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Morphometry of the lumbar pedicle in North West India

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SUMMARY

Any structural deviation of the pedicle may result in interference of the weight transmission mechanism and compression of neural structures. This comprehensive anatomical study was conducted on 30 dry L3 lumbar vertebrae and 10 adult male cadavers obtained from Department of Anatomy, Govt. Medical College Hospital, Chandigarh. The specimens belonged to a North West Indian population. In the present study, the following measurements were taken with the help of a vernier caliper: vertical height(h) and pedicle width(w) in dry L3 lumbar vertebrae; interpedicular distance (GH) in dry L3 lumbar vertebrae and cadaveric specimens of all lumbar vertebra, and interpedicular distance between adjacent lumbar vertebrae in cadaveric specimen.

In the dry bone specimens (L3) the mean height of the pedicle was 14.0 ± 1.1 mm on right side and on left side the mean was 14.1 ± 1.0 mm. The mean width of the pedicle was 8.7 ± 1.4 mm on right and on the left side the mean was 8.7 ± 1.7 mm. The mean interpedicular distance between the medial surface of the right & left pedicle of same vertebra was 20.5 ± 1.3 mm, whereas in the cadaveric specimen (L3) the mean value was 22.7 ± 1.73mm and the distance increased from L1 (21.6 mm ± 1.69) to L5 (25.4 mm ± 3.19).

However, an increase was seen in the interpedicular distance between adjacent lumbar vertebrae from the Ll-L2 to L2-L3 levels and thereafter a decrease from the L3-L4 to L4-L5 levels on the right side. On the left side, a similar trend was seen, except that L2-L3 and L3-L4 had similar means. This study provides data from an Indian population for orthopaedic procedures.

Key words: Pedicle – Vertebra – Lumbar Spine – Morphometry

INTRODUCTION

Inceoglu et al. (2005) reported that since it is the mobile part of the vertebral column the lumbar region is subject to instability following trauma, in particular that related to road traffic accidents, the use of heavy mechanical devices, and adventure sports, apart from besides surgical laminectomies, degenerative conditions, congenital defects, and metastasizing malignant tumors of the prostate and other pelvic organs.

Several devices such as rods, plates or wires can be fixed to the spinal column by screws for

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immobilization (Amonoo-Kuofi, 1995). The factors involved in establishing stability using implants include accurate screw fixation and good bone quality for proper screw path (Zindrick et al., 1986). In the recent past, transpedicular screw implantation techniques have gained popularity over anterior instrumentation and hook-rod devices as the means of spinal fixation (Zindrick et al., 1987). The unique anatomy of pedicles provides an excellent implantation site for screw fixation in reconstructive spinal surgeries with a view to maintaining and restoring stability in such patients (Roy-Camiller et al., 1986).

The reduced transverse interpedicular distance of the vertebra has been reported by Clinotti et al. (2002) as one of the primary causes of the narrowing of the vertebral canal in the cervical and lumbar regions and also the narrowing of the intervertebral foramen transmitting spinal nerves, which is limited above and below by the pedicles of the adjacent vertebrae, resulting in neural compression.

King (1948) was the first to attempt screw emplacement parallel to the inferior border of the lamina and across the facet joints for internal fixation of the lumbosacral region, whereas Boucher (1959) successfully initiated passing long screws through the lamina and pedicle into the vertebral body below for spinal fusion, with internal splinting by screw fixation, thus temporarily stabilizing L4 to L5 and L5 to Sl.

According to King (1948), screws inserted into the pedicle for the reduction and stabilization of spondylolisthesis have afforded good results.

Magerel (1984) developed adjustable external spinal skeletal fixation for stabilizing the lower thoracic and lumbar spine in patients with acute spinal trauma, in which screws were firmly anchored through the pedicle into the vertebral bodies, although the foundation for pedicle screws and posterior plates was established earlier by Roy-Camiller et al. (1986). Those authors designed and used posterior plates with screws driven parallel to the sagittal plane into the pedicles and articular processes to counter the complications of pedicle screw plate stabilization, including lumbar fractures and malunions.

In 1948, a new segmental instrumentation of pedicle screw fixation with spinal plates contoured for anatomic positioning to enhance graft consolidation and fusion for disorders of the thoracolumbar spine was developed by King.

Luque (1986) introduced another method of interpeduncular segmental fixation using pedicle screws wired to Luque rods. Further enhancements of pedicle screw fixation techniques were associated with considerations of the anatomical contours, mobility, complications such as screw loosening, screw migration, screw breaking, nerve root impingement, and deep wound infection.

Materials and Methods

The present study addresses the morphometry of the pedicle of human lumbar vertebrae in the following different materials. All measurements were done at three different sittings, and the mean of the values corrected to the nearest millimeter was recorded.

A: Morphometry of dry bone

Direct gross morphometry of the pedicles of randomly selected 30 fully ossified human lumbar vertebrae was carried out. Deformed and broken vertebrae were excluded from the study.

The following measurements of both sides were recorded using a sliding vernier caliper.

Vertical height (h): The closest points just opposite each other on the upper (C) and lower margins (D) of the pedicles in the vertical plane on its lateral aspect.

Pedicle width (w): The deepest points on the medial (A) and lateral (B) surfaces of each pedicle. The thickness was measured at right angles to the long axis of pedicle.

Interpedicular distance (GH): This is the maximum distance between the medial surfaces of the right (G) and left (H) pedicles of the same vertebra.

B: Morphometry of cadaveric specimens

This part of the study was performed on ten normal adult male cadavers. Cadavers with any gross anomalies, a history of any intervertebral disc collapse, and osteophytes were excluded from the study. The shape of the vertebral canal and intervertebral foramina was noted and the following parameters were recorded using a sliding vernier caliper:

Interpedicular distance between adjacent lumbar vertebrae: This is the vertical diameter of the intervertebral foramina at its rim and was measured from the root of the transverse process of the vertebra above to the root of the transverse process of the vertebra below.

It was recorded on both the right and left sides separately.

Then, the intervertebral disc of each segment of the lumbar part of the vertebral column was cut transversely using a hand saw, and the following parameters were measured in each vertebrae.

Interpedicular distance between medial surface of the right (G) and left (H) pedicles of the same vertebra: This was recorded as the transverse diameter of the vertebral canal.

Results

Gross observations of the L3 Vertebra

The pedicles of lumbar vertebrae were present between the lamina and the vertebral body. They were thicker near the ends and constricted in the middle. The upper and lower surfaces of the pedicles were concave.

A: In Dry Bone

While observing the gross morphometry, the following measurements of pedicles of 30 fully ossified human lumbar vertebrae were recorded on both sides:

Vertical height (h): The mean height of the pedicle was 14.0 ± 1.1 mm on the right side, with minimum value of 11.0 mm and a maximum of 15.6 mm (Fig. 1). On the left side, the mean height was 14.1 ± 1.0 mm, with a minimum value of 11.7 mm and a maximum value of 16.0 mm. The difference in the measurements between the right and left side was statistically insignificant ($p > 0.05$).

Pedicle width (w): The mean width of the pedicle was 8.7 ± 1.4 mm on the right side with a minimum value of 5.5 mm (Fig. 2) and a maximum of 10.8 mm. On the left side, the mean width was 8.7 ± 1.7 mm with a minimum value of 5.4 mm and a maximum of 12.5 mm. The difference in measurements between the right and left side was statistically insignificant ($p > 0.05$).

Interpedicular distance (GH): The mean interpedicular distance between the medial surface of the right & left pedicle of the same vertebra was 20.5 ± 1.3 mm, with a minimum value of 18.0 mm and a maximum of 25.1 mm (Fig. 3).

The correlation coefficient between the height and width of the pedicle was 0.429, pointing to a positive correlation between the two.

B: In Cadaveric Specimens

The shape of the intervertebral foramen in the upper levels was oval; in the middle levels

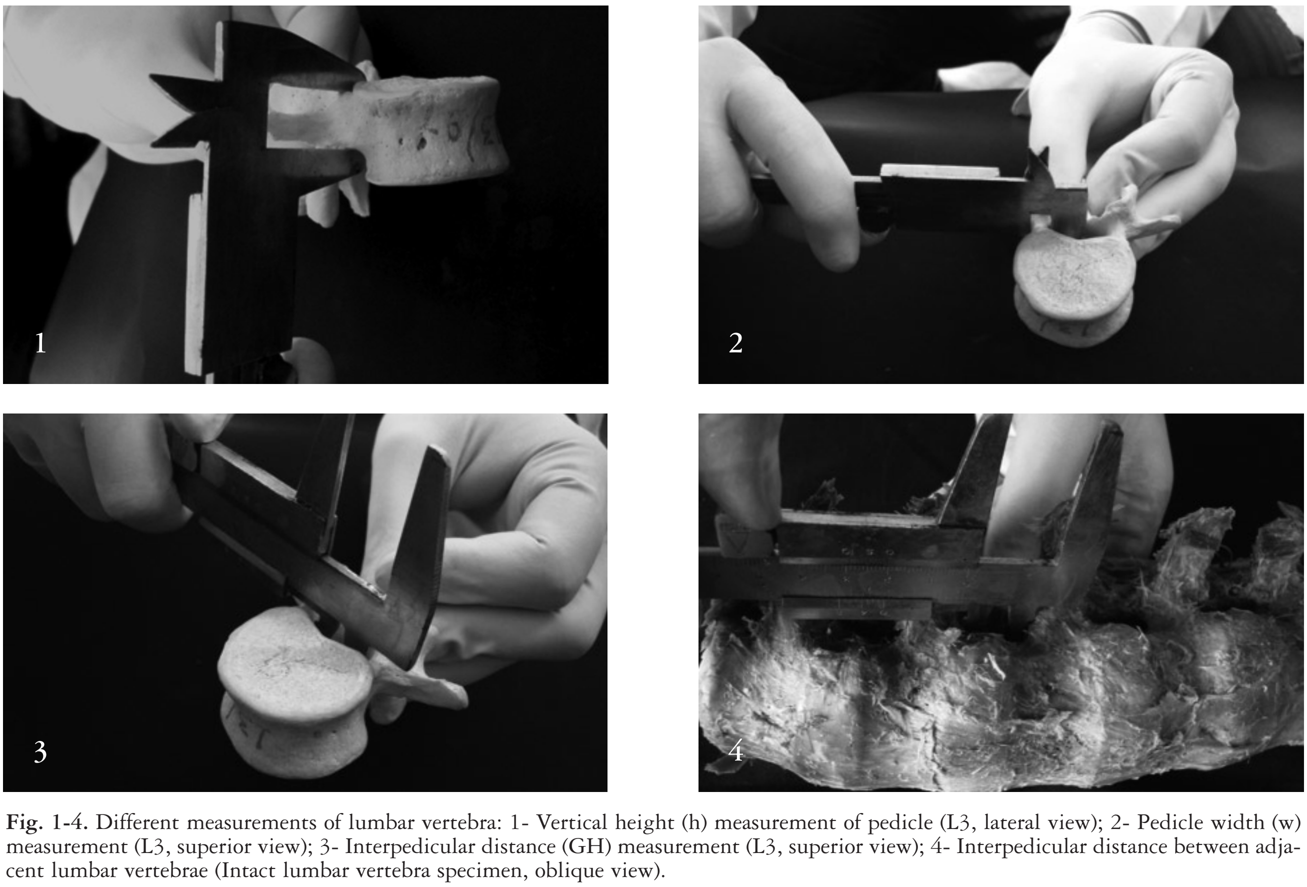

Fig. 1-4. Different measurements of lumbar vertebra: 1- Vertical height (h) measurement of pedicle (L3, lateral view); 2- Pedicle width (w) measurement (L3, superior view); 3- Interpedicular distance (GH) measurement (L3, superior view); 4- Interpedicular distance between adjacent lumbar vertebrae (Intact lumbar vertebra specimen, oblique view).

Table 1. Interpedicular distance between adjacent lumbar vertebrae.

		RIGHT	LEFT	P-VALUE
L1-L2	Mean	16.9 mm	15.1 mm	0.041*
	S.D.	1.58	2.27	
	Range	15.2-20.4 mm	9.5-17.3 mm	
L1-L2	Mean	18.0 mm	17.2 mm	0.079
	S.D.	1.91	2.47	
	Range	14.9-20.3 mm	13.2-20.6 mm	
L1-L2	Mean	16.9 mm	17.2 mm	0.450
	S.D.	2.02	2.23	
	Range	13.9-20.0 mm	13.6-20.7 mm	
L1-L2	Mean	16.6 mm	16.6 mm	0.970
	S.D.	2.57	2.37	
	Range	12.7-20.7 mm	12.8-19.5 mm	

gradual narrowing was observed in the lower part of the intervertebral foramen, affording it an inverted 'tear drop' or key-hole appearance. The intervertebral foramina were observed to have different shapes, such as round or oval, auricular, or teardrop, in the different specimens.

The following parameters were measured on intact lumbar vertebral specimen from 10 adult male cadavers:

Interpedicular distance between adjacent lumbar vertebrae (Table 1):

Right side: This was maximum between L2 and L3 (18.0 mm) and minimum between L4 and L5 (16.6 mm) (Fig. 4).

Left side: This was maximum between L2 and L3, L3 and L4 (17.2 mm) and minimum between L1 and L2 (15.1 mm).

There was an increase in the interpedicular distance from the Ll-L2 to L2-L3 levels, a decrease from L3-L4 to L4-L5 levels being observed thereafter on right side. On the left side, a similar pattern was seen, except no change was observed from the L2-L3 to L3-L4 levels.

The difference between the right and left side was statistically insignificant except at the L1- L2 level ($p < 0.05$).

Interpedicular distance between the medial surface of the right (G) and left (H) pedicle of the same vertebra (Table 2). This was maximum at L5 (25.4 mm) and minimum at L1 (21.6 mm) (Fig. 3).

It was observed that the interpedicular distance increased gradually from L1 to L5.

Table 2. Interpedicular distance between medial surface of right & left pedicle of the same vertebrae.

L1	Mean	21.6 mm
	S.D.	1.69
	Range	19.3-24.1 mm
L2	Mean	22.0 mm
	S.D.	1.46
	Range	19.5-24.3 mm
L3	Mean	22.7 mm
	S.D.	1.73
	Range	19.8-25.3 mm
L4	Mean	23.1 mm
	S.D.	2.25
	Range	20.2-26.6 mm
L5	Mean	25.4 mm
	S.D.	3.19
	Range	20.4-30.0 mm

Discussion

Since it is the mobile part of the vertebral column, the lumbar region is frequently involved during accidents, degenerative conditions, congenital defects, and neoplastic metastases Thus it may require instrumentation for its activity to be regained.

Surgical intervention in this region requires a thorough knowledge of the anatomy to identify a suitable site for instrumentation aimed at spinal fixation. The vertebral pedicles are used for the placement of screws through them for management of unstable lumbar spines and such a procedure offers potential advantages over anterior instrumentation and hook-rod devices, as reported by Matsuzaki et al. (1990). With the help of screws, several devices such as rods, plates or wires can be applied to the spine for immobilization or fixation (Amonoo-Kuofi, 1995).

A misplaced or misdirected pedicle screw may cause injuries to the pedicle cortex, nerve root, facet joint and vital adjacent structures (Misenhimer et al., 1989; Weinstein et al., 1988). Thus, for safer pedicle screw placement it is important to understand pedicle dimensions and angulations for the development of techniques and devices for spinal instrumentation.

In pedicle screw insertion, the screw is passed through the posterior aspect of the pedicle into the body of the vertebra anteriorly. Since the success of this technique depends upon the ability of the screw to obtain strength within the vertebral body, the choice of the screw to be used is determined by the minimum diameter of the pedicle. Therefore, morphometric data concerning pedicles is useful in preoperative planning and also in designing pedicle screws and other implantable devices.

Being a typical lumbar vertebra, located in the middle of the lumbar vertebral column, in the present study L3 was selected in dry bone specimens for morphometric analysis.

In our study of dry lumbar vertebra (L3), the mean vertical height of the pedicle was 14.0 ± 1.1 mm on the right side with a minimum value of 11.0 mm. On the left side, the mean height was 14.1 ± 1.0 mm, with a minimum value of 11.7 mm, while the mean width of the pedicle was 8.7 ± 1.4 mm on the right side, with a minimum value of 5.5 mm and on the left side the mean width was 8.7 ± 1.7 mm, with a minimum value of 5.4 mm. Similar findings have been reported by other authors (Misenhimer et al., 1989; Berry et al., 1987; Hou et al., 1993; Scoles et al., 1988; Wolf et al., 2001) with minimum differences. Higher values for vertical height were reported by Arora et al. (2005) (16.42 mm in males and 15.6 mm in females) and Singel et al. (2004) (10.4 mm in males and 10.6 in females).

Vertical height is of little significance because in our series height was larger than the width at almost all levels and screw diameter is decided by the minimum diameter of the pedicle.

Almost all studies have reported that the mean values of the vertical height and width of the lumbar pedicle were higher in males than in females and this can be explained in terms of the greater upper body weight of males (Steffee et al., 1986). In contrast, Singel et al. (2004) reported that the vertical height of the pedicle and its width were greater in females than in males, although the difference was minimal.

The findings of the present study are quite similar to those reported in a previous report by Lien et al. (2007) stating that the values for the left and right pedicles of the lumbar vertebrae were nearly the same. This is the only reference available in which pedicle width was measured separately for the right and left sides.

It is apparent from all the studies that (1) the vertical height of the pedicle is always more than its width and (2) the vertical height and width of the vertebrae are directly proportional to each other and both values have a minimal sexual variation.

The mean vertical height was 14.1 mm on the right side and 14.1 mm on the left side, while the mean width of the pedicle was 8.8 mm on the right side and the mean width was 8.8 mm on the left side. The difference between the findings of the current study and those of Lien et al. (2007) is marginal.

The transverse interpedicular distance (GH) is between the medial surfaces of the pedicles of the same vertebra constitute the lateral walls of the vertebral canal. The antero-posterior shortening of the pedicle and the reduction in transverse interpedicular distance is one of the commonest causes of stenosis of the vertebral canal. In the present study, the interpedidular distance was observed in the L3 vertebra only, while it was observed at each vertebral level of the cadaveric lumbar spine.

Since there are no studies available addressing cadaveric specimens, the mean interpedicular distance in the cadaveric specimen of present study was compared with dry bone study as well as with radiological studies.

It was observed in 30 dry bones (L3) studied that the maximum transverse interpedicular distance was 25.1 mm and the minimum was 18 mm, with a mean value of 20.5 ± 1.3 mm.

It gradually increased from L1 to L5 in the cadaveric specimens. The values of the mean interpedicular distances of the present study are comparatively lower at all lumbar levels than in the other studies. It is also evident from the fact that in the Indian population the mean interpedicular distance is more in Guyaratis as compared to North Indians. The difference in values in dry bone recordings and the cadaveric specimens could be because of the presence of soft tissue around the specimens, while recording from the plain radiographs in some studies the magnification factor and the observer bias cannot be ruled out.

Postacchini et al. (1983) studied Indian as well as Italian skeletons in Rome and observed slightly lower readings in the Indian population, while the interpedicular distances in Italian skeleton swere quite similar to those observed in the present study.

The interpedicular distance between adjacent lumbar vertebrae is the vertical height of the intervertebral foramen. The shape of intervertebral foramina at upper levels was oval, while there was a gradual narrowing of the lower part of the intervertebral foramina in L3 and below, giving it an inverted 'tear drop' or keyhole appearance.

In most studies, including this one, the maximum dimensions were recorded between L2-L3, while the dimensions of L2-L3 and L3-L4 were fairly similar. Generally, the dimensions were lowest in L1-L2 followed by L4-L5. The vertical diameter displayed an increase from the L1-L2 to the L2-L3 levels and thereafter a statistically non-significant decrease from L3-L4 to L4-L5. The anteroposterior diameter decreased from L1-L3 and thereafter a significant bilateral increase at L4-L5 was seen. This was also reported by Devi and Rajagopalan (2005).

When the associated intervertebral disc is normal, the majority of foramina are oval in outline, but when the disc is abnormal, the auricular shape predominates and the ratio of oval to auricular foramina is reversed Since the intervertebral disc is an important constituent in the middle of the anterior wall of the intervertebral foramen, its integrity has bearing on the vertical diameter of the intervertebral foramina (Cinotti et al., 2002). An accurate interpretation can only be given after also considering the other components.

The plates used for spine fixation of in the study by Roy-Camiller et al. (1986) had holes every 1.3 cm, and they fixed the screws at alternate holes, the average distance between two pedicles being 2.6 cm between the entry point of two consecutive pedicles. The plates in the study of Steffee et al. (1986) had a distance of 2.6 cm between the centers of two slots to accommodate the specially designed Steffee pedicular screw. These implants match the interpedicular distance for the Indian population fairly well but may need some modification since the distance between the centers of two adjacent pedicles was around 29 mm (range 29 mm to 32 mm).

To conclude, for the Indian population Steffee pedicle screws of 5.5 mm diameter can be used safely in lumbar vertebrae since the diameter of the pedicular screw is governed by the minimum diameter of the pedicle, which in the present study was across the width (8.7 mm). The possibilities of this kind of study remain unexplored and deserve further attention.

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