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“MORPHOMETRIC STUDY OF PEDICLES OF LUMBAR  
VERTEBRAE – A CROSS-SECTIONAL STUDY”

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By

**Dr. SHIVANAND N. DODDANINGAPPAVAR**

Dissertation submitted to the  
KLE University, Belgaum, Karnataka

In Partial Fulfillment  
of the requirements for the degree of

M. D. (ANATOMY)

Under the Guidance of

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**MAY - 2009**

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I hereby declare that this dissertation entitled  
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STUDY”** is a bonafide and genuine research work carried  
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## LIST OF ABBREVIATIONS USED

CT	-	Computed Tomography
IPD	-	Interpedicular distance
L <sub>1</sub>	-	First lumbar vertebra
L <sub>2</sub>	-	Second lumbar vertebra
L <sub>3</sub>	-	Third lumbar vertebra
L <sub>4</sub>	-	Fourth lumbar vertebra
L <sub>5</sub>	-	Fifth lumbar vertebra
mm	-	Millimeter
MRI	-	Magnetic resonance imaging
S <sub>1</sub>	-	First sacral vertebra
S.D.	-	Standard deviation
T <sub>9</sub>	-	Ninth thoracic vertebra
T <sub>12</sub>	-	Twelfth thoracic vertebra

## **ABSTRACT**

### **Background and objectives**

The pedicles offer the strongest points of attachment to the spine. Most spinal instrumentation systems use screws for fixation placed into the pedicle. The screw design, details, biomechanics and implantation safety depend upon the anatomic constraints, especially the morphometry of pedicles.

The objectives of the present study were to provide morphometrical data support for successful pedicle screw fixation and also to analyse the quantification of spinal stenosis directly relevant to Belgaum region.

### **Methods**

Twenty five sets of normal, adult, dry lumbar vertebrae were studied for their dimensions (height, width and length of the pedicles, mid-sagittal diameter and interpedicular distance) with the help of Vernier caliper.

The material for the study that is total of 125 lumbar vertebrae were obtained from 25 cadavers from the Department of Anatomy, Jawaharlal Nehru Medical College, Belgaum. The study was conducted during a period of one year from January 2007 to December 2007.

### **Results**

The following readings (Mean  $\pm$  Standard Deviation) were obtained for different dimensions of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> respectively.

- Height of the pedicle:  $19.5 \pm 2.89$ ,  $18.4 \pm 3.74$ ,  $18.1 \pm 3.21$ ,  $17.7 \pm 2.51$  and  $18.7 \pm 3.08$ .
- Width of the pedicle:  $10.7 \pm 2.03$ ,  $12.8 \pm 2.73$ ,  $13.4 \pm 2.66$ ,  $14.9 \pm 2.51$  and  $20.9 \pm 3.36$ .
- Length of the pedicle:  $15.5 \pm 2.69$ ,  $15.8 \pm 2.75$ ,  $16.1 \pm 2.91$ ,  $14.2 \pm 2.84$  and  $13.6 \pm 2.05$ .
- Mid-sagittal diameter:  $18.3 \pm 2.86$ ,  $16.2 \pm 3.26$ ,  $16.0 \pm 3.32$ ,  $17.8 \pm 3.12$  and  $18.1 \pm 2.99$ .
- Interpedicular distance:  $22.5 \pm 3.46$ ,  $22.9 \pm 3.14$ ,  $24.8 \pm 3.22$ ,  $24.9 \pm 3.47$  and  $27.1 \pm 4.01$ .

### **Conclusions and interpretation**

The morphometrical data obtained in our study would be helpful for the surgeons dealing with the transpedicular fixation in selecting the largest fully threaded screw that can be safely accommodated by the pedicle. The data would also come handy to the clinicians dealing with the problem of low backache and in diagnosis of spinal stenosis.

The present study concludes that, the different dimensions of the lumbar pedicle morphometry which have been studied would be of help for successful pedicle screw fixation with minimum post-operative complications and also for quantification of spinal stenosis, specifically relevant to this region of Belgaum city.

**Key words**

Lumbar vertebrae; Pedicles; Spinal stenosis; Transpedicular screw fixation;

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## *Introduction*

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## *Objectives*

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*Conclusion*

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*Summary*

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## **INTRODUCTION**

The growing interest in transpedicular screw fixation for spinal stabilizing implants is the basis for the improved morphometric details about the pedicles.<sup>1</sup> 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 brucellosis and tuberculosis.

Performing pedicular screw fixation is technically challenging.<sup>2</sup> The key to intracanal anatomy is the location of the pedicle.<sup>3</sup> 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 this procedure must take pedicle dimensions into consideration.<sup>4</sup>

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.

A break in the cortex of the pedicle can result from the misplaced screw.<sup>5</sup> Intraoperative complications for the pedicle screw fixation include screw cut out or maldirection, and pedicle fracture.<sup>6</sup>

The stability of the pedicle screw and its pullout strength depends 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.<sup>1</sup>

A number of implants have been devised or are being developed and are been reviewed extensively elsewhere.<sup>7</sup>

Thus a design effort was undertaken in 1981 to overcome the shortcomings.<sup>7</sup> 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,<sup>8</sup> but these are limited in certain ways.

No standard deviations or ranges are reported and because of these and other limitations to available data, the current study has been undertaken to define certain important morphometric details relative to the human vertebral pedicle.<sup>4</sup>

One of the most important and pertinent cause of chronic low backache especially in elder age group could be lumbar canal stenosis.<sup>9</sup> 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.<sup>10,11</sup>

Due to common occurrence of low backache and 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 in the back and sciatic pain is well established.

Keeping these objectives in mind, the present study has been done.

## **OBJECTIVES**

1. To develop a lumbar spinal morphometrical data directly relevant to Belgaum region, specifically the dimension of pedicle and spinal canal.
2. To analyse the quantification of spinal stenosis.
3. To provide morphometrical data support for successful pedicle screw fixation.

## **REVIEW OF LITERATURE**

### **ANATOMY OF LUMBAR VERTEBRAE**

#### **Lumbar vertebrae**

These are five in number and are distinguished by their large size and absence of costal facets and transverse foramina.

#### **Features of lumbar vertebrae<sup>12</sup>**

- Vertebral body is large and wider transversely and deeper in front. On the anterior aspect its vertical extent is more than on the posterior aspect. This accounts for the ventral convexity of the lumbar part of vertebral column.
- Vertebral foramen is triangular, larger than that of thoracic vertebra but smaller than that of cervical vertebra.
- Laminae are broad and short but do not overlap as much as they do in the thoracic region.
- Spinous process is almost horizontal, quadrangular in shape and thickened along its posterior and inferior borders.
- The superior articular processes bear vertical concave articular facets facing posteromedially, with a rough mamillary process on their posterior borders.
- Inferior articular processes have vertical convex articular facets facing anterolaterally.

- Transverse processes are thin and long except in the more substantial fifth pair.
- A small accessory process marks the postero-inferior aspect of the root of each transverse process.

### **Anatomy of pedicle<sup>5</sup>**

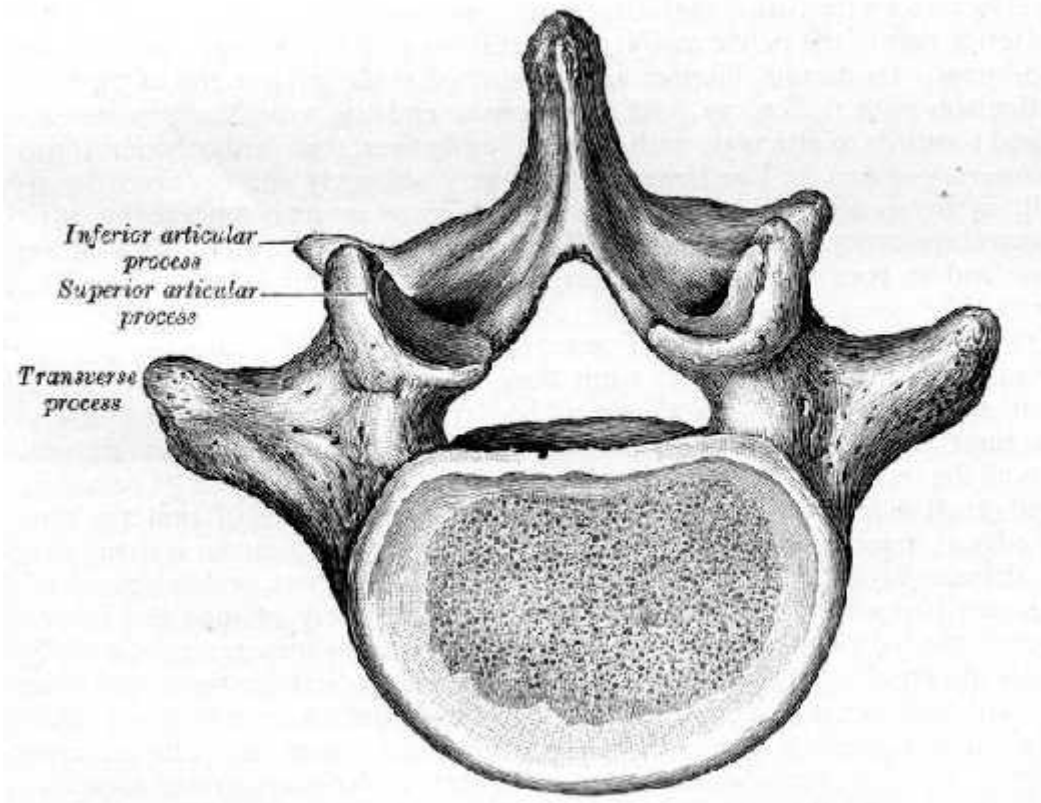
The pedicle is a very strong, cylindrical, anatomic bridge between the dorsal spinal elements and the vertebral body. It is composed of a strong shell of cortical bone and a core of cancellous bone and presents superior and inferior vertebral notches which form the intervertebral foramina. Pedicles serve as the load transmitting struts between the neural arch and the vertebral body.

### **Relations of pedicle**

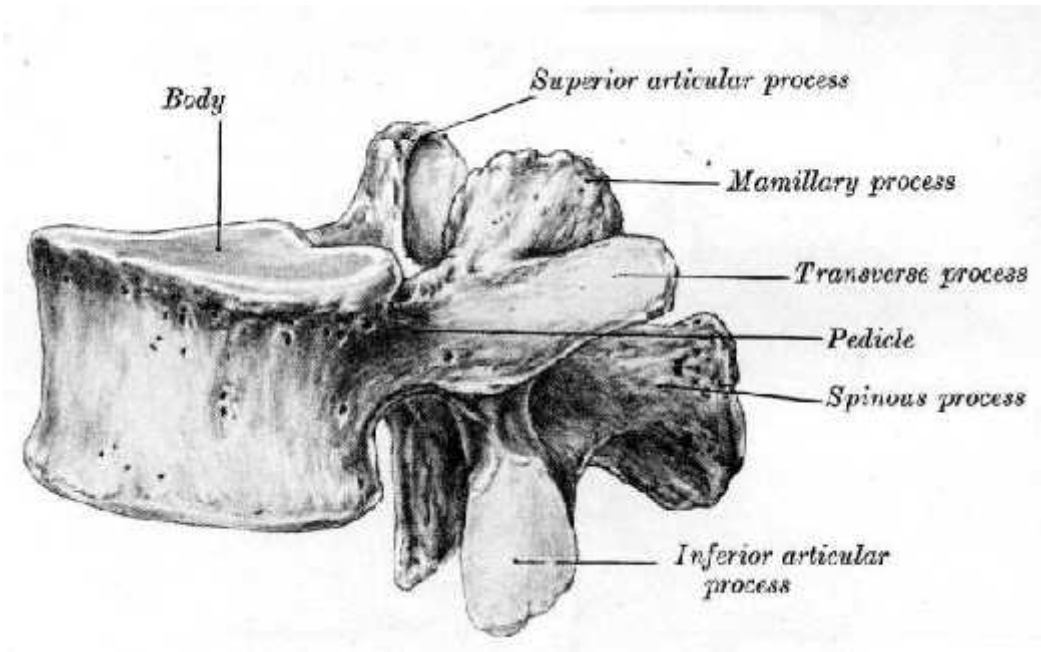
Pedicles are closely related to important structures on all sides. Knowing these structures helps the surgeon to avoid penetrating pedicle during surgery.

They are:

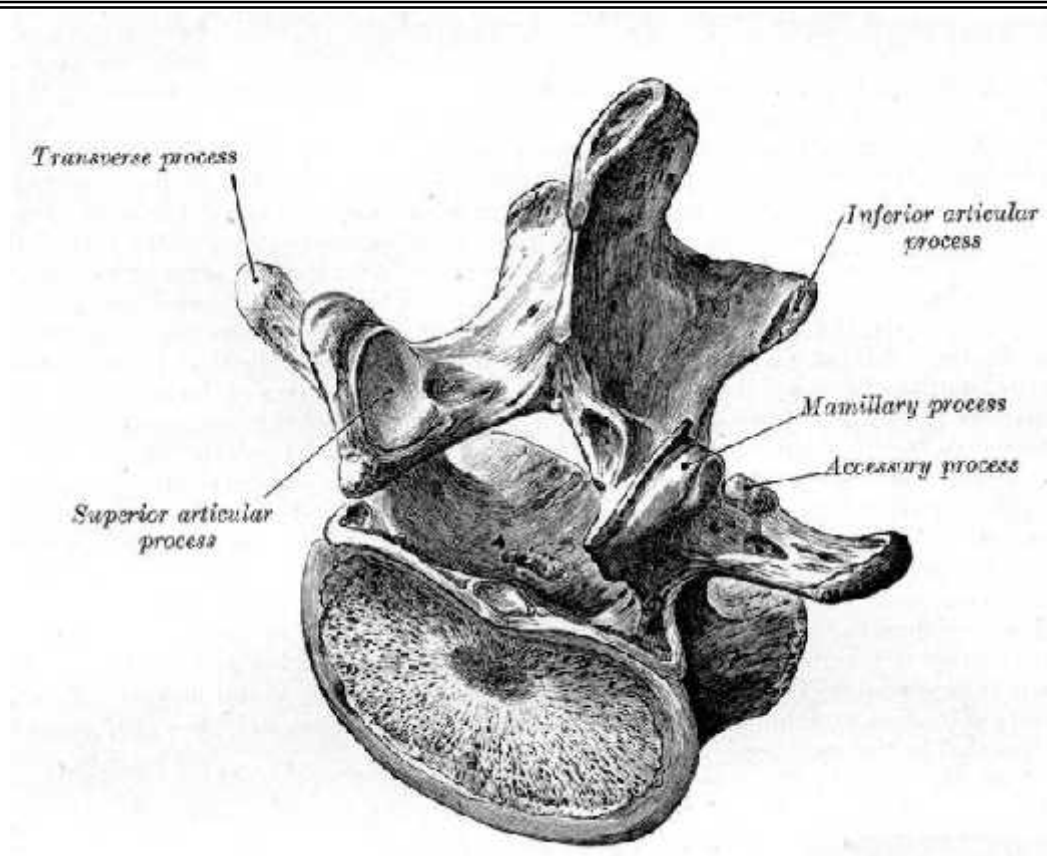
1. Medial to pedicles lie the epidural space, nerve root and dural sac.
2. Caudally lies the exiting nerve root from the same level.
3. Laterally and cranially, nerve root from the level above lies closely.



**Figure No 1: Superior aspect of lumbar vertebra**



**Figure No 2: Lateral aspect of lumbar vertebra**



**Figure No 3: Posterior aspect of lumbar vertebra**

### **Ossification<sup>12</sup>**

All lumbar vertebrae ossify from three primary centres – one for body or centrum and one for each half of the neural arch. These appear in the third month of intra-uterine life. The two halves of the neural arch fuse with each other, posteriorly during the first year. Fusion of the neural arch with the centrum occurs during the sixth year. The posterolateral parts of the body develop from the primary centre of the neural arch.

There are seven secondary centres as follows:

- (1) An upper annular epiphysis for the upper surface of the body.
- (2) A similar epiphysis for the lower surface of the body.

(3) and (4) one centre for the tip of each transverse process.

(5) and (6) one centre for each mamillary process.

(7) One centre for the tip of the spine.

### **Development**<sup>13</sup>

Vertebrae develop from the sclerotome portions of the somites, which are derived from paraxial mesoderm. During fourth week, sclerotome cells migrate around the spinal cord and notochord to merge with the cells from the opposite somite on either side of the neural tube.

Around the notochord each sclerotomic segment is divided into equal cranial and caudal parts by a transitory split or loosening between the two groups of cells known as the sclerotomic fissure. The parafissural mesoderm condenses to form a dense transverse plate which is called the perichondral disc, whilst the less dense, caudal part of one segment fuses with the slightly smaller and more dense cranial part of the adjoining segment. This fusion defines the blastemal centrum of a vertebra.

The vertebral components become more clearly defined and chondrification of these mesenchymatous models produces a cartilaginous vertebral column. Each centrum is chondrified from a pair of centres which appear during the sixth week and quickly coalesce. Each half of neural arch is chondrified from a centre starting at its base and extending ventrally into the pedicles, to meet, expand and blend with the centrum, and dorsally into the laminae. But the latter do not meet in the midline until the fourth month. Thus the presumptive vertebral body is compound a centrum with dorsolateral accessions,

expansions from the pedicles of the neural arch. The transverse and articular processes are chondrified in continuity with the neural arches. The patterning of shapes of the different vertebrae is regulated by Hox genes.

### **Spinal stenosis syndrome**

It consists of low back pain, usually in an adult approaching middle age, accompanied by claudication in the lower limbs. Classically, the patient complains of pain, weakness and numbness in the lower limbs on walking and relief cannot be achieved merely by standing and resting; the patient finds it necessary to undo his lumbar lordosis by bending or crouching. There may be objective neurological signs such as loss of tendon jerk or changes in sensibility. These features are even more suggestive if the peripheral circulation is normal.

Narrowing of the spinal canal may be developmental, or it may be the consequence of degenerative changes from ageing, injury or disease or after spinal operations. Lumbar canal stenosis can be present at birth as a congenital malformation in disorders like achondroplasia.<sup>14</sup>

### **Osteomyelitis**

It is still uncommon in India and it is a disease of childhood and adolescence occurring in the undernourished. Lumbar and lower thoracic vertebrae are known to be affected more frequently by osteomyelitis. In the year 1979, Goldmann AB et al noted that the incidence of osteomyelitis of spine is around two to four percent<sup>15</sup> and this type of vertebral osteomyelitis is more commonly seen in adults between the age group of 20 to 60 years.<sup>16</sup>

The infection of spine is typified by pyogenic and tuberculous osteomyelitis of the spine and the deformity may be either scoliosis or kyphosis both giving rise to pain.<sup>17</sup>

### **Spondylosis**

It refers to defect in the pars interarticularis and is more commonly seen in the fifth lumbar vertebra, but may occur at other lumbar levels.<sup>18</sup> It is more commonly observed in Whites.<sup>19</sup> The most frequent occurrence is reported in the Eskimo Skeletons.

### **Tuberculosis**

Tuberculosis of the spine that is Pott's disease forms 50 to 60% of total incidence of skeletal tuberculosis and is most commonly seen in thoracic spine of children and thoracolumbar spine of adults.<sup>15</sup> About two percent of patients with spinal tuberculosis have an absence of pedicle.<sup>20</sup>

### **Osteoporosis**

It is a most common degenerative condition affecting the ageing lumbar spine.<sup>21</sup> It involves a loss of bone substance and may occur as a consequence of disease.<sup>22</sup>

In the year 1947, Sarpyener described congenital stenosis of vertebral canal associated with spina bifida as well as congenital stenosis without any other developmental anomalies.<sup>23</sup>

Vogi and Osborne in 1949<sup>24</sup> and Spillane in 1952<sup>25</sup> stated that the narrowing of bony vertebral canal as a cause of compression of spinal cord or of cauda equina may be the result of bone disease, such as chondrodystrophia foetalis or any developmental anomaly.

In the year 1954, Verbiest reported some patients who developed signs of compression of caudal nerve roots due to abnormal developmental narrowness of bony vertebral canal.<sup>26</sup>

In the year 1955, Simril N. A. et al felt that abnormal widening of one or more interpedicular spaces is strongly suggestive of an intraspinal mass even though the absolute measurements were within the normal limits.<sup>27</sup>

In the year 1962, Epstein described based on plain radiographic study, that anteroposterior diameter less than 18 mm is suggestive of stenosis of the canal.<sup>28</sup>

In the year 1966, Hinek et al did the morphometrical study of interpedicular distances in children and adult, based on roentgenograms of lumbar region of white American subjects and reported a steady increase in interpedicular distances from L<sub>1</sub> to L<sub>5</sub>.<sup>29</sup>

According to Taveras and Wood (1976) “a change in the normal oval contour of the pedicles or in the interpedicular distances, as shown in the frontal film may indicate the presence of an expanding lesion within the vertebral canal”.<sup>30</sup>

In the year 1977, Eisenstein measured the anteroposterior and transverse diameters of the canal and body with Vernier calipers on adult skeletons belonging to South African Sotho Nigroids and White Caucasoids.<sup>1</sup>

In the year 1982, Amonoo Koufi H .S. et al had compared the Nigerian and South African vertebral canals on the basis of radiographic observations. They reported that there is a steady increase of interpedicular distance from first to fifth lumbar vertebrae. The interpedicular distance may narrow progressively from first to fifth lumbar vertebrae in achondroplasia.<sup>31</sup>

In the year 1988, Scoles P. V. et al with different morphometric studies on adult lumbar vertebral column suggested that the best method for determining actual pedicle dimensions is by direct careful measurements of cadaver specimens.<sup>32</sup>

In the year 1989, Janjua and Mohammed have done the measurements of normal adult lumbar spinal canal and suggested that the canal to vertebral body ratio value beyond 1:5 is conclusive of stenosis of lumbar vertebral canal.<sup>33</sup>

### **Transpedicular screw fixation**

The major advancement in lumbar spine care in the recent past has been the development of pedicle screw internal fixation systems.<sup>2</sup>

The oval shaped pedicle is narrowest in the transverse plane. It is in this plane that the maximum allowable pedicle screw diameter is determined. Screws larger than the pedicle can cause pedicle breakage or thread cutout.<sup>34</sup> The pedicle

is much wider in the sagittal plane and does not limit the maximum diameter of a pedicle screw.

Performing pedicular screw fixation is technically challenging and time consuming especially during the earlier part of the practice.

Cadaver dissection studies and observing an experienced surgeon performing the procedure, make things easier. However, an intimate knowledge of pedicular anatomy in general, especially entry point and the direction in particular at various levels is mandatory before embarking on pedicular screw fixation.<sup>2</sup>

Optimal placement of pedicular screws is the primary aim in this procedure.

All the forces exerted over the posterior elements of spine are channeled through the pedicles and transmitted to the body. A screw placed from the posterior aspect through the pedicle into the vertebral body involves all the three columns described by Denis in spinal instability.<sup>2</sup>

In 1944, King<sup>35</sup> first developed the concept of using pedicles as the means of spinal fixation and it wasn't until 1959 that Boucher reported on the actual success of obtaining a posterior flexion by passing screws through the lamina and pedicle into the vertebral body.<sup>36</sup>

Since the 1970's, Roy Camille and colleagues<sup>37</sup> and Louis<sup>38</sup> have used transpedicular screws to fix plates to the spine.

In 1976, Saillant measured the thoracic and lumbar pedicles, but only included mean values.<sup>8</sup>

In the same year, Baddely reported that outlines of the pedicles are well demarcated on plain antero-posterior radiographs and accurate measurements may be made directly from the films.<sup>39</sup>

In 1980's, Steffee et al<sup>40,41</sup> and associates and Luque<sup>42</sup> used slotted plates in an attempt to alleviate the problem of screw breakage in screw and plate systems. Arthur D. Steffee in 1982 found that, the pedicles are the strongest part of the spine to fix from posterior to anterior and developed the variable screw. Steffee's variable screw placement system provided rigid fixation and excellent fusion rates, but screw breakage continued to be a problem.<sup>6</sup>

In 1986 Krag et al, using CT scan data, measured the lower thoracic and lumbar spine.<sup>7</sup>

In 1987, Berry et al, using direct specimen measurement technique, looked at select pedicles in the spine.<sup>43</sup>

In 1988, Roy Camille et al, reported that 10% of pedicle screws were placed incorrectly.<sup>44,45,46</sup>

In the same year Weinstein et al reported an overall failure rate of 21% from cadaveric studies.<sup>47</sup>

In 1990 Olsewski J. M. et al studied the morphometry of lumbar spine and anatomical perspectives related to transpedicular fixation.<sup>48</sup>

In 1992, a detailed description of the lower thoracic and lumbar pedicle and relative landmarks on the posterior surface of the spine have been reported by Zindrick et al.<sup>4,49</sup>

In the same year (1992), Thomas N. Bernard and Charles E. Seibert MD studied the average pedicle diameter and reported that the pedicles of L<sub>4</sub>, L<sub>5</sub> and S<sub>1</sub> can safely accept pedicle screws with 7 mm outer diameter.<sup>50</sup>

In 1993, Scott W. Atlas described markedly thinned pedicles as a normal variant in the entire lumbar spine, as seen on routine films, as well as CT scan.<sup>51</sup>

In the same year, Errico and Palmer established that measurements obtained directly from plain films correlated well with values measured from computerized tomograms and from anatomical specimens.<sup>52</sup>

In 1994, Hou et al quantitatively evaluated pedicle dimensions in a Chinese population and proposed zone concepts to define the pedicle centre on the posterior surface of the lamina.<sup>53</sup>

In the same year, Amonoo Koufi studied the horizontal and vertical diameter of the pedicles of the lumbar vertebrae from plain antero-posterior radiographs of the lumbar spines of male and female subjects. He reported that the pattern of variation with age differed for horizontal and vertical diameters. After the 5<sup>th</sup> decade, female horizontal and vertical diameters showed a tendency to increase while male diameters decreased.<sup>54</sup>

In the year 1994, Kim N H et al had studied the different dimensions of the lumbar vertebral pedicle in Korean population and compared it with that of

Westerners and stressed its relevance in transpedicular screw fixation which is indicated in unstable spine compression like traumatic listhesis, wedge compression fracture, primary and secondary tumors, infections like brucellosis and tuberculosis.<sup>55</sup>

In 1995, Srdjan R. Mirkovic investigated intervertebral foraminal anatomy of L<sub>2</sub> – S<sub>1</sub> by the anatomic dissection of 96 foraminal levels in 12 human cadaveric spines and concluded that either a 7.5 mm cannula placed in line with the medial one third of the pedicle or a 6.3 mm cannula located in the midline of the pedicle appears safe.<sup>56</sup>

In 1996, Nabil A. Ebraheim studied 250 lumbar vertebrae and reported that the average distance from the projection point of the lumbar pedicle axis to the midline of the transverse process consistently varied at different levels.<sup>57</sup>

In 2002, James J. Y. et al, studied the treatment of upper, middle and lower thoracic and lumbar spine injuries with transpedicular instrumentation and concluded that pedicle screw fixation of thoracic and lumbar spinal injuries is a reliable and safe method of posterior spinal stabilization.<sup>58</sup>

In the year 2007, Yu Hailong et al studied the computer analysis of the safety of using three different pedicular screw insertion points in the lumbar spine in the Chinese population and reported that pedicle breakthrough occurs more easily in the medial and lateral walls if the entry point is far away from the axial line of the pedicle.<sup>59</sup>

In the year 2007, Shiu Bi Lien, Nien-Hsein Liu and Shing-Sheng Wu studied 15 sets of human vertebrae and reported that in the lower thoracic spine,

the nerve roots were nearly parallel to the rib direction, the superior and inferior distances were similar and lateral distances were greater. In the lumbar spine, the superior distances were greater than the inferior distances because of the caudal direction of the nerve roots. The lateral distance of lumbar pedicle to the nerve roots was 2.4 to 9.6 mm and was smaller in the lower lumbar spine.<sup>60</sup>

## **METHODOLOGY**

Twenty five sets of normal, adult, dry lumbar vertebrae were studied. The material for the study that is the total of 125 lumbar vertebrae were obtained from 25 cadavers from the Department of Anatomy, Jawaharlal Nehru Medical College, Belgaum.

The vertebrae were obtained from the dissection room cadavers by taking cross sections of the body at T<sub>12</sub> and S<sub>1</sub> levels and were buried in soil for 90 days for maceration. Then they were immersed in water for 15 days. After this the tissues which were still undissolved were removed. Care was taken not to damage the vertebrae.

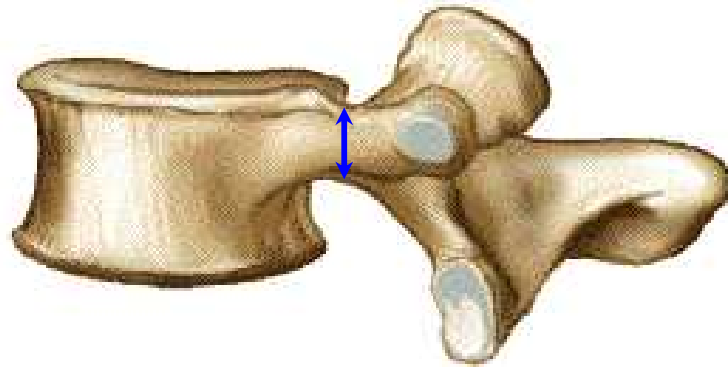
The following measurements were taken with the help of Vernier caliper (Photograph No. 1).

1. Superoinferior diameter (Height) of the pedicle was taken as the narrowest diameter between the superior and inferior surface of pedicle (Figure No. 4).
2. Transverse diameter (Width) of the pedicle was taken as the narrowest diameter between the medial and lateral surface of pedicle (Figure No. 5).
3. Length of a pedicle was taken from the body to the line joining superior articular facets, transverse process and the lamina (Figure No. 6).

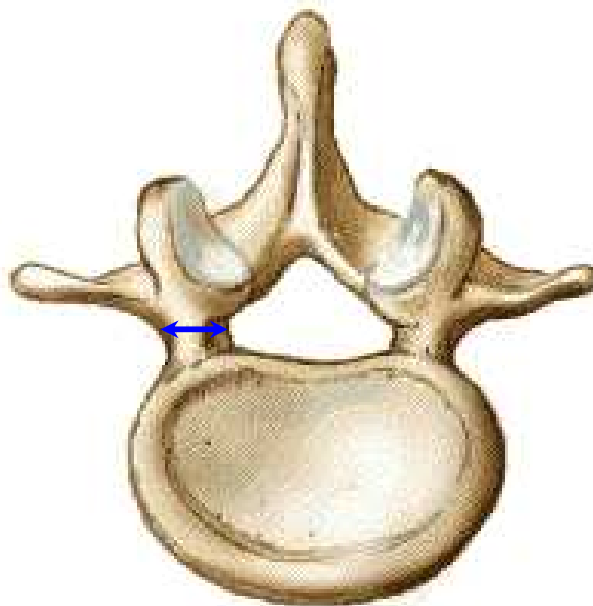
4. Mid-sagittal diameter of vertebral canal was measured in the midline sagittal plane between the wall of vertebral body and laminal arch (Figure No. 7).
  
5. Interpedicular distance that is transverse diameter of the canal was taken as the greatest distance between the pedicles of a vertebra (Figure No. 8).

### **Statistical analysis**

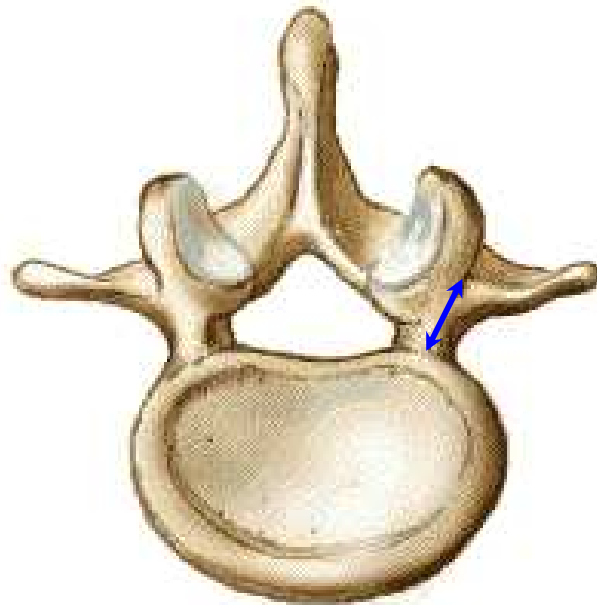
The mean and standard deviation were calculated from the readings obtained. The range of different dimensions was also noted.



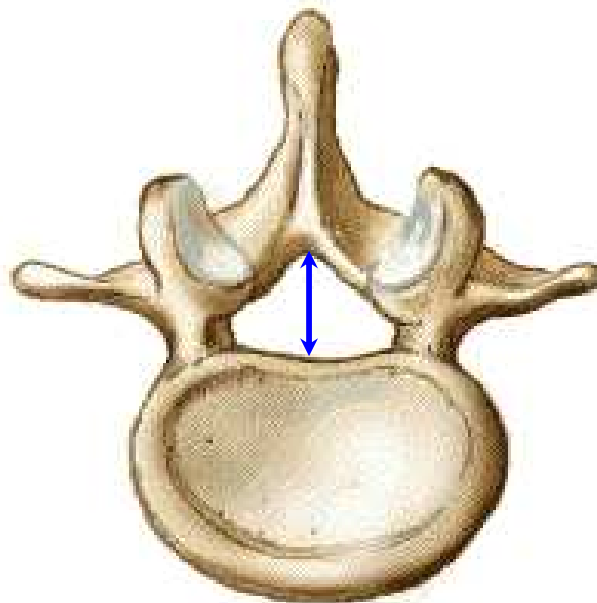
**Fig No. 4: Height of the Pedicle**



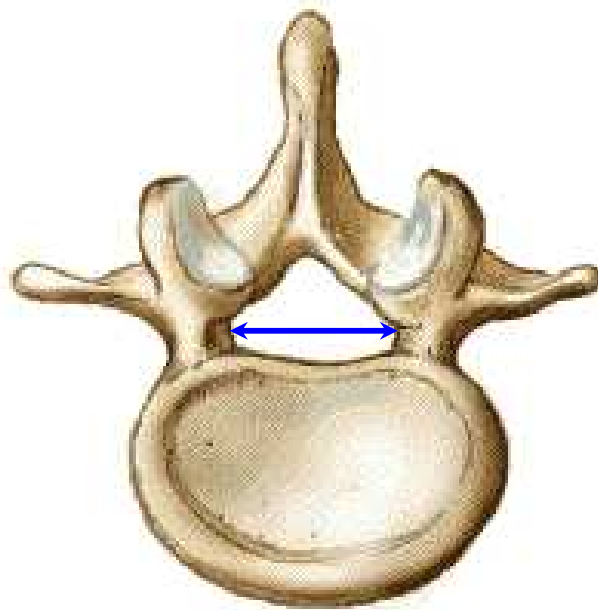
**Figure No 5: Width of the Pedicle**



**Figure No 6: Length of the Pedicle**



**Figure No 7: Mid-sagittal Diameter of the vertebral canal**



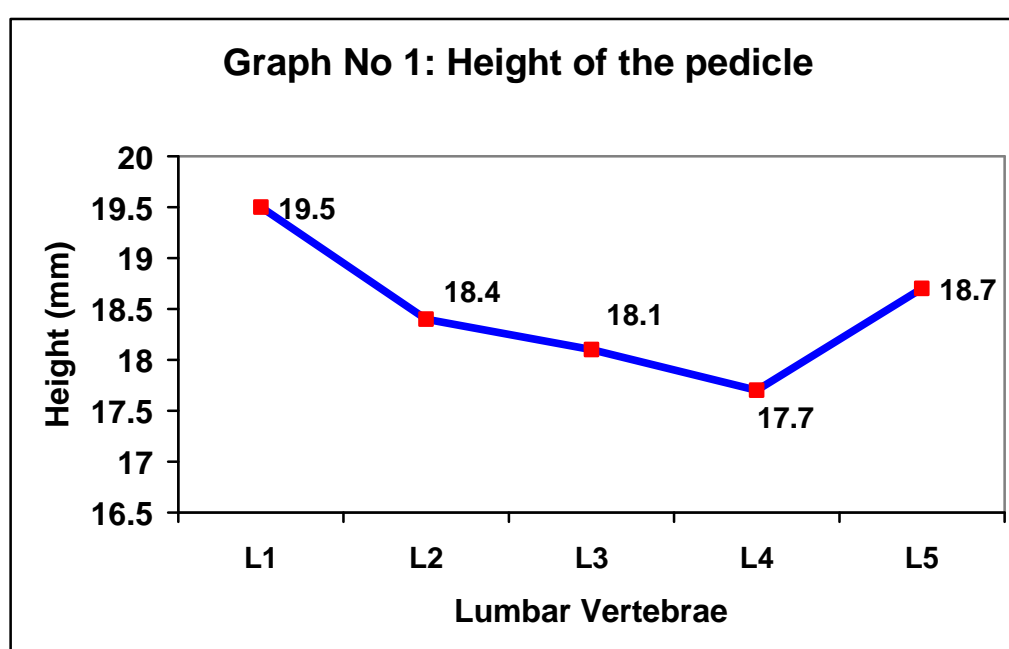
**Figure No 8: Interpedicular distance**

## RESULTS

The readings of different dimensions obtained in our study are shown in the Master Chart (Annexure II). The mean  $\pm$  SD and ranges of these readings were noted and tabulated for further observations.

**Table No. 1: Height of the pedicle**

Vertebral level	Height (in mm)		Range in mm
	Mean	SD	
L <sub>1</sub>	19.5	2.89	13.1 – 21.8
L <sub>2</sub>	18.4	3.74	13 – 24.9
L <sub>3</sub>	18.1	3.21	13 – 26.7
L <sub>4</sub>	17.7	2.51	14 – 23.9
L <sub>5</sub>	18.7	3.08	12 – 23.9



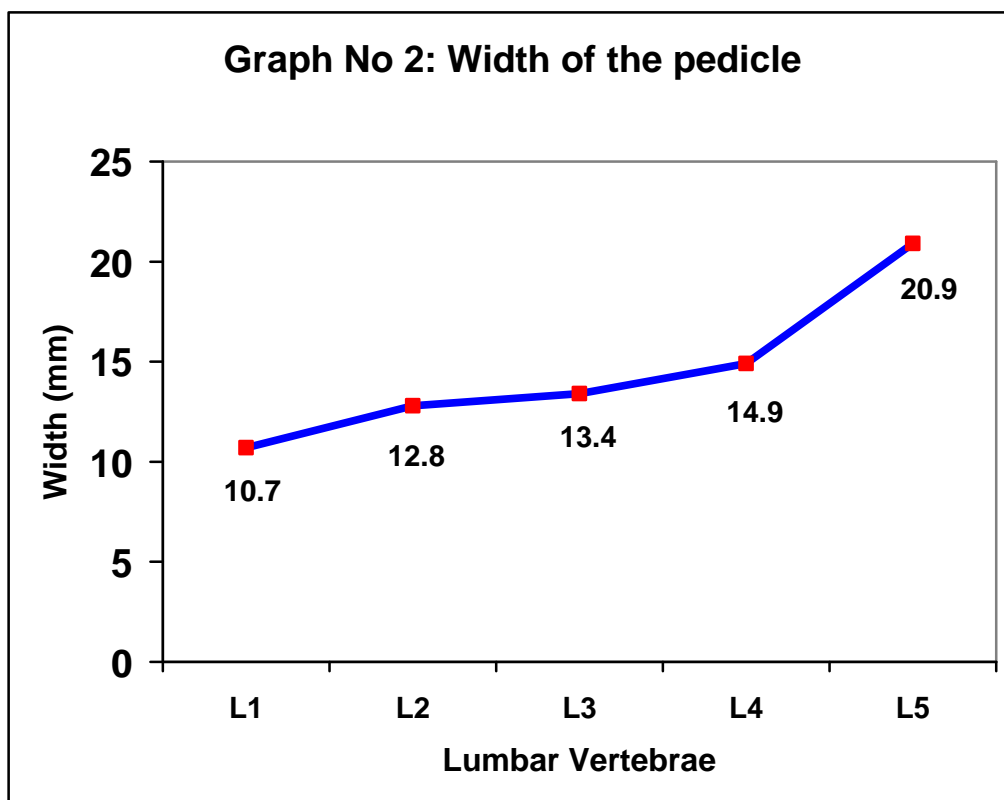
The mean  $\pm$  Standard Deviation (in mm) for the height of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were  $19.5 \pm 2.89$ ,  $18.4 \pm 3.74$ ,  $18.1 \pm 3.21$ ,  $17.7 \pm 2.51$  and  $18.7 \pm 3.08$  respectively.

The range (in mm) for the height of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 13.1 – 21.8, 13.0 – 24.9, 13.0 – 26.7, 14.0 – 23.9 and 12.0 – 23.9 respectively.

The minimum (12.0 mm) and maximum (26.7 mm) readings for height of the pedicles were noted at L<sub>5</sub> (Set No. 16) and L<sub>3</sub> (Set No. 13) respectively (Photograph No. 2).

Table No. 2: Width of the pedicle

Vertebral level	Width (in mm)		Range in mm
	Mean	SD	
L <sub>1</sub>	10.7	2.03	7 – 14.6
L <sub>2</sub>	12.8	2.73	8.2 – 19.9
L <sub>3</sub>	13.4	2.66	8 – 17.8
L <sub>4</sub>	14.9	2.51	10.3 – 22.6
L <sub>5</sub>	20.9	3.36	14.1 – 28.7



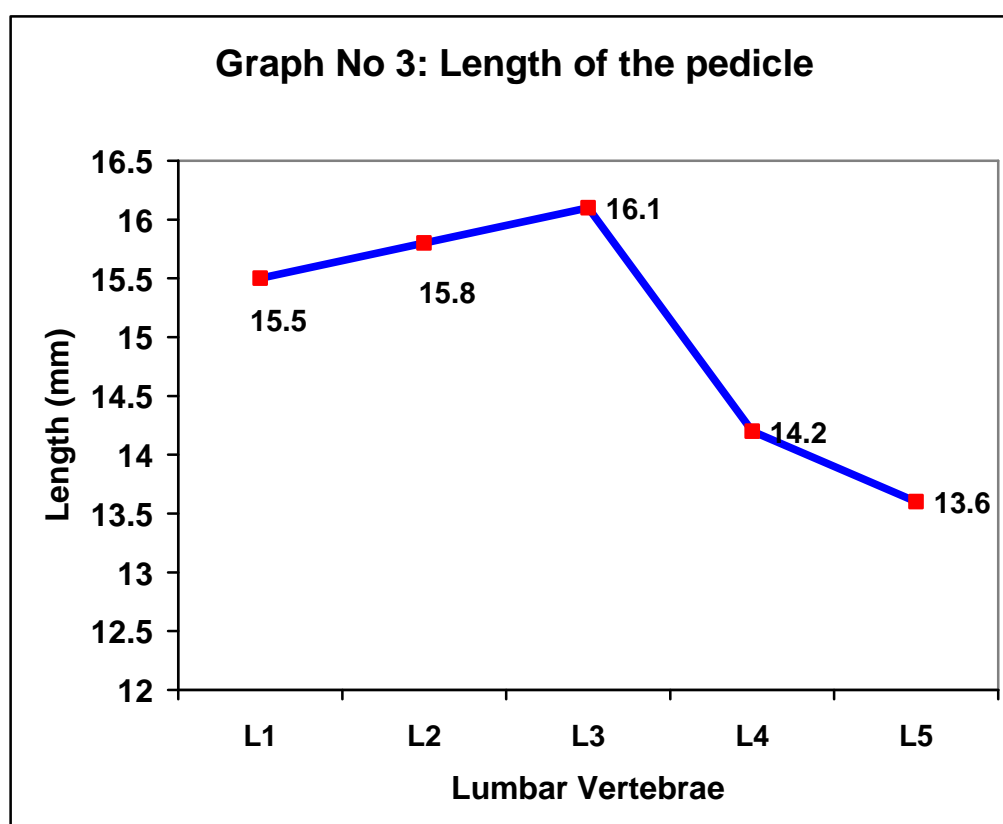
The mean  $\pm$  Standard Deviation (in mm) for the width of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were  $10.7 \pm 2.03$ ,  $12.8 \pm 2.73$ ,  $13.4 \pm 2.66$ ,  $14.9 \pm 2.51$  and  $20.9 \pm 3.36$  respectively.

The range (in mm) for the width of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 7.0 – 14.6, 8.2. – 19.9, 8.0 – 17.8, 10.3 – 22.6 and 14.1 – 28.7 respectively.

The minimum (7.0 mm) and maximum (28.7 mm) readings for width of the pedicles were noted at L<sub>1</sub> (Set No. 21) and L<sub>5</sub> (Set No. 3) respectively (Photograph No.3)

Table No. 3: Length of the pedicle

Vertebral level	Length (in mm)		Range in mm
	Mean	SD	
L <sub>1</sub>	15.5	2.69	10.1 – 21.9
L <sub>2</sub>	15.8	2.75	10.1 – 19.8
L <sub>3</sub>	16.1	2.91	11.2 – 20.8
L <sub>4</sub>	14.2	2.84	7.2 – 19.7
L <sub>5</sub>	13.6	2.05	8.4 – 17.8



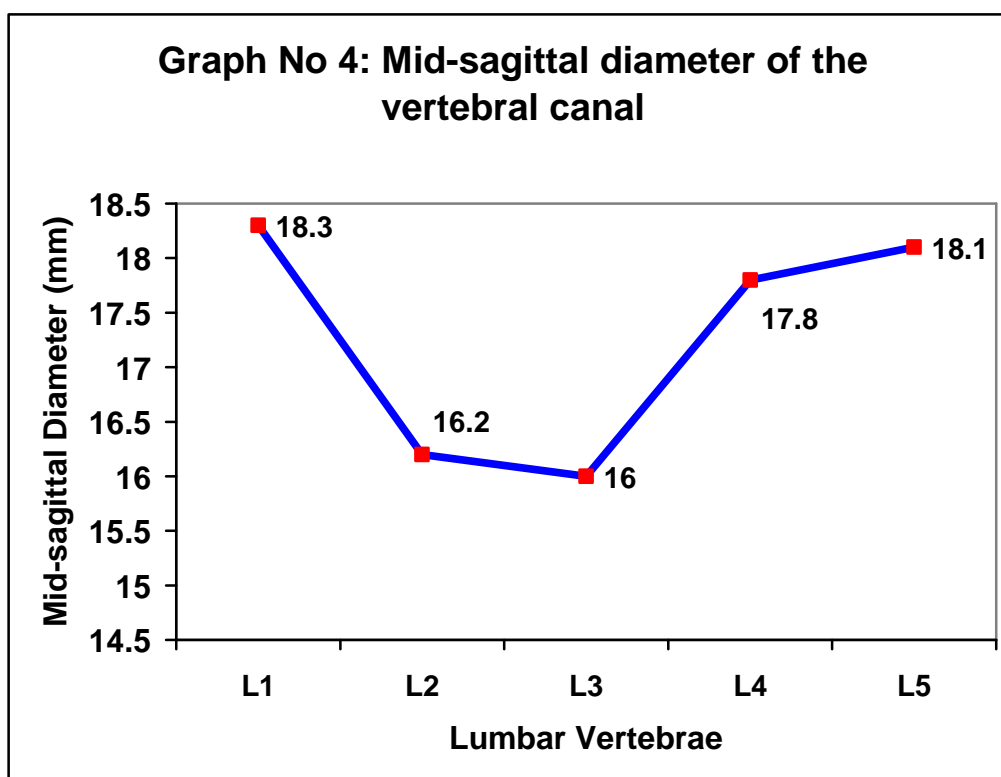
The mean  $\pm$  Standard Deviation (in mm) for the length of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were  $15.5 \pm 2.69$ ,  $15.8 \pm 2.75$ ,  $16.1 \pm 2.91$ ,  $14.2 \pm 2.84$  and  $13.6 \pm 2.05$  respectively.

The range (in mm) for the length of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 10.1 – 21.9, 10.1 – 19.8, 11.2 – 20.8, 7.2 – 19.7 and 8.4 – 17.8 respectively.

The minimum (7.2mm) and maximum (21.9mm) readings for length of the pedicles were noted at L<sub>4</sub> (Set No. 10) and L<sub>1</sub> (Set No. 17) respectively (Photograph No. 4).

Table No. 4: Mid-sagittal diameter of the vertebral canal

Vertebral level	Mid-sagittal diameter (in mm)		Range in mm
	Mean	SD	
L <sub>1</sub>	18.3	2.86	13.9 – 23.7
L <sub>2</sub>	16.2	3.26	10.3 – 23.7
L <sub>3</sub>	16.0	3.32	11.1 – 23
L <sub>4</sub>	17.8	3.12	12 – 23.9
L <sub>5</sub>	18.1	2.99	14.1 – 24.9



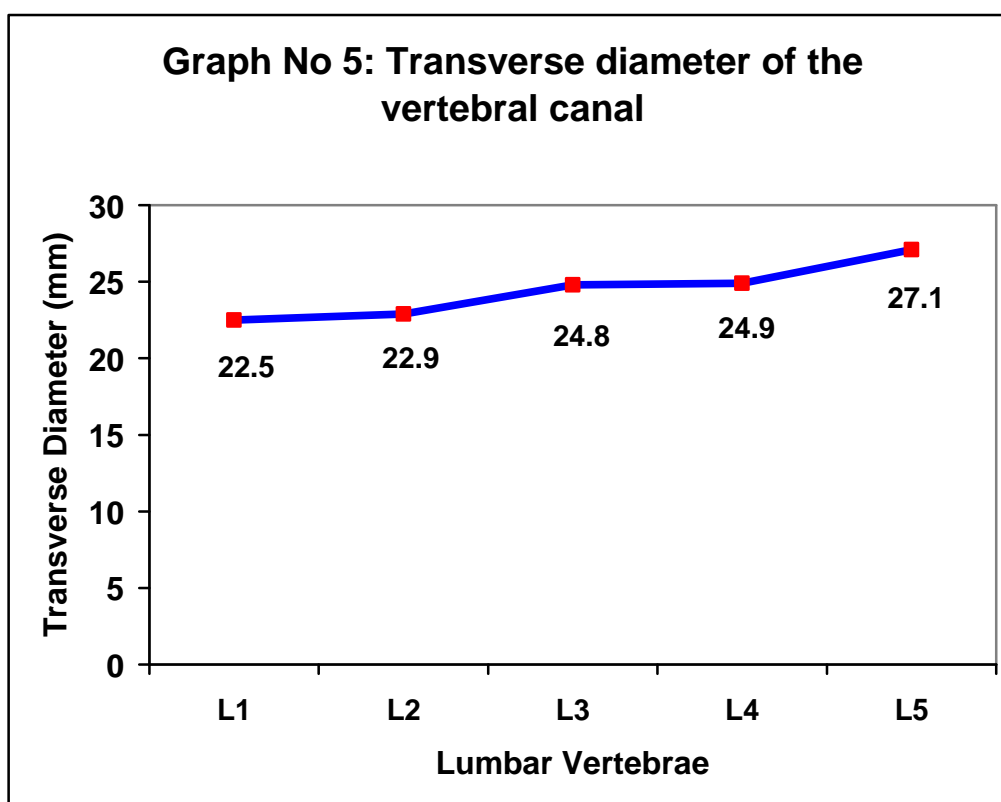
The mean  $\pm$  Standard Deviation (in mm) for the mid-sagittal diameter of the vertebral canal of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were  $18.3 \pm 2.86$ ,  $16.2 \pm 3.26$ ,  $16.0 \pm 3.32$ ,  $17.8 \pm 3.12$  and  $18.1 \pm 2.99$  respectively.

The range (in mm) for the mid-sagittal diameter of the vertebral canal of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 13.9 – 23.8, 10.3 – 23.7, 11.1 – 23.0, 12.0 – 23.9 and 14.1 – 24.9 respectively.

The minimum (10.3mm) and maximum (24.9mm) readings for the mid-sagittal diameter were noted at L<sub>2</sub> (set No. 4) and L<sub>5</sub> (Set No. 14), respectively (Photograph No. 5).

**Table No. 5: Interpedicular distance (Transverse diameter of the vertebral canal)**

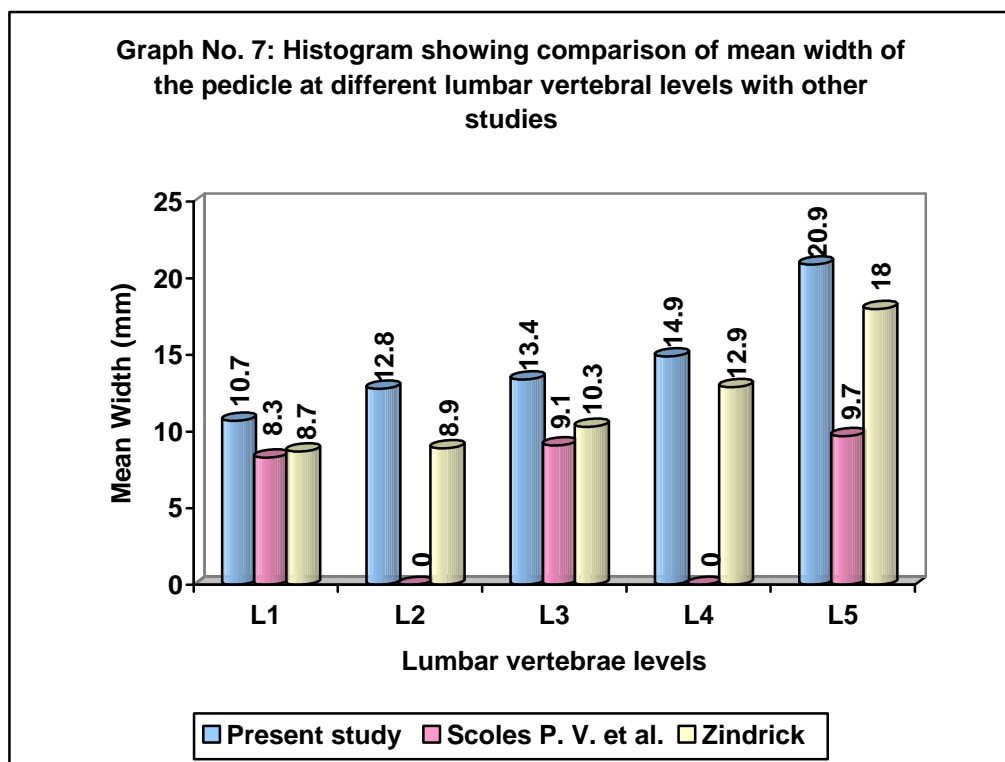
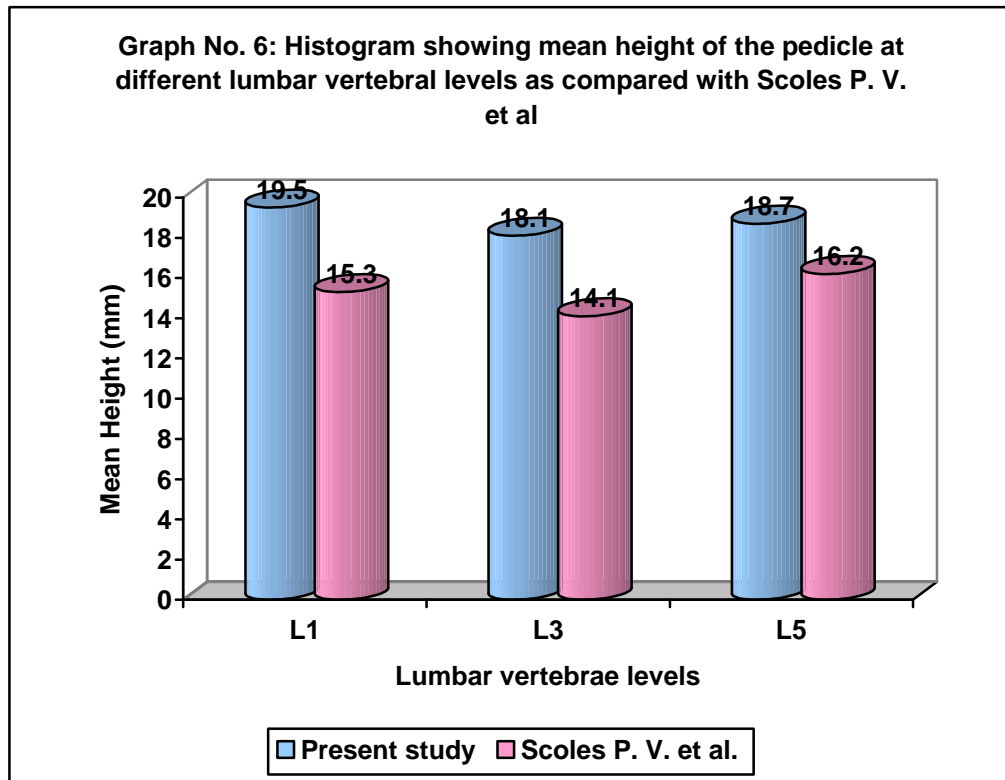
Vertebral level	Interpedicular distance (in mm)		Range in mm
	Mean	SD	
L <sub>1</sub>	22.5	3.46	15.1 – 29.7
L <sub>2</sub>	22.9	3.14	14.2 – 30.7
L <sub>3</sub>	24.8	3.22	16.6 – 30.8
L <sub>4</sub>	24.9	3.47	14.3 – 30.8
L <sub>5</sub>	27.1	4.01	17.3 – 34.8



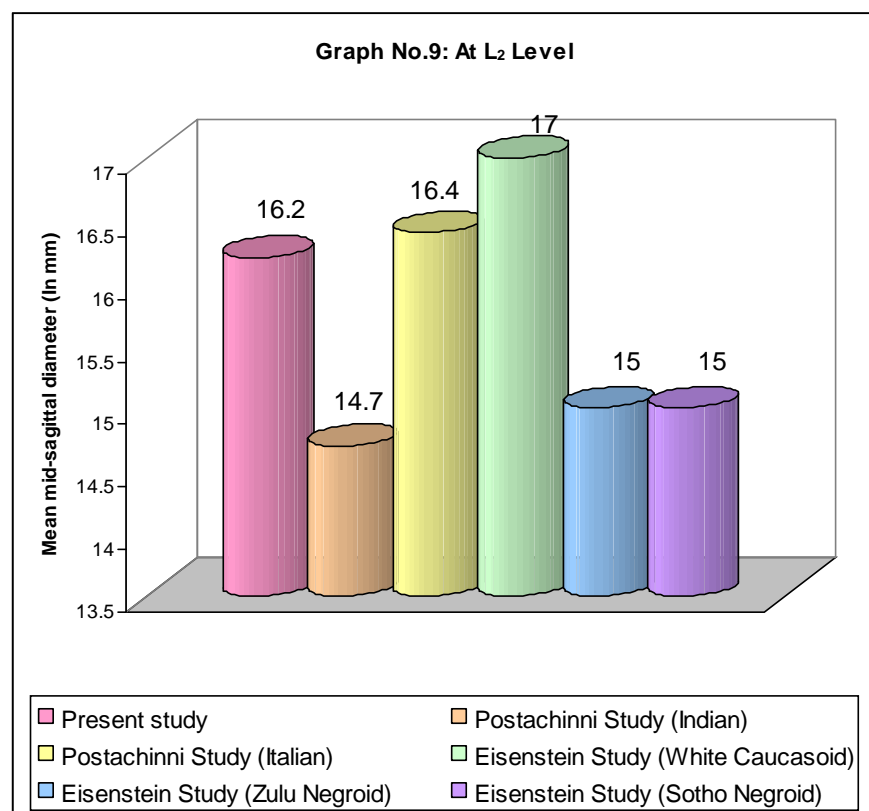
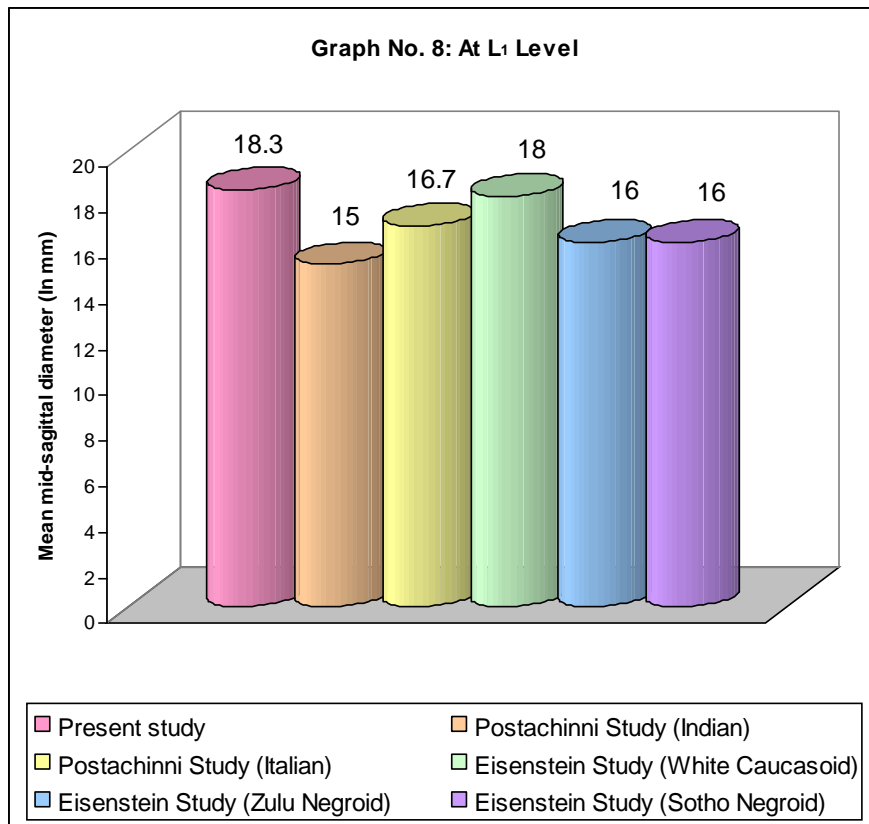
The mean  $\pm$  Standard Deviation (in mm) for the IPD of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were  $22.5 \pm 3.46$ ,  $22.9 \pm 3.14$ ,  $24.8 \pm 3.22$ ,  $24.9 \pm 3.47$  and  $27.1 \pm 4.01$  respectively.

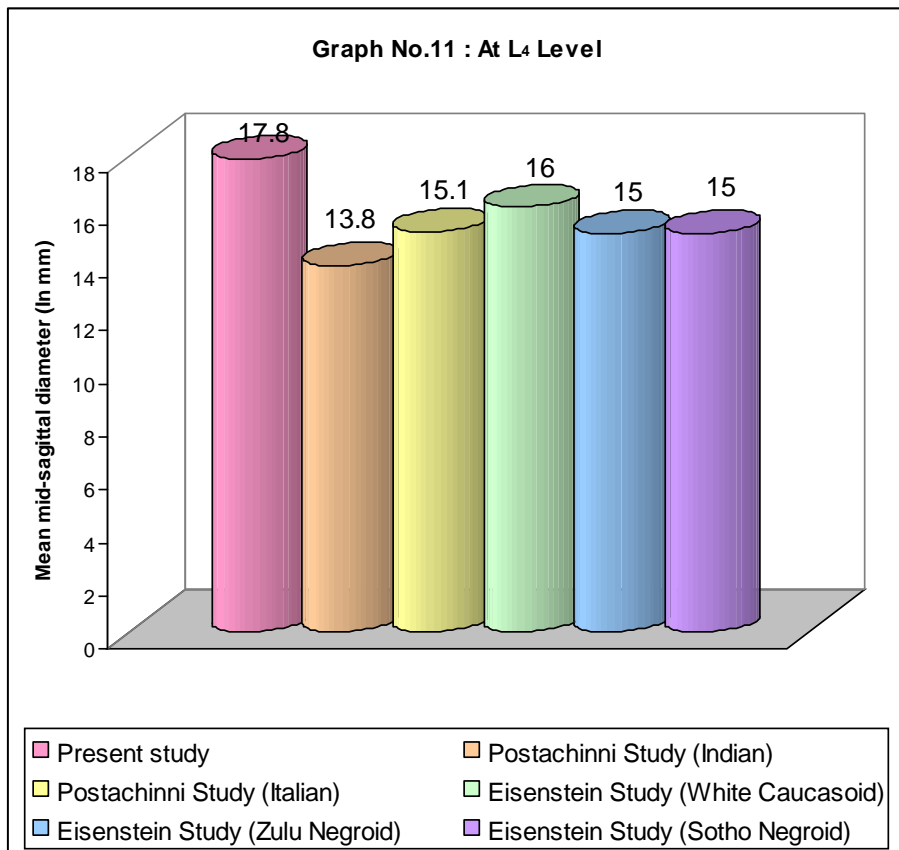
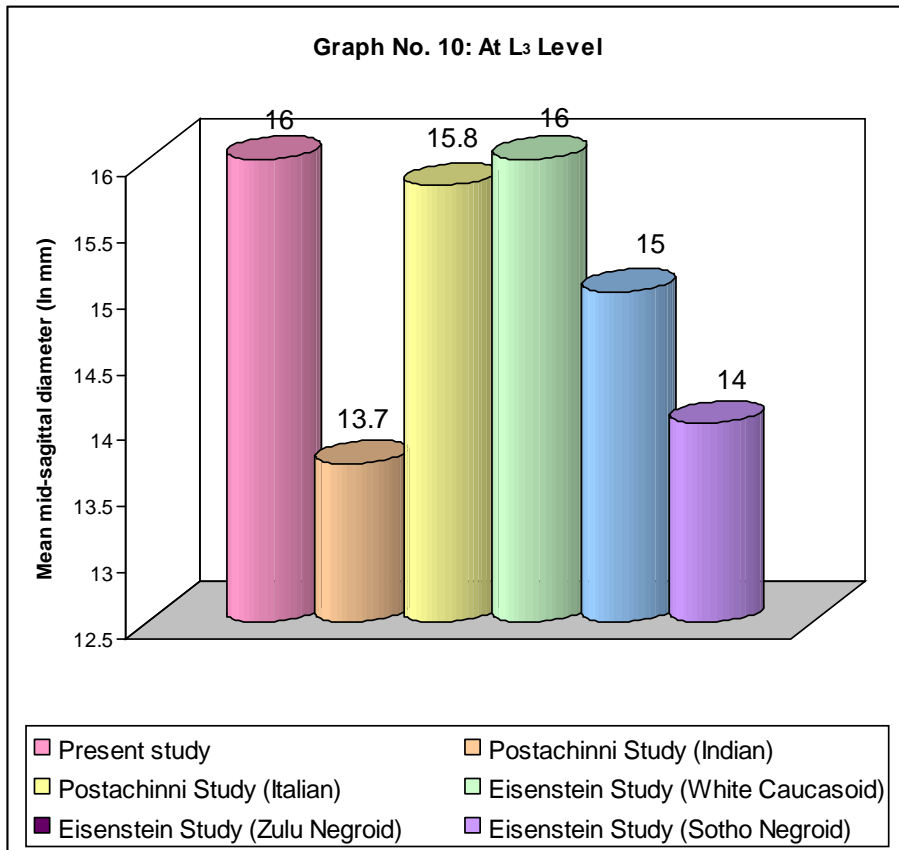
The range (in mm) for the IPD of the lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 15.1 – 29.7, 14.2 – 30.7, 16.6 – 30.8, 14.3 – 30.8 and 17.3 – 34.8 respectively.

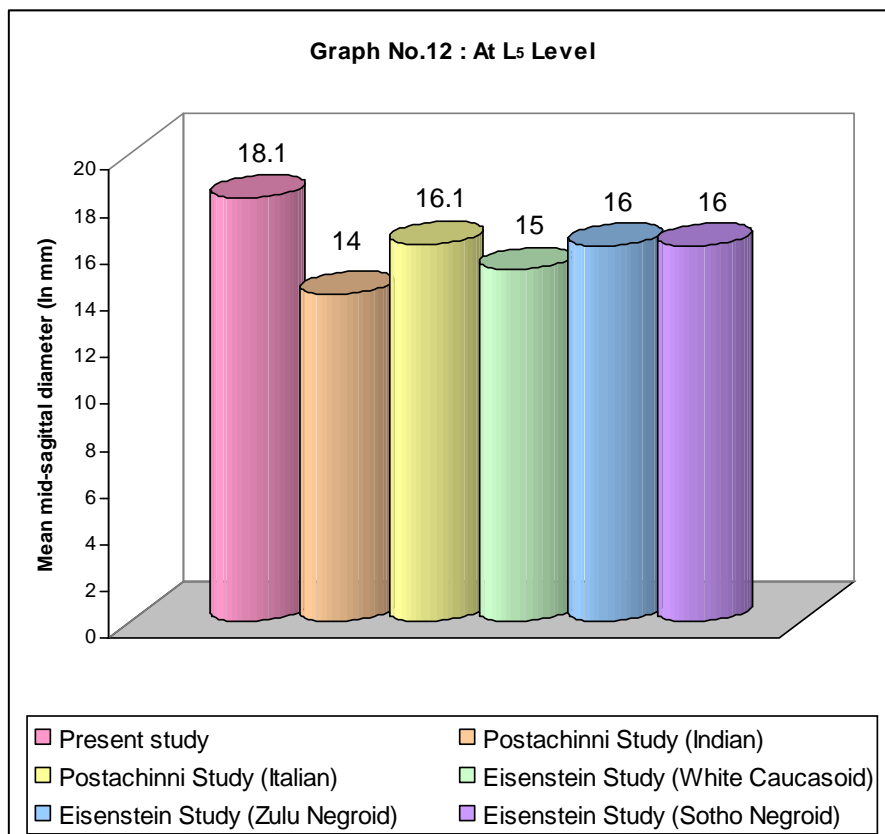
The minimum (14.2mm) and maximum (34.8 mm) readings for IPD were noted at L<sub>2</sub> (Set No. 5) and L<sub>5</sub> (Set No. 19) respectively (Photograph No. 6).



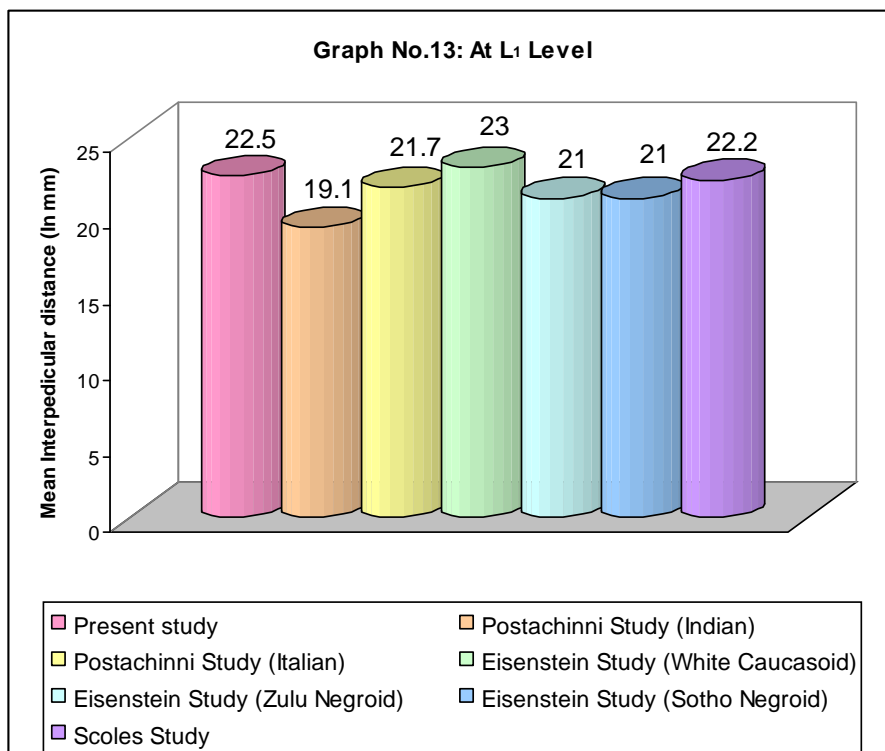
**Histograms showing mean mid-sagittal diameter in our study as compared with other studies**

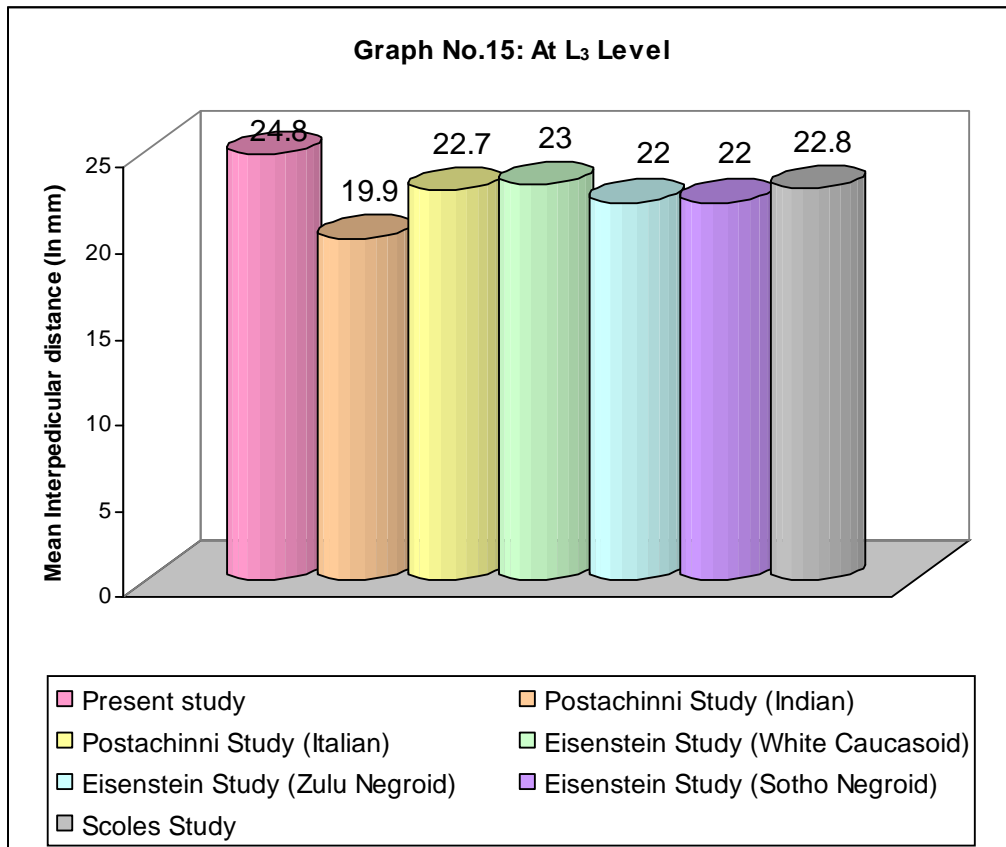
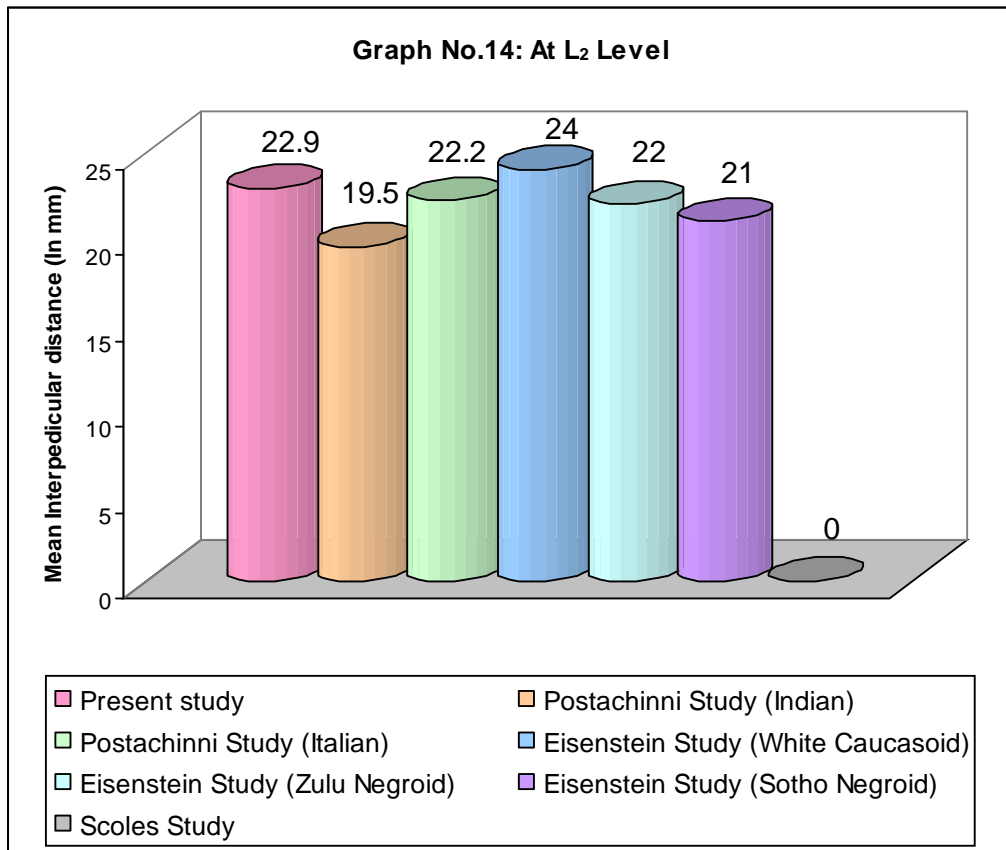


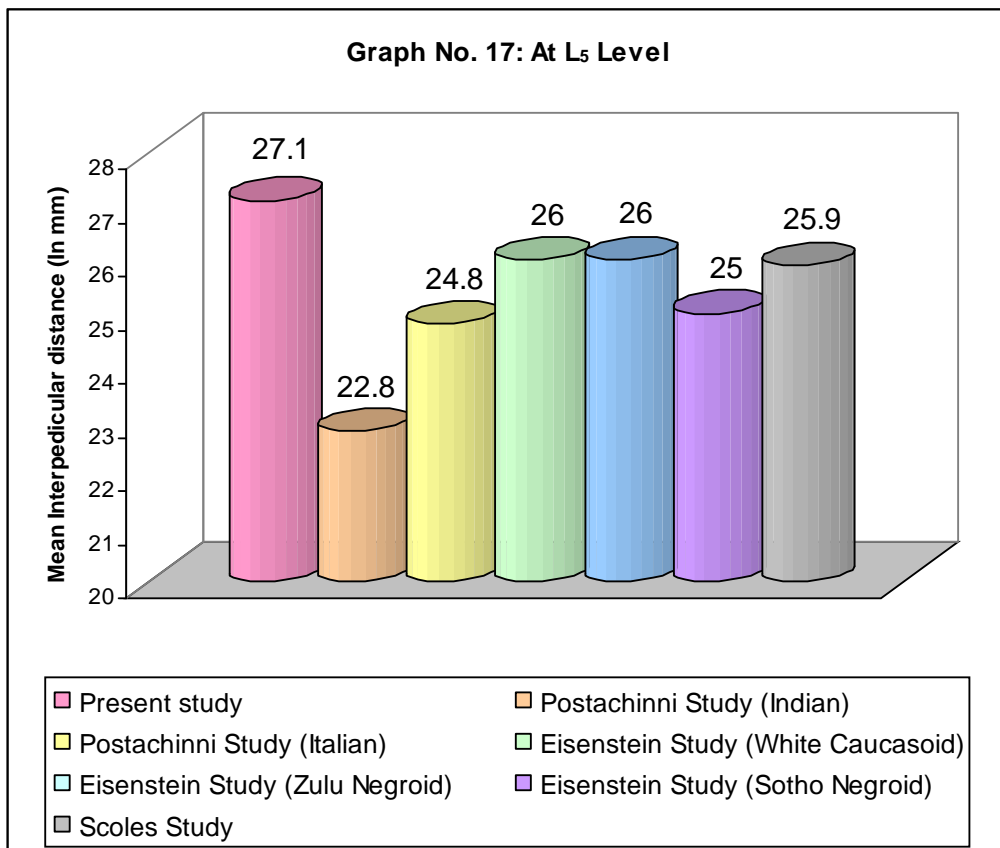
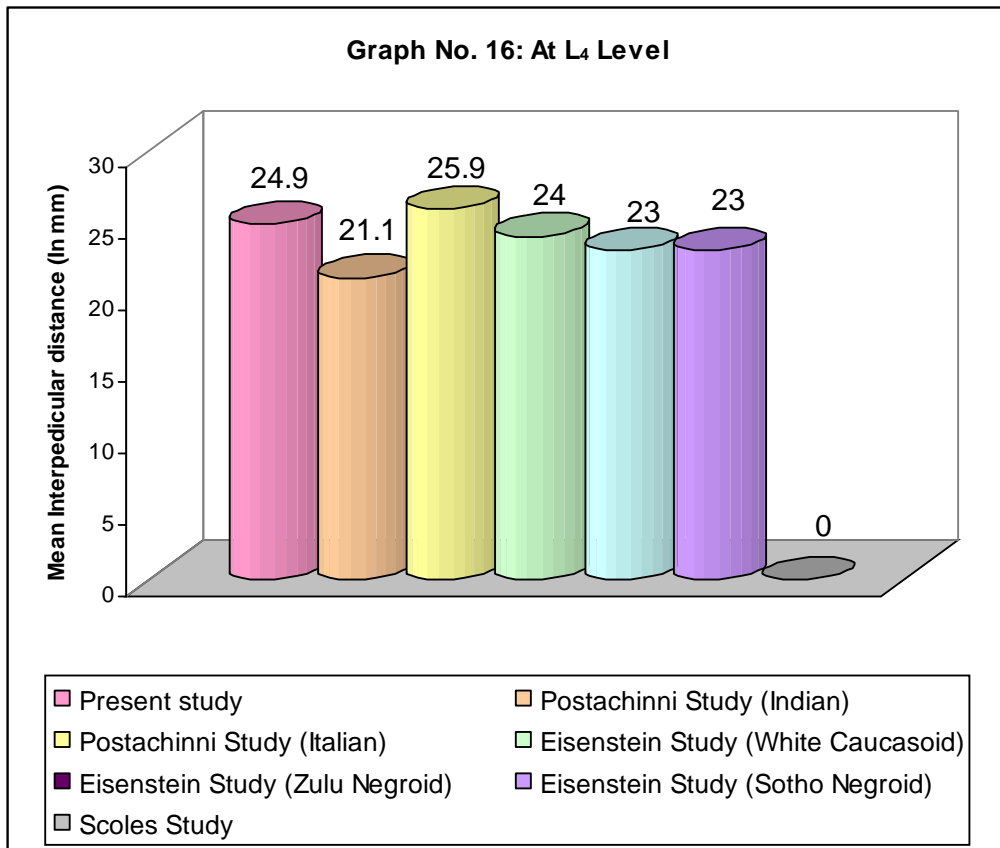




**Histograms showing mean IPD in our study as compared with other studies**







## **DISCUSSION**

A variety of conditions resulting from degenerative, traumatic and other abnormalities of the lumbar spine are best managed by achieving spinal stability and attaining a solid fusion. To decrease failures in arthrodesis a number of different devices have been developed to provide internal stability while the fusion is exhaling. Because the pedicle offers the strongest point of attachment to the spine, most spinal instrumentation systems use screws for fixation placed in to the pedicle and then the vertebral body.

However, a number of complications associated with pedicle screw fixation have been reported.<sup>61,62</sup> One of the most serious complications related to pedicle screw usage is neurological injury, secondary to misplaced pedicle screws injuring a nerve root or the cauda equina.

To minimize the complications a number of techniques have been employed. These include varying points of insertion, pre-measuring and assessing the pedicle size on the preoperative CT and / or MRI scan, use of intra operative fluoroscopy or image guidance, use of electrophysiologic monitoring while entering and tapping the pedicle, probing the pedicle with small metal tools after entering the pedicle, etc.

In developing countries, many of the above listed techniques are not routinely available in the operating room. Hence in this part of the world, screw design, details, biomechanics and implantation safety depend upon the anatomic constraints, especially the morphometry of pedicles.

Moreover, one of the most important and pertinent cause of chronic low backache is the lumbar canal stenosis. Even though the problems of low backache are equally prevalent all over the Universe, we see little studies being done in Indian context, especially in this region of Belgaum city.

In view of this, the present study has been undertaken to study the morphometry of lumbar pedicles with regards to, height of the pedicle, width of pedicle, length of the pedicle, mid-sagittal diameter of the vertebral canal and interpedicular distance.

### **Height of the pedicle**

The narrowest diameter between the superior and inferior surface of the pedicle was measured using Vernier calipers on 25 sets of adult lumbar vertebrae. The mean readings (in mm) observed for the height of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 19.5, 18.4, 18.1, 17.7 and 18.7 respectively.

The maximum mean value was noticed at L<sub>1</sub> level and minimum at L<sub>4</sub> level. There was a decreasing pattern observed in the mean from L<sub>1</sub> to L<sub>4</sub> and then an increase at L<sub>5</sub> level.

In the study done by Scoles P. V. et al,<sup>32</sup> the mean readings (in mm) observed for the height of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>3</sub>, and L<sub>5</sub> were 15.3, 14.1 and 16.2 respectively. (Scoles studied only L<sub>1</sub>, L<sub>3</sub>, and L<sub>5</sub>).

The mean at L<sub>5</sub> was higher than that at L<sub>1</sub> level in their findings. The range of height of pedicle (in mm) at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in

our study were 13.1 to 21.8, 13.0 to 24.7, 13.0 to 26.7, 14 to 23.9 and 12.0 to 13.9 respectively.

The range of height of the pedicle (in mm) at L<sub>1</sub>, L<sub>3</sub>, and L<sub>5</sub> in the study done by Scoles P. V. et al<sup>32</sup> were 13.1 to 19.0, 12.4 to 17.2 and 9.0 to 25.2 respectively.

The minimum height of the pedicle was noted at L<sub>5</sub> (Set No. 16) and maximum height was noted at L<sub>3</sub> (Set No. 13) in our study. In the study done by Scoles P. V. et al both the minimum and maximum readings were noted at L<sub>5</sub>.

### **Width of the Pedicle**

The narrowest diameter between the medial and lateral surfaces of the pedicle was measured in 25 sets of lumbar vertebrae. The mean readings (in mm) observed for the width of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 10.7, 12.8, 13.4, 14.9 and 20.9 respectively.

There is an increase in the pattern observed from L<sub>1</sub> to L<sub>5</sub> level with the minimum and maximum mean at L<sub>1</sub> and L<sub>5</sub> level respectively. In the study done by Scoles P. V. et al<sup>32</sup> the mean width of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>3</sub> and L<sub>5</sub> were 8.3, 9.1 and 9.7 respectively.

In the study done by Michael R Zindrick et al,<sup>4</sup> the mean width of the pedicles of lumbar vertebrae L<sub>1</sub> to L<sub>5</sub> were 8.7, 8.9, 10.3, 12.9 and 18.0 respectively.

The range of width of the pedicle (in mm) at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in our study were 7.0 to 14.6, 8.2 to 19.9, 8.0 to 17.8, 10.3 to 22.6 and 14.1 to 28.7 respectively.

The range of width of the pedicle (in mm) at L<sub>1</sub>, L<sub>3</sub> and L<sub>5</sub> in the study done by Scoles P.V. et al<sup>32</sup> were 6.0 to 11.9, 6.4 to 12.0 and 6.4 to 14.7 respectively.

The range of width of the pedicle (in mm) at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in the study done by Zindrick et al<sup>4</sup> were 4.5 to 13.0, 4.0 to 13.0, 5.3 – 16.0, 9.1 to 17.0 and 9.1 to 29.0 respectively.

The minimum width of the pedicles was noticed at L<sub>1</sub> and the maximum width of the pedicle was noticed at L<sub>5</sub> level and our observations are in line with that of other studies.

As regarding the transpedicular screw fixation, the variables that seem to influence screw implant strength include outer screw diameter, minor diameter, tooth profile, tooth pitch and the depth of screw penetration.<sup>63</sup> Although these variables have been studied extensively, there is no consensus of opinion concerning which of these variables is responsible for implant strength.<sup>1,64,65</sup>

Most investigators of pedicle screw system now recommend selecting the largest fully threaded screw that can be safely accommodated by a pedicle. The depth of penetration should be 50 to 80% of anteroposterior distance, without any attempt been made to engage the interior cortex of the vertebral body.

The outer diameters of the most commonly used pedicle screws with good success rate range from 5 mm to 7 mm.

In our study, there was no pedicle with a diameter less than 7 mm at any of the lumbar vertebrae.

Comparing the results of the study done by Nam-Hyun-Kim<sup>55</sup> on Koreans with those of Zindrick et al<sup>34</sup> study on Westerners, the width of pedicles at L<sub>1</sub> and L<sub>2</sub> levels was greater in Westerners than in Koreans.

The percentage of width of the pedicle less than five mm at L<sub>1</sub> and L<sub>2</sub> levels was more than 20% in study of Scoles P.V et al<sup>32</sup> and 1.5 to 3.1% in that of Nam-Hyun-Kim on Koreans, but in our study, there in no pedicle with the width less than 5 mm.

### **Length of the Pedicle**

The antero-posterior length of the pedicles was measured in 25 sets of lumbar verbebrae. The mean readings (in mm) observed for the length of the pedicles of lumbar vertebrae L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>, L<sub>4</sub> and L<sub>5</sub> were 15.5, 15.8, 16.1, 14.2 and 13.6 respectively.

There is an increasing pattern from L<sub>1</sub> to L<sub>3</sub> level and then a decreasing pattern from L<sub>3</sub> to L<sub>5</sub> levels. The minimum mean was noted at L<sub>5</sub> and maximum at L<sub>3</sub> level.

There are very few studies in literature regarding the length of the pedicles of verbetrae.

However, in a study by Krag et al,<sup>1</sup> they have reported that the pedicle length ranges between approximately 5 mm and 25 mm, is nearly constant between T<sub>9</sub> (mean: 20.18 mm) and T<sub>12</sub> (mean: 18.06 mm), then gradually decreases to L<sub>5</sub> (mean 15.0 mm) and this finding is consistent with the decreasing volume of the cauda equina in the spinal canal as one progresses caudally.<sup>1</sup>

Pedicle length is important because it defines the minimum length of the screw needed to obtain a grip on the entire pedicle. The pedicle itself seems to be stronger site for screw placement than the vertebral body. Even though both locations contain cancellous bone, the trabeculae in the pedicle appear to be stronger and thicker. In addition the pedicle cortex is quite thick, allowing the screw threads in many cases actually to engage the cortical bone.

#### **Mid-sagittal diameter of the vertebral canal**

The mean readings (in mm) observed for the mid-sagittal diameter at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in our study on 25 sets of lumbar vertebrae were 18.3, 16.2, 16.0, 17.8 and 18.1 respectively.

It shows a decreasing pattern from L<sub>1</sub> to L<sub>3</sub> level and then an increasing pattern from L<sub>3</sub> to L<sub>5</sub> levels. The minimum mean was noted at L<sub>3</sub> and maximum at L<sub>1</sub> level.

We also compared our findings with earlier studies done by Postachinni F.<sup>66</sup> on Indian and Italian subjects and also with study done by Eisenstein<sup>14</sup> on different groups of South Africans.

The mean readings (in mm) observed for the mid-sagittal diameter at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in the study done by Postachinni F<sup>66</sup> on Indian subjects were 15.0, 14.7, 13.7, 13.8 and 14.0 respectively and on Italian subjects were 16.7, 16.4, 15.8, 15.1 and 16.1 respectively.

The study of Postachinni F<sup>66</sup> on Indian subjects shows the same pattern like ours, but the readings were slightly on the lower side with minimum reading of 13.7 mm (mean) seen at L<sub>3</sub> level and maximum of 15.0 mm at L<sub>1</sub> level.

The mean readings (in mm) observed for the mid-sagittal diameter at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in the study done by Eisenstein<sup>14</sup> on Caucasoid males were 18, 17, 16, 16 and 15 respectively, on Zulu Negroid males were 16, 15, 15, 15 and 16 respectively and on Sotho Negroid males, the mean readings were 16, 15, 14, 15 and 16 respectively.

The pattern noted in Sotho Negroid similar to that of our findings with a minimum mean noted at L<sub>3</sub>.

The pattern observed in Caucasoid males was different, in the sense that, it showed a decrease in pattern from L<sub>1</sub> to L<sub>5</sub>, with the same mean at L<sub>3</sub> and L<sub>4</sub> (16 mm). The minimum mean mid-sagittal diameter of the canal was noted at L<sub>5</sub> level.

In case of Zulu Negroid the average mean of mid-sagittal diameter of the canal at second, third and fourth lumbar levels are same.

According to Joseph A. E. et al, the normal sagittal diameter of lumbar spinal canal is 15 to 25 mm. A diameter of less than 12 mm confirms the

presence of stenosis and intermediate values are suggestively abnormal and this stenosis usually involves multiple segments rather than a single isolated area, the most frequent levels of involvement being L<sub>4</sub> to L<sub>5</sub> and L<sub>3</sub> to L<sub>4</sub>, which often makes it difficult to perform lumbar puncture.

According to Eisenstein,<sup>14</sup> (1977), mid-sagittal diameter of canal less than 13 mm was considered stenotic and in his study done on 2166 lumbar vertebrae there were twenty eight vertebrae having a diameter of less than 13 mm (1.3%) but the most interesting finding was that even these stenotic vertebrae were only marginally below the lower limit of normal, none being less than 11 mm in mid-sagittal diameter.

In our study, there were 8 lumbar vertebrae (6.4%) with mid-sagittal diameter of canal less than 13 mm out of the 125 lumbar vertebrae and a total of 29 lumbar vertebrae (23.2%) had mid-sagittal diameter of the canal less than 15 mm.

The minimum diameter noted in our study was at L<sub>2</sub> (10.3 mm in lumbar vertebrae set No. 4) and the maximum diameter noted was at L<sub>5</sub> (24.9 mm in lumbar vertebrae set No. 12 and 14).

The mid-sagittal diameter, however, was narrower dimension than IPD, the average being 17.28 mm.

The range of the mid-sagittal diameter of lumbar vertebral canal from L<sub>1</sub> to L<sub>5</sub> were 13.9 – 23.8, 10.3 – 23.7, 11.1 – 23.0, 12.0 – 23.9 and 14.1 – 24.9 respectively.

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**Transverse diameter of the Lumbar vertebral canal: Interpedicular distance (IPD)**

The mean readings (in mm) observed for the interpedicular distance at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in our study were 22.5, 22.9, 24.8, 24.9 and 27.1 respectively.

We also compared our readings with earlier studies done by Postachinni F.,<sup>66</sup> Eisenstein,<sup>14</sup> and Scoles P. V. et al.<sup>32</sup>

The mean readings (in mm) observed for IPD at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in the study done by Postachinni F.<sup>66</sup> on Indian subjects were 19.1, 19.5, 19.9, 21.1 and 22.8 respectively and on Italian subjects were 21.7, 22.2, 22.7, 25.9 and 24.8 respectively.

The mean readings (in mm) observed for IPD at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in the study done by Eisenstein<sup>14</sup> on white Caucasoids were 23.0, 24.0, 23.0, 24.0 and 26.0 respectively, on Zulu Negroids were 21.0, 22.0, 22.0, 23.0 and 26.0 respectively and on Sotho Negroids were 21.0, 21.0, 22.0, 23.0 and 25.0 respectively.

The mean readings (in mm) for the IPD at L<sub>1</sub>, L<sub>3</sub> and L<sub>5</sub> in the study done by Scoles P. V. et al.<sup>32</sup> were 22.2, 22.8 and 25.9 respectively.

The readings of our study and those of Postachinni's<sup>66</sup> on Indian skeletons showed slight difference, with our readings being slightly on the higher side but the readings are similar in that they follow the same increasing pattern from L<sub>1</sub> to L<sub>5</sub> level.

But the readings noted on Italian subjects by Postachinni and those of Eisenstein on different groups of South Africans are different from our readings with respect to pattern, though the values are almost same as seen in our study.

According to Eisenstein,<sup>14</sup> (1977), the average lower limit of normal IPD is 18mm, any diameter less than this is considered as stenotic.

In our study at least 5 lumbar vertebrae were found to be stenotic with IPD less than 18 mm [L<sub>1</sub> - 1 (Set No. 4), L<sub>2</sub>-1 (Set No. 20), L<sub>3</sub>-1 (Set No. 20), L<sub>4</sub>-1 (Set No. 4), L<sub>5</sub>-1 (Set No. 10)].

The smallest IPD was 14.2 mm (noted at L<sub>2</sub> in the Set No.5) and the highest IPD was 34.8 mm (noted at L<sub>5</sub> in the Set No. 19). The average IPD noted was 24.44 mm.

In Eisenstein's study done on 2166 vertebrae, the IPD of the canal averaged 23 mm and was remarkably constant from the first to fifth lumbar vertebrae with the average lower limit of 18mm and 18 lumbar vertebrae were stenotic in this dimension and no transverse diameter was less than 16 mm.<sup>14</sup> But in our study, IPD of 3 lumbar vertebrae are less than 16 mm. (Set No.4, L<sub>1</sub>-15.1 mm; Set No.5, L<sub>2</sub>-14.2 mm and Set No. 4, L<sub>4</sub>-14.3 mm).

The IPD was the largest dimension of the canal in all of the vertebrae examined, a finding that supports previous studies indicating that the mid-sagittal diameter is the most significant dimension of the spinal canal.

The range of IPD (in mm) at different vertebral levels from L<sub>1</sub> to L<sub>5</sub> in our study were 15.1 to 29.7, 14.2 to 30.7, 16.6 to 30.8, 14.3 to 30.8 and 17.3 to 34.8 respectively.

The range of IPD (in mm) at L<sub>1</sub>, L<sub>3</sub> and L<sub>5</sub> in the study done by Scoles P. V. et al<sup>32</sup> were 18.3 to 25.6, 18.8 to 26.1 and 21.3 to 32.6 respectively.

The range in our study is almost similar to that observed by Scoles P. V. et al.<sup>32</sup> Mean IPD varies among different age groups and also between two sexes.<sup>29</sup> Normally, these distances increase steadily from L<sub>1</sub> to L<sub>5</sub>, but it has been reported by some authors that the distances can actually decrease from above downwards in Mongolism (Trisomy 21).<sup>67</sup>

The lumbar part of the neural canal houses the cauda equina, and narrowing of the bony ring of the canal, which may be developmental or acquired, may lead to compression of these nerve roots and cause low back pain. Measurement of the transverse diameter of the lumbar spinal canal is therefore a useful aid in the diagnosis of the lumbar spinal stenosis syndrome. It is probable that the marked differences observed were due to regional (environmental) differences in the size of the canal.

## **CONCLUSION**

A key to a successful transpedicular screw insertion is that the small pedicle is correctly entered by the screw and the walls are not penetrated. Choosing the proper entry point for inserting pedicle screws is the first step to prevent penetration of the pedicle wall. Penetration of the cortex or fracture of the pedicle may result from the use of relatively oversized screws. Some of the complications that have been reported include dural tears, leakage of cerebrospinal fluid and injuries to the nerve roots with neurological deficits.

In the present study we have made an attempt to understand the morphometry of the lumbar pedicles to decrease the risk of postoperative complications.

The present study concludes that, the different dimensions of the pedicle which have been studied would be of great help for successful pedicle screw fixation and also for quantification of spinal stenosis, especially in this area of Belgaum city.

There are, of course, a few limitations in our study. Our study group is small. We could not trace whether the person was having low backache or any spinal disease when alive. We have not analyzed the cause of death.

However our study has thrown up a number of avenues for future research. If our limitations are overcome in larger studies, we would have strong guidelines for efficient surgery of transpedicular screw fixation and also for effective quantification of spinal stenosis.

## SUMMARY

A study of morphometry of pedicles on 25 sets of normal, adult, dry lumbar vertebrae was taken up. The material for the study that is the total of 125 lumbar vertebrae were obtained from 25 cadavers from the department of Anatomy, Jawaharlal Nehru Medical College, Belgaum.

The mean height of the pedicle showed a decreasing pattern from L<sub>1</sub> to L<sub>4</sub>, followed by an increase at L<sub>5</sub>, the maximum height being at L<sub>1</sub> and minimum height being at L<sub>4</sub>.

The mean width of the pedicle showed an increase in pattern from L<sub>1</sub> to L<sub>5</sub>, the maximum width being at L<sub>5</sub> and minimum width being at L<sub>1</sub>. There was only one lumbar vertebra (L<sub>1</sub>) with pedicle width equal to 7 mm. There were no pedicles with the width less than 7 mm among any of the 125 lumbar vertebrae in our study. This may be due to small study group. This suggests that it is dangerous to use a 7 mm screw during transpedicular screw fixation surgery at L<sub>4</sub> level.

The mean length of the pedicle showed an increasing pattern from L<sub>1</sub> to L<sub>3</sub>, followed by a decreasing pattern from L<sub>3</sub> to L<sub>5</sub>, the maximum length being at L<sub>3</sub> and minimum length being at L<sub>5</sub>.

The mean mid-sagittal diameter of the vertebral canal showed a decreasing pattern from L<sub>1</sub> to L<sub>3</sub> followed by an increasing pattern from L<sub>3</sub> to L<sub>5</sub>, suggesting that the narrowest mid-sagittal diameter of the canal is at L<sub>3</sub>. The mid-sagittal diameter, however, was narrower dimension than IPD.

Among the 125 lumbar vertebrae studied, there were 8 lumbar vertebrae (6.4%) with mid-sagittal diameter of the canal less than 13 mm, indicating that they are stenotic.

The mean IPD showed an increasing pattern from L<sub>1</sub> to L<sub>5</sub>, the maximum IPD being at L<sub>5</sub> and minimum IPD being at L<sub>1</sub>.

There were 5 lumbar vertebrae with the IPD less than 18 mm, indicating that they are stenotic.

The IPD was the largest dimension of the vertebral canal in all of the vertebrae examined.

It is probable that the marked differences observed as compared to other studies were due to regional (environmental) differences in the dimensions of pedicles.

With this data on the morphometrical findings of the pedicles of lumbar vertebrae, we hope that it could be of some use possibly in cases of suspected spinal stenosis and also in transpedicular screw fixation to prevent post-operative complications.

These figures could also be of forensic importance because of the observed racial, ethnic and regional variations. However, for the purpose of authentic use, further progressive study in the same direction is desirable.

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**ANNEXURE I – PHOTOGRAPHS**



**Photograph No. 1: Vernier caliper**



**Photograph No. 2: Lumbar vertebrae showing minimum and maximum height of the pedicles**



**Photograph No. 3: Lumbar vertebrae showing minimum and maximum width of the pedicles**



**Photograph No. 4: Lumbar vertebrae showing minimum and maximum length of the pedicles**



**Photograph No. 5: Lumbar vertebrae showing minimum and maximum mid-sagittal diameter of vertebral canal**



**Photograph No. 6: Lumbar vertebrae showing minimum and maximum interpedicular distance**

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**ANNEXURE II – MASTER CHART**
**Height of the pedicle**

<b>Set No.</b>	<b>L<sub>1</sub></b>	<b>L<sub>2</sub></b>	<b>L<sub>3</sub></b>	<b>L<sub>4</sub></b>	<b>L<sub>5</sub></b>
1	21.6	16.0	18.3	23.9	16.0
2	15.4	23.6	22.6	14.2	15.3
3	15.1	19.5	17.3	21.7	18.6
4	21.6	15.1	19.5	20.8	14.2
5	17.4	15.1	16.1	20.6	18.3
6	19.7	15.0	15.2	18.5	23.7
7	18.7	16.3	18.4	20.8	18.4
8	21.7	17.2	19.7	15.3	19.4
9	21.8	21.7	18.4	15.1	17.3
10	20.8	19.5	18.4	20.7	18.6
11	16.4	18.5	22.9	19.5	17.3
12	13.1	24.9	15.1	19.5	19.6
13	21.7	23.9	26.7	21.8	23.9
14	20.7	22.9	20.4	17.3	15.2
15	17.0	13.0	25.8	19.6	14.2
16	19.7	22.9	20.6	17.3	12.0
17	15.3	13.0	20.6	16.3	18.5
18	14.1	16.2	19.2	19.8	18.4
19	20.8	13.0	20.8	17.6	18.5
20	14.3	21.9	18.8	14.0	12.1
21	17.6	20.6	16.0	19.6	14.1
22	18.5	17.1	19.2	16.4	21.6
23	19.5	20.5	22.7	19.7	17.6
24	15.1	15.1	13.0	19.6	19.7
25	14.2	18.6	21.6	19.3	20.5

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**Width of the Pedicle**

Set No.	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>5</sub>
1	8.1	13.5	11.6	12.6	15.7
2	13.5	12.2	12.6	13.1	16.0
3	12.3	10.2	16.2	22.6	28.7
4	13.2	12.5	14.5	14.1	19.3
5	14.6	13.3	13.4	17.6	18.4
6	12.6	14.8	12.4	12.1	22.5
7	8.1	13.6	9.3	15.2	20.3
8	12.2	15.9	13.5	13.2	20.1
9	10.4	14.4	14.4	16.7	20.5
10	12.6	9.2	13.5	10.3	14.1
11	9.3	15.8	14.9	17.6	25.6
12	9.2	19.9	8.0	13.0	19.4
13	9.2	13.5	15.6	17.6	24.6
14	10.2	8.2	16.6	13.5	20.4
15	11.0	9.0	14.4	15.4	17.2
16	9.3	11.3	15.7	15.8	24.6
17	11.7	13.8	8.1	12.5	19.5
18	11.5	12.7	13.2	13.4	22.5
19	12.5	11.2	14.8	15.3	20.5
20	9.5	11.3	9.1	14.6	21.7
21	7.0	16.4	16.7	15.4	19.2
22	10.4	11.5	14.4	15.3	22.2
23	12.3	15.7	17.8	13.3	22.6
24	10.2	11.0	11.3	17.7	20.7
25	7.1	9.4	12.5	15.5	25.6

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**Length of the Pedicle**

Set No.	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>5</sub>
1	17.5	14.3	14.2	16.3	13.4
2	15.5	10.1	18.5	15.6	12.6
3	18.8	13.3	18.7	14.5	15.6
4	12.5	13.2	12.1	13.5	15.8
5	19.9	15.4	12.1	12.3	14.6
6	13.4	10.3	12.5	11.5	8.4
7	16.8	19.8	17.6	11.0	17.8
8	17.6	15.7	18.6	15.8	11.4
9	15.6	17.5	13.3	10.2	14.7
10	14.3	12.2	19.8	15.1	14.4
11	14.0	15.7	15.5	7.2	12.5
12	15.4	13.1	19.4	15.7	14.6
13	14.1	19.6	16.5	12.2	13.4
14	17.4	12.3	13.0	12.0	14.6
15	10.2	15.5	16.6	15.4	15.5
16	13.4	17.6	17.7	15.4	13.5
17	21.9	13.1	20.8	19.6	13.2
18	10.1	17.5	11.2	13.2	14.5
19	14.0	17.6	19.8	15.6	12.2
20	16.4	11.1	15.4	13.4	14.3
21	15.3	14.3	17.6	19.7	10.0
22	15.3	15.3	18.5	16.6	11.2
23	15.6	15.4	14.4	17.8	12.2
24	16.4	18.7	12.2	13.4	15.5
25	17.5	17.4	17.8	13.4	15.6

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**Mid-sagittal diameter**

Set No.	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>5</sub>
1	21.7	13.6	18.5	20.6	16.6
2	18.6	21.7	21.6	22.2	23.9
3	18.3	20.5	23.0	20.7	18.7
4	18.7	10.3	16.3	17.4	17.3
5	19.7	15.3	20.9	18.6	21.9
6	20.6	21.1	14.3	15.6	15.6
7	20.9	23.7	18.8	21.9	16.2
8	22.9	19.6	18.7	13.1	17.4
9	13.9	19.6	12.1	15.6	17.8
10	18.4	15.1	15.3	19.5	18.6
11	23.8	16.7	14.3	15.4	19.8
12	16.5	15.1	19.4	14.3	24.9
13	16.0	14.0	14.3	20.5	18.5
14	22.8	14.1	18.7	15.0	24.9
15	17.3	14.1	18.6	20.4	14.4
16	17.3	15.1	18.4	19.8	15.3
17	20.7	20.8	14.0	17.3	17.2
18	16.6	18.5	12.3	23.9	14.1
19	17.4	17.2	19.5	19.5	17.1
20	19.5	14.5	12.0	12.0	17.3
21	18.5	15.2	13.2	18.5	15.5
22	14.4	15.2	15.4	14.2	15.0
23	14.2	14.3	11.1	16.3	17.6
24	14.2	16.2	15.1	17.6	18.4
25	15.3	12.3	19.7	14.3	19.4

**Interpedicular distance**

<b>Set No.</b>	<b>L<sub>1</sub></b>	<b>L<sub>2</sub></b>	<b>L<sub>3</sub></b>	<b>L<sub>4</sub></b>	<b>L<sub>5</sub></b>
1	20.0	26.6	22.1	27.7	28.8
2	26.6	22.5	22.3	21.1	24.4
3	29.7	27.6	29.8	29.6	31.3
4	15.1	23.6	27.9	14.3	26.4
5	27.7	14.2	29.6	30.8	28.5
6	23.3	22.6	23.6	22.5	20.1
7	20.2	24.4	27.3	23.0	22.1
8	22.3	22.4	24.5	24.2	30.6
9	22.4	19.1	23.5	24.6	25.8
10	27.9	21.1	22.1	25.5	17.3
11	23.7	25.7	24.5	24.5	22.6
12	18.1	23.3	30.8	21.5	26.2
13	26.7	20.3	24.5	29.6	25.1
14	22.1	22.9	22.4	23.0	30.7
15	24.6	20.1	25.4	28.6	25.5
16	20.0	24.6	21.0	23.5	29.5
17	22.2	22.5	23.2	24.4	24.3
18	19.1	30.7	27.8	27.7	30.3
19	19.0	21.6	25.6	25.6	34.8
20	23.5	21.4	16.6	21.3	28.6
21	21.0	21.1	23.5	22.2	31.7
22	25.7	24.7	27.5	25.4	30.5
23	20.5	22.3	24.5	22.2	30.5
24	20.2	22.2	22.4	25.4	25.7
25	22.6	25.5	27.9	25.5	27.7