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Original Research Article

Analysis of Thoracolumbar Vertebral Pedicle Morphology with Dimensions of Commercially Available Pedicle Instrumentation

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Conflict of interest: Nil

Abstract

Background: Intra-operative problems encountered by surgeons include pedicle fracture, neurovascular injury, and screw cut-out. To avoid these difficulties, it is essential to compare the pedicle length and axis length with those of commercially available pedicle screws.

Main objective of the study: The main objective of the study is to determine the optimum length of pedicle screw by finding the pedicle length and pedicle axis length with axial view of thoracolumbar CT using Radiant Dicom viewer technology, and quantifying the average pedicle length among the normal population and comparing it with commercially available screws.

Methodology: The study is a retrospective and analytical investigation conducted among 150 participants aged 12-80 years, comprising both genders. Radiant Dicom viewer shows axial CT of the thoracolumbar spine area. Subjects with spinal deformity, spine malignancy, spine fracture, spine infection, congenital abnormalities, and thoracolumbar surgical history were excluded from the study. The study protocol was presented to the institutional ethics committee for approval and was approved. Informed consent was obtained from all participants. The confidentiality of the data collected was strictly ensured by electronic storage.

Results: The study found gender-specific differences in pedicle length. Males' minimum particle length is 12.05 mm, and maximum length is 23.90 mm. Females' particle length ranges from 11.95 to 20.25 mm. Males had a pedicle axis length of 31.85mm to 49.65mm, while females had a length between 27.50mm and 44.60mm.

Conclusions: The pedicle axis length in the L1 vertebra showed significant differences between males and females. As a result, we may conclude that pre-operative computed tomography examination of patients is necessary, along with the selection of the proper screw length, to prevent post-operative complications in the spine in the future.

Keywords: Vertebral Body, Computed Tomography, Pedicle length, Pedicle screws, Thoracolumbar region.

Introduction

One of the typical issues people deal with on a daily basis is back pain. Back pain affects about 80% of people worldwide at some point in their lives. The lumbar and thoracic regions of the spine, which are important for the transfer of biomechanical movements, are primarily affected by back pain.

Weight transfer in the spine is facilitated by the robust and substantial pedicles, an essential component of the vertebra. The spinal fixation method based on transpedicular screws was first described by Roy-Camille et al. [1]. Since 1963, the method has become more popular and a basic application of spinal fixation in recent years [2]. Despite the developments in implant technology and imaging methods over this time period and advances in surgical techniques, there are still potential problems and complications of transpedicular screw application[3]. Therefore, improvements in spinal fixation and healthy functional development of the pedicle screw system are important areas to be studied.

The thoracolumbar region is the area of transfer of biomechanical movement in the spine, therefore, it

is the area where pathologies are seen most often. These pathologies include trauma, degenerative diseases, osteoporotic compression fractures, instabilities, neoplastic diseases, and infections [4].

The intricate nature of the thoracic spine presents unique challenges for orthopedic surgeons specializing in spinal interventions, particularly those involving pedicle screw fusion. As surgical techniques evolve and demand precision, a profound understanding of thoracic spine morphology becomes paramount for optimizing patient outcomes, minimizing complications, and advancing the field of spinal orthopedics. The anatomy, neighboring structures and gender specific morphology have previously been described in a plethora of studies [5–9]

Surgical intervention may be indicated after trauma or subsequent degenerative or deformity changes in the thoracic spine. The indications for surgical treatment include failed conservative treatment, vertebral instability, impaired sensory or motor functions, and tumors. A vast number of scores and classifications exist that can be collected preoperatively (for example “Bauer Score”, “Modified score for therapeutic decision making in OF”, “AO Spine Thoracolumbar Injury Classification System and Treatment Algorithm”) to ease the decision-making process [10–13]. A common type of surgery performed in the thoracic spine is the spinal fusion (or temporary dorsal stabilization respectively), which works through screw placement in the pedicles and has been established for a long time [14–16]

This kind of surgery aims to stabilize the spine by fusing two or more vertebrae together. In degenerative cases, this fusion aims to restore the physiological axis, rotation, and inclination of the spine and decrease motion and therefore pain in the affected segment. In fractures, the pedicle screws build the base for the fixateur interne that bridges the affected segment that allows it to heal. In either case, a fundamental understanding of pedicle morphology is crucial for obtaining optimal results. For these kinds of surgeries, long-term benefits are difficult to achieve. Screw placement is crucial for obtaining benefits and avoiding complications. Different screw placement techniques, such as the costotransverse screw technique, have been analyzed but seem to be inferior compared to the standard pedicle screw fixation [17]. Since the introduction of computed tomography (CT)-navigation systems for intraoperative use, screw placement has been shown to be more accurate [18-20]

In addition vertebral pedicles are used for some of orthopedic procedure also like biopsies, kyphoplasties, vertebroplasties [21-23]. For successful screw fixation in pedicles there won’t be any incongruity between Pedicle length as well as pedicle axis length [24].Accuracy of pedicle screw fixation is still formidable. Thus spinal surgeons should have in depth knowledge of morphometric details of pedicles.

Misplacement of screw has been reported range up to 40 % [25] .The incidence of pedicle screw breach, a consequence of spinal instrumentation, varies from 1.7% to 35% with open insertion and from 2.6% to 12.3% with minimally invasive surgery. When performing spinal fixation on an L1 patient in lateral view, it was recommended that the length of the pedicle screws not exceed 85% of the length of the vertebral body [26].

It is essential to securely insert pedicle screws within the bone confines of each pedicle to lower the possibility of harming nearby neurovascular tissues [27]. The morphometry of the pedicle varies from population to population since underlying racial variations in human skeletal morphology have long been recognized. Differences in pedicle size, form, and angulation have been documented in anatomical groups belonging to different racial, ethnic, and regional categories, even within the same population [13].

Pedicle screw fixation was used in conjunction with spinal fusion surgery to provide a fixed position for the treated area's vertebrae. By holding the bone grafts in place while the spine heals, they stabilize and support the spine following surgery [28]. The commercially available screws length ranges from 30mm to 60mm. The size, length, and placement of the pedicle screw were crucial since improper pedicle screw positioning can result in pedicle fractures, visceral injuries, spinal cord injuries, vascular injuries, and damage to the nerve roots. By carefully examining the pedicle length and pedicle axis length of the spine by CT imaging before surgery all these issues can be prevented.

Materials and Methods

The study was carried out among 150 patients attending the orthopedic department of Chennai medical college, Trichy, in the age group between 12 and 80 years, including both the genders.

The axial view CT films of thoracolumbar region were studied and more preferably L1 vertebra was selected. Pedicle length and pedicle axis length were measured on both sides and the averages of respective lengths were measured.

Study Design: Retrospective analytical study

Study Centre: Chennai Medical College, Trichy, Tamil Nadu, India.

Study Variable

Inclusion Criteria: Both male and female patients undergoing axial view of CT of thoracolumbar region, in the age group of 12 to 80 years.

Exclusion Criteria: Patients having following conditions were exclded from the study

- Spinal deformity,
- Tumors in spine ,
- Fracture in spine,
- Infection in spine,
- Congenital anamoly,
- History of surgery in thoracolumabar region.

Instruments Used

Pedicle length: The pedicle length was measured from the dorsal margin of the vertebral body to the articular processes along the longitudinal axis [29].

Pedicle axis length: This is the angle that the pedicle's longitudinal axis forms with the vertebral body's midline [30].

The artificial implant companies like Geeco, Medtornics, Jayon, Globus, Adler, Sharma, Matrix and BMK Korea were investigated, and the pedicle screws were sorted out and also their range of Pedicle screw lengths were noted down.

Statistical Analysis

The collected data were analyzed with IBM-SPSS statistics software 23.0 Version. To describe the data descriptive statistics frequency analysis was used, percentage analysis was used for categorical variables and the mean & S.D were used for continuous variables. To find the significance in categorical data Chi-Square test was used. The probability value <0.05 is considered as significant level.

Result

Table 1: Minimum and maximum value of Pedicle Length & Pedicle Axis Length in males and females

Sex	Average Pedicle Length		Average Pedicle Axis Length	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
Male	12.05	23.9	31.85	49.65
Female	11.95	20.25	27.5	44.6

Table 2: Age-wise pedicle morphology Minimum and maximum value of PL & PAL in males and females

Age	Age-wise Pedicle Morphology	Male	Female
Less than 20	Pedicle Length	17.75±0.42	17.87±2.37
	Pedicle Axis Length	39.6±0.78	41.675±2.17
Between 20 to 40	Pedicle Length	16.725±2.40485	16.35±1.35
	Pedicle Axis Length	39.45±2.86	37.22±3.35
Between 40 to 60	Average Pedicle Length	16.34±2.35	16.49±2.42
	Pedicle Axis Length	39.35±2.49	36.65±3.31
Between 60 to 80	Pedicle Length	17.19±2.58	17.27±2.58
	Pedicle Axis Length	39.99±3.08	38.66±5.35
More than 80	Pedicle Length	17.35±2.93	0
	Pedicle Axis Length	36.78±3.51	0

Table 3: Statistical comparison of Pedicle Length (PL) & Pedicle Axis Length (PAL) between male and female in Right (R)& Left side (L)

Group	Male	Female	P-Value
RPL	17.36	16.98	0.385
RPAL	40.56	39.07	0.0224
LPL	16.39	15.95	0.3833
LPAL	38.31	36.33	0.0026

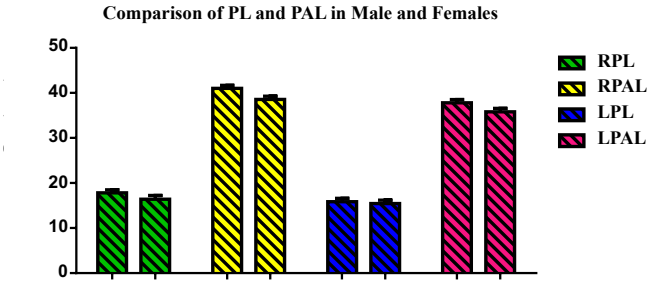

Figure 1: Comparison of Mean combined Pedicle Length & Pedicle Axis Length between males and females in Right & Left side

In the present study, the average pedicle length in males ranged from 12.05 mm to 23.9 mm, while in females it ranged from 11.95 mm to 20.25 mm. Similarly, the average pedicle axis length in males varied between 31.85 mm and 49.65 mm, whereas in females it ranged from 27.5 mm to 44.6 mm. Overall, both the pedicle length and pedicle axis length were found to be greater in males compared to females, indicating a consistent sexual dimorphism in pedicle morphology.

In the present study, age-wise analysis of pedicle morphology showed that in individuals <20 years, the mean pedicle length was 17.75 ± 0.42 mm in males and 17.87 ± 2.37 mm in females, with pedicle axis lengths of 39.6 ± 0.78 mm and 41.68 ± 2.17 mm, respectively. In the 20–40 years group, males had pedicle length 16.73 ± 2.40 mm and females 16.35 ± 1.35 mm, with axis lengths 39.45 ± 2.86 mm and 37.22 ± 3.35 mm. For 40–60 years, pedicle length was 16.34 ± 2.35 mm in males and 16.49 ± 2.42 mm in females, with axis length 39.35 ± 2.49 mm and 36.65 ± 3.31 mm. In 60–80 years, the pedicle length measured 17.19 ± 2.58 mm in males and 17.27 ± 2.58 mm in females, with axis length 39.99 ± 3.08 mm and 38.66 ± 5.35 mm. Among subjects >80 years, males showed pedicle length 17.35 ± 2.93 mm and axis length 36.78 ± 3.51 mm, while no female subjects were present. Overall, pedicle dimensions showed minimal age-related variation, with males generally having slightly higher values than females.

In the present study, comparison of pedicle parameters between sexes revealed that the right pedicle length (RPL) was slightly higher in males (17.36 mm) than in females (16.98 mm), though this difference was not statistically significant (p = 0.385). The right pedicle axis length (RPAL) was significantly greater in males (40.56 mm) compared to females (39.07 mm) (p = 0.0224). Similarly, the left pedicle length (LPL) was marginally higher in males (16.39 mm) than females (15.95 mm) with no significant difference (p = 0.3833), whereas the left pedicle axis length (LPAL) showed a statistically significant difference, being greater in males (38.31 mm) than in females (36.33 mm) (p = 0.0026).

Discussion

In the present study, the average pedicle length in males ranged from 12.05 mm to 23.9 mm, while in females it ranged from 11.95 mm to 20.25 mm. Similarly, the average pedicle axis length in males varied between 31.85 mm and 49.65 mm, whereas in females it ranged from 27.5 mm to 44.6 mm, indicating consistently greater values in males and suggesting sexual dimorphism in pedicle morphology. Comparable findings have been reported in previous studies, where males demonstrated significantly higher pedicle dimensions due to larger vertebral body size and bone mass [1,2]. Age-wise analysis revealed minimal variation in pedicle morphology. In individuals below 20 years, the mean pedicle length was 17.75 ± 0.42 mm in males and 17.87 ± 2.37 mm in females, with pedicle axis lengths of 39.6 ± 0.78 mm and 41.68 ± 2.17 mm, respectively. In the 20–40 years group, males showed pedicle length 16.73 ± 2.40 mm and females 16.35 ± 1.35 mm, with axis lengths 39.45 ± 2.86 mm and 37.22 ± 3.35 mm. For the 40–60 years group, pedicle length was 16.34 ± 2.35 mm in males and 16.49 ± 2.42 mm in females, with corresponding axis lengths of 39.35 ± 2.49 mm and 36.65 ± 3.31 mm. In the 60–80 years age group, males had pedicle length 17.19 ± 2.58 mm and females 17.27 ± 2.58 mm, with axis lengths of 39.99 ± 3.08 mm and 38.66 ± 5.35 mm, while among those above 80 years, the pedicle length and axis length in males were 17.35 ± 2.93 mm and 36.78 ± 3.51 mm, respectively. These results indicate that pedicle dimensions remain largely stable across age groups, consistent with earlier morphometric studies suggesting minimal remodeling of vertebral structures with advancing age [3,4]. When comparing pedicle parameters between sexes, the right pedicle length (RPL) was slightly higher in males (17.36 mm) than in females (16.98 mm), though this difference was not statistically significant (p = 0.385). The right pedicle axis length (RPAL) was significantly

greater in males (40.56 mm) compared to females (39.07 mm) (p = 0.0224). Similarly, the left pedicle length (LPL) was marginally higher in males (16.39 mm) than in females (15.95 mm) (p = 0.3833), while the left pedicle axis length (LPAL) also showed a statistically significant difference, being greater in males (38.31 mm) than in females (36.33 mm) (p = 0.0026). These findings align with prior reports where male pedicle axis lengths were significantly longer, reflecting sexual dimorphism in vertebral anatomy [5,6]. Studies on different populations have also noted that mean pedicle lengths and axis lengths in the Indian population are slightly smaller than those reported in Western data, likely due to constitutional and anthropometric differences [7,8]. Moreover, morphometric evaluations across populations consistently emphasize the clinical importance of individualized preoperative CT-based assessment for pedicle screw fixation, as variations in pedicle size, particularly axis length, can influence screw trajectory and safety margins [9,10]. Thus, the present study reinforces the need for region- and sex-specific morphometric databases to optimize spinal instrumentation and minimize surgical complications.

Conclusion

Irrespective of technique, pedicle screw fixation with posterior instrumentation is a strong fixation method for thoracolumbar spine. While placing the pedicle screw in L1 vertebrae, assessment of the length of the screw pre-operatively is as equally important as the screw entry point and orientation to avoid neurovascular injuries intra-operatively.

So, provisionally the average screw size may be 25 mm to 55 mm in contrary to the present available commercial screw size of 30 to 60 mm. Significant differences were observed among males and females in terms of the pedicle axis length in the L1 vertebra (p=0.0125).

Thus, we can conclude the need for the pre-operative evaluation of patients with computed tomography while selecting the appropriate screw length so as to avoid any further complications in the spine.

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