±2.18 mm and on the left side ranged from 4.1-15.2mm with a mean of 8.93±2.27 mm in typical vertebrae. (Table No. 1)

2. The pedicle height at the midpoint of the pedicle on the right side ranged from 9.96-17.4 mm with a mean of 13.95 ± 1.46 mm and on the left side ranged from 9.98–18.9mm with a mean of 13.93±1.59 mm in typical vertebrae. (Table No. 1)

3. The interpedicular distance ranged from 9.9mm to 25.4mm with a mean of 20.41±2.32 in typical vertebra. (Table No. 1)

4. The pedicle width at the midpoint of the pedicle on the right side ranged from 10.8-21.5 mm with a mean of 17.69±2.57 mm and on the left side ranged from 14.4-20.9mm with a mean of 17.68±2.02 mm in Atypical vertebrae. (Table No.2)

5. The pedicle height at the midpoint of the pedicle on the right side ranged from 11.9-17.6 mm with a mean of 14.7±1.69 mm and on the left side ranged from 12.1–17.2 mm with a mean of 14.48±1.73mm in typical vertebrae. (Table No.2)

6. The interpedicular distance ranged from 23.4mm to 28mm with a mean of 25.37±1.58 in Atypical vertebra. (Table No.2)

| Parameters                        | Mean     | Std Dev | Max mm | Min mm | p value |
|-----------------------------------|----------|---------|--------|--------|---------|
| Average width of pedicle          |          |         |        |        |         |
| Right side                        | 8.63048544 | 2.183572 | 15.6   | 4.2    | 0.364   |
| Left side                         | 8.93398058 | 2.277565 | 15.2   | 4.1    |         |
| Average height of pedicle         |          |         |        |        |         |
| Right side                        | 13.9539806 | 1.461955 | 17.4   | 9.96   | 0.999   |
| Left side                         | 13.9386408 | 1.594433 | 18.9   | 9.98   |         |
| Average interpedicular distance   |          |         |        |        |         |
|                                  | 20.4131068 | 2.329212 | 25.4   | 9.9    |         |

Table 1: Dimensions of Typical Vertebrae - No.s 104
Dimensions of Typical Vertebrae:

|                                | Mean mm | Std. Dev. | Max mm | Min mm | P value |
|--------------------------------|---------|-----------|--------|--------|---------|
| Average width of pedicle       |         |           |        |        |         |
| Right Side                     | 17.693  | 2.572     | 21.5   | 10.8   | 0.930   |
| Left Side                      | 17.687  | 2.028     | 20.9   | 14.4   |         |
| Average height of pedicle      |         |           |        |        |         |
| Right Side                     | 14.733  | 1.697     | 17.6   | 11.9   | 0.844   |
| Left Side                      | 14.48   | 1.732     | 17.2   | 12.1   |         |
### Dimensions of Atypical Vertebrae:

| Average interpedicular distance | 25.37333333 | 1.582704136 | 28 | 23.4 |

**Table 2: Dimensions of Atypical Vertebrae-Nos-15**

**Graph 3**

**Graph 4**
### Table 3: Comparison of Width of pedicle in typical and atypical vertebrae

|          | Average width of pedicle | Mean mm     | Std. Dev       | P value |
|----------|--------------------------|-------------|----------------|---------|
| Typical  | Right side               | 8.63048544  | 2.183572       | 0.364   |
|          | Left side                | 8.93398058  | 2.277565       |         |
| Atypical | Right side               | 17.69333333 | 2.571677237    | 0.93    |
|          | Left side                | 17.68666667 | 2.027618824    |         |
|                      | Average Height of pedicle | Mean mm | Std Dev | P value |
|----------------------|---------------------------|---------|---------|---------|
| Typical              |                           |         |         |         |
| Right side           | 13.9539806                | 1.461955|         | 0.999   |
| Left side            | 13.9386408                | 1.594433|         |         |
| Atypical             |                           |         |         |         |
| Right side           | 14.73333333               | 1.6973685|        | 0.844   |
| Left side            | 14.48                     | 1.7317208|        |         |

**Table 4: Comparison of Height of pedicle in typical and atypical vertebrae**

|                      | Mean mm   | Std Dev    |         |         |
|----------------------|-----------|------------|---------|---------|
| Typical              | 20.4131068| 2.329212   |         |         |
| Atypical             | 25.37333333| 1.582704136|        |         |

**Table 5: Comparison of interpedicular distance of typical and atypical vertebrae**

**DISCUSSION:** The Lumbar region and is often involved during accidents, degenerative disorders, congenital defects, and neoplastic metastases. Therefore it may need artificial fixation for its activity to be regained. Every structural deformity of the pedicle might affect the weight conduction mechanism and might compress the neural structures. There are wide varieties of studies done on lumbar pedicles. In various ethnic regions both radiologically as well as by direct measurements.

Pedicle screw fixation is a popular and preferred method of spine stabilization. It gives rigid, segmental stabilization and also allows preservation of motion. Although some newly developed navigation techniques may help the surgeons to place pedicle screws more safely, still a clear knowledge of the pedicle morphometry is necessary, especially in deformed spines to optimize starting point and trajectory of the screw path.

Transverse pedicle width is an important factor which determines the diameter of screws that can be safely accommodated in a pedicle without breaching the lateral and medial cortex. The pedicle of the vertebra is also been used as a fixation site for vertebral implants. There is an increase in the diameter at the cranial–caudal direction of lumbar pedicle. Because of increase in vertical as well as horizontal dimension, the shape of the lumbar pedicle becomes oval. This increase in dimensions with oval shape is well correlated to more physiological and mechanical loads at this level. After transfacet screw placement by King there has been continuous development in the screw placement techniques by various surgeons such as Boucher, Pennel et al., Louis, Dick and Steffee et al.

Porter et al. suggested that good physical activity were associated with good strength of vertebral column in mature individuals. The variation in measurements of pedicles in different age groups may be due to the difference in mechanical load. Kothe et al. reported the cortical difference in thickness of vertebral pedicle. Chawla et al. report that vertical height is always greater than its width; same was observed in our study also. According to Amonoo-Kuofi, the studies reported by Pal & Routal, in the lumbar region, the pedicles play an important role in the...
transfer of weight from the neural arch to the anterior part of the vertebral column. But according to the studies by Pal & Routal in the lumbar region where the curvature is concave posteriorly, the load is transmitted from anterior to posterior; i.e: from the anterior part of the vertebral column to the neural arch. This is in accordance with the position of the line of gravity.

They also told that at the level L5, load through the pedicles has to pass in an antigravity direction, i.e.: opposite to the direction of inclination of the pedicles. Thus the transfer of load from the body to the laminae in L5 (and to certain extent in L4) will be upwards against gravity, making L5 possessing strongest pedicles and maximum width. In the Present study also the width of pedicles is maximum at L5 level.

During pedicle screw fixation, pedicle screw is passed through the posterior aspect of the pedicle into the vertebra anteriorly. The success of this technique depends on the ability of the screw to obtain strength within the vertebral body. In our study on typical lumbar vertebrae, the mean height was 13.953 mm on right side and 13.938 mm on left side. As compared to the present study, slightly higher values were reported by Arora et al.19 for vertical height (16.42 mm) and lower values by Singel et al.20 (10.4 mm). In Aruna and Rajeshwari,21 the range for the breadth was 4.5–22 mm and the range for the height was 10–20 mm. In the present study, its mean width range for typical vertebrae was 8.630 mm on right side and 8.933mm on left side. In the present study, there was significant correlation between height and width of right and left side of typical and atypical vertebrae. It was observed in the present study that in typical vertebrae the height of the pedicle on both right and left side was more as compared to width which was not the same in atypical.

Singel et al.,22 Lien et al.,23 Tan et al.,24 Wolf et al.25 and Mitra et al.26 found that the pedicle width of the lumbar segment increased progressively from L1 to L4 and increased abruptly at L5. In the present study also all the values of right and left side pedicles of atypical vertebrae were more as compared to typical vertebrae. This showed that the height and width of the pedicles went on increasing towards the caudal vertebrae, which was seen in all the reported studies.

The Interpedicular distance is between the medial surfaces of the pedicles of the same vertebra constitute the lateral walls of the vertebral canal. The reduction in interpedicular distance and anteroposterior shortening of the pedicle are the commonest causes of stenosis of the vertebral canal. In the present study, the maximum interpedicular distance was 9.9 mm and the minimum was 25.4 mm, with a mean value of 20.413±2.329 mm in typical vertebrae but in atypical vertebrae maximum was 28mm and minimum was 23.4mm with mean of 25.37±1.58 mm. Postacchini et al.27 studied Indian as well as Italian skeletons in Rome and observed slightly lower readings in the Indian population, while the interpedicular distances in Italian skeletons were quite similar to those observed in the present study.

CONCLUSION: Thus, according to the above discussion, the present study concludes that there is always an increase in width of lumbar pedicles proceeding from L1 to L5 levels and the width being maximum at L5 level to enable in weight transmission. Further in this study there was significant correlation between height and width of right and left side of typical and atypical
vertebrae. It was observed in the present study that in typical vertebrae the height of the pedicle on both right and left side was more as compared to width which was not the same in atypical.

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