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Original Research Article

Morphometric analysis of pedicles of lumbar vertebrae in South Indian population: A computed tomographic study

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Abstract

The pedicle is the strongest part of the vertebra and Pedicle screws are used to anchor other surgical devices used in a variety of surgical procedures relating to the spine. The concept of using pedicle screw to help arthrodesis was first described by King in 1944. In 1970, Roy-Camille first applied the pedicle screw plating system for the lumbar spine. Many systems are used that incorporate plates, hook and rod system (Harrington and Moe) and external pins to obtain secure purchase of the vertebrae. A descriptive cross-sectional study was conducted in the Department of Orthopaedics and data was collected from the Department of Radio-Diagnosis, S. Nijalingappa Medical College and Hanagal Shri Kumareshwar Hospital and Research Centre Bagalkot, by using CT scan images of the patients undergoing CT KUB for unrelated disease. A total of 30 adult individuals (15 males and 15 females) were included for the study. In our study, it was reported that the pedicle height was gradually decreasing from L1 to L5 on both sides in both genders. The average height in this plane was reported to mean range from 11.82 mm in the L1 vertebra to 8.03 mm in the L5 vertebra.

Keywords: Morphometric analysis of pedicles, lumbar vertebrae, computed tomographic

Introduction

The spinal column is a complex system of bones and Connective tissues which not only supports the body but also protects the spinal cord and associated nerves from damage. The lumbar pedicles play a crucial role in the transfer of body weight from the neural arch to the anterior part of the vertebral column. There are many types of spinal column disorders, including those caused by abnormalities, disease or trauma. Patients who suffer from such conditions often experience extreme and debilitating pain, as well as diminished nerve function [1].

The pedicle is the strongest part of the vertebra and Pedicle screws are used to anchor other surgical devices used in a variety of surgical procedures relating to the spine [1]. The concept of using pedicle screw to help arthrodesis was first described by King in 1944 [2]. In 1970, Roy-Camille first applied the pedicle screw plating system for the lumbar spine. Many systems are used that incorporate plates, hook and rod system (Harrington and Moe) and external pins to obtain secure purchase of the vertebrae [3]. Posterior stabilization of the injured spine with the help of pedicle Screw fixation has become an increasingly popular

technique of Instrumentation [4]. It has gained in popularity in the field of spinal surgery as it provide three dimensional fixation over the shortest vertebral segment [5] better fusion rate [6], facilitating neurological recovery by improving vertebral alignment [7], laminectomy can be performed at levels to be fused. However, some potential complications, such as pedicle fracture, cutout with subsequent loss of stability, loosening of the Screw [5], dural tears, leakage of cerebrospinal fluid and injuries to the nerve roots with neurological deficits [27]. Knowledge of the pedicles is crucial for the sound application of these systems [8]. Several researchers have used computed Tomography (CT) data to assess pedicle anatomy [8, 15, 16, 17, 22, 26, 27]. Others have directly assessed lumbar pedicle anatomy using calipers and goniometers or specially designed devices [14, 19, 23, 28]. These studies have yielded variations in Morphology of the vertebrae, the reasons for these variations are unclear, but they may be related, in part, to the race, age and gender differences of the specimen sources, as well as to the differences in the experimental technique.
This study aimed to determine indices of lumbar pedicle anatomy of the South Indian population and to compare these data with the results of all previously reported researches.

Materials and Methods

A descriptive cross-sectional study was conducted in the Department of Orthopaedics and data was collected from the Department of Radio-Diagnosis, S. Nijalingappa Medical College and Hanagal Shri Kumareshwar Hospital and Research Centre Bagalkot, by using CT scan images of the patients undergoing CT KUB for unrelated disease. A total of 30 adult individuals (15 males and 15 females) were included for the study. The images of individuals having normal spinal architecture without any obvious fracture and deformity of the vertebrae were included and having history of spinal surgery, deformities and preexisting spinal pathology were excluded from the study.
Pedicle width (PW), pedicle height (PH), Pedicle Axis length (PAL), Inter Pedicle distance (IPD), Transverse Pedicle Angle (TPA) and Sagital Pedicle Angle (SPA) of lumbar vertebrae were measured in millimeters by lines drawn on the CT scan images. The interpedicular distance (IPD) was measured at the midshaft of the pedicle (fig 3). We chose the narrowest dimensions of pedicles in both the transverse and the sagittal planes as the pedicle width (PW, mediolateral outer cortical of the pedicle, fig 1) and the pedicle height (PH, craniocaudal outer cortical diameter of the pedicle, fig 2), The length of the pedicle was measured from posterior cortex to the midpoint of the anterior vertebral cortex at each spinal level (PAL, fig 4).
Sagittal pedicle angles (SPA, fig 2), Transverse pedicle angles (TPA, Fig 5) were measured by drawing the reference lines. The transverse pedicle angle (TPA) was obtained by measuring the angle between a line placed through the center of the pedicle a line parallel to the vertebral midline in the transverse plane. The sagittal pedicle angle (SPA) was measured between the line through the centre of pedicle and the superior vertebral body border in the sagittal plane.
All the scans available in the department were taken for the study. Data was collected and entered in Microsoft excel. Point estimate at 95% Confidence Interval was calculated along with frequency and proportion for binary data. The collected data was analyzed by using the Statistical Package for the Social Sciences version 16 (SPSS 16.0) for descriptive statistical analysis. P value was calculated to find the level of significance and p value <0.05 was considered as significant.

Result

Age and Gender: There were 30 patients (15 males and 15 female) with mean age of

34.28±10.806.

Pedicle width: In both genders, the mean values for Pedicle width were found minimum at L1 (6.20±1.265 mm in males, 5.80±1.207 mm in females) and maximum at L5 (12.88±1.66 mm in males, 11.53±1.767 mm in females) Hence, it was found that the pedicle width was gradually increasing from L1 to L5 in both genders as shown in table 1. It was reported that the difference in measurements between both genders is not significant except at L5.

Table 1: Pedicle Width (PW) in mm

Pedicle width	Male	Female	P value	T value
	Mean ± SD	Mean ± SD		
L1	6.20±1.265	5.80±1.207	0.383	0.886
L2	6.87±1.356	6.20±1.612	0.231	1.226
L3	7.80±2.042	7.60±1.882	0.782	0.279
L4	10.21±1.626	9.07±1.534	0.06	1.956
L5	12.88±1.66	11.53±1.767	0.020	2.463

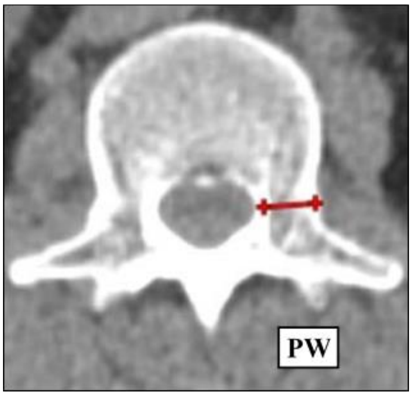


Fig 1: Pedicle width (PW)

Pedicle height: The mean values for height of pedicle was found maximum at L1 (11.93±0.884 mm in males, 11.80±0.862mm in females) and minimum at L5 (7.93±0.884mm in males, 8.13±0.640mm in females). Hence, it was reported that the height was gradually decreasing from L1 to L5 on both sides in both genders as shown in table 2. There was statistically insignificant difference in pedicle height between males and females at all Lumbar vertebral level.

Table 2: Pedicle Height (PH) in mm

Pedicle Height	Male	Female	P value	T value
	Mean ± SD	Mean ± SD		
L1	11.93±0.884	11.80±0.862	0.679	0.418
L2	11.20±1.014	11.13±0.834	0.846	0.197
L3	10.33±0.816	10.00±0.845	0.281	1.099
L4	9.47±0.990	9.27±0.884	0.564	0.584
L5	7.93±0.884	8.13±0.640	0.484	0.710

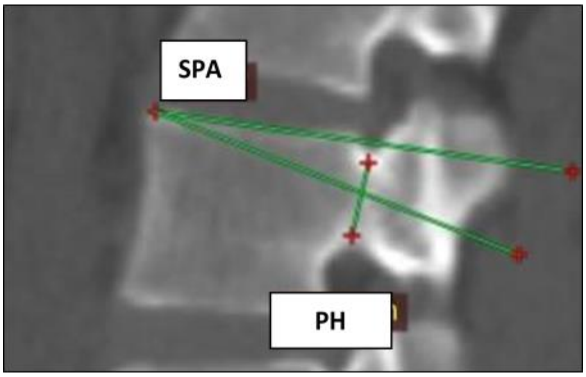


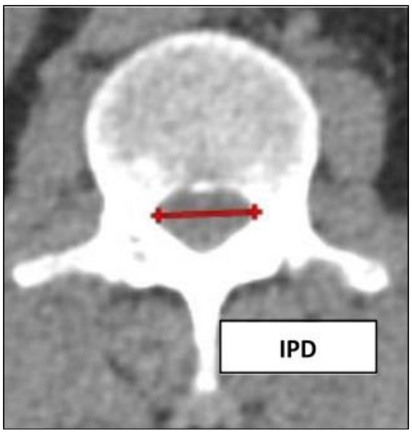
Fig 2: Pedicle height (PH) and Sagital pedicle Angle (SPA)

Interpedicular distance (IPD)

The widest IPD measured at the midline of each pedicle. But in both genders the IPD was the narrowest at the L1 vertebra (21.93±1.940mm in males, 21.20±1.568mm in females) and widest at the L5 vertebra (28.40±2.293mm in males, 28.87±2.949mm in females). Hence, it was observed that the pedicle thickness was gradually increasing from L1 to L5 on both sides in both genders. There was statistically insignificant difference between males and females at all lumbar vertebral level as shown in table 3.

Table 3: Interpedicular distance (IPD) in mm

Interpedicular distance (IPD)	Male	Female	P value	T value
	Mean ± SD	Mean ± SD		
L1	21.93±1.940	21.20±1.568	0.274	1.116
L2	22.84±2.134	21.73±1.870	0.133	1.547
L3	23.67±2.093	22.93±1.335	0.251	1.172
L4	25.67±2.093	24.33±1.447	0.052	2.029
L5	28.40±2.293	28.87±2.949	0.632	0.484



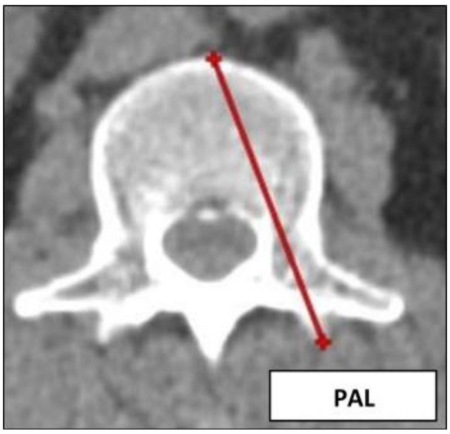


Fig 3: Interpedicular distance (IPD) **Fig 4:** Pedicle Axis

Pedicle Axis length (PAL): The mean values for Pedicle Axis Length was found maximum at L1 (52.20±2.210 mm in males, 50±2.100mm in females) and minimum at L5 (48.93±2.631 mm in males, 46.87±2.031mm in females). Hence, it was found that the pedicle chord length was gradually decreasing from L1 to L5 on both sides in both genders as shown in table 4. There was a statistically significant difference between pedicle axis length of males and females at all lumbar vertebral level except L4, L5 vertebrae.

Table 4: Pedicle Axis length (PAL) in mm

Pedicle Axis length (PAL)	Male	Female	P value	T value
	Mean ± SD	**Mean ± SD**		
L1	52.20±2.210	50.87±2.100	0.101	1.694
L2	51.73±1.751	50.53±2.326	0.122	1.596
L3	51.73±2.052	50.13±2.615	0.073	1.864
L4	50.40±2.098	48.43±2.681	0.035	2.214
L5	48.93±2.631	46.84±2.031	0.023	2.408

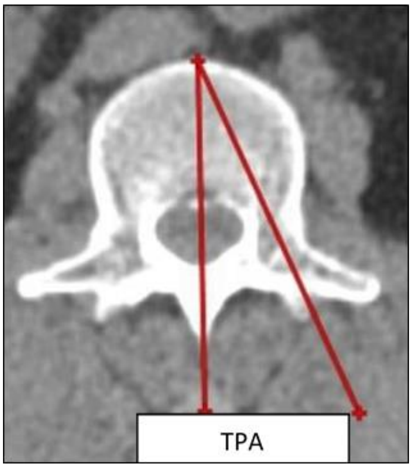


Fig 5: Transverse Pedicle Angle (TPA)

Transverse pedicle angles (TPA) and Sagital pedicle angles (SPA)

Transverse pedicle angles and Sagital pedicle angles varied in both genders in all lumbar pedicles. TPA ranged from 20° to 39°, SPA ranged from 11° to 19°. Mean and SD for TPA and SPA is shown in tables 5 and 6. TPA is statistically significant only at L4; SPA is statistically significant only at L5.

Table 5: Transverse pedicle angle (TPA) in degree

Transverse pedicle angle	Male	Female	P value	T value
	Mean ± SD	**Mean ± SD**		
L1	23.40±2.063	22.60±1.724	0.800	1.152
L2	23.33±1.915	22.73±1.223	0.315	1.023
L3	25.00±2.070	24.47±1.598	0.436	0.790
L4	27.87±2.386	26.13±2.167	0.047	2.083
L5	32.53±4.172	31.60±5.974	0.624	0.496

Table 6: Sagital pedicle angles (SPA) in degrees

Sagital pedicle angle	Male	Female	P value	T value
	Mean ± SD	**Mean ± SD**		
L1	14.07±1.710	14.47±1.125	0.455	-0.757
L2	14.13±1.552	14.67±1.047	0.279	-1.103
L3	14.07±1.335	14.67±1.047	0.182	-1.370
L4	14.33±1.397	14.71±1.069	0.419	-0.820
L5	13.80±1.821	15.20±1.014	0.015	-2.602

Table 7: Comparison of pedicle dimensions of our study with the other studies within India

S. No	Study	Level	PW	PH	IPD	TPA	SPA	PAL
1	Our study	L1	6.00±1.232	11.87±0.860	21.55±1.764	23±1.912	14.27±1.437	51.53±2.224
		L2	6.53±1.502	11.17±0.913	22.30±2.054	23.03±1.608	14.40±1.329	51.13±2.113
		L3	7.70±1.932	10.17±0.834	22.30±1.725	24.73±1.837	14.37±1.217	50.93±2.449
		L4	10.21±1.626	9.37±0.928	25.00±1.894	27.00±2.407	14.52±1.243	49.45±2.558
		L5	12.88±1.166	8.03±0.765	28.03±2.606	32.07±5.085	14.50±1.614	47.90±2.537
2	Mitra *et al*. [14] (2001; direct measurement)	L1	7.5	16.3	37.3	11	5	46.8
		L2	7.59	15.5	38.5	9.5	5.8	49.7
		L3	8.67	15.1	38	10.8	5.9	49.35
		L4	9.81	15.1	31.0	12.3	5.2	49.83
		L5	14.64	14.8	33	24.3	0.6	46.87
3	Acharya *et al.* [15] (2009, CT based)	L1	7.20±0.93	ND	ND	ND	ND	ND
		L2	7.62±0.84	ND	ND	ND	ND	ND
		L3	8.97±1.01	ND	ND	ND	ND	ND
		L4	11.12±1.01	ND	ND	ND	ND	ND
		L5	13.91±1.16	ND	ND	ND	ND	ND
4	Chadha *et al.* [16] (2001, CT based)	L1	6.69±1.55	ND	ND	8.78±5.76	ND	47.49±3.26
		L2	7.26±1.43	ND	ND	10.03±4.33	ND	49.05±8.28
		L3	8.43±1.42	ND	ND	12.25±4.89	ND	46.25±6.074
		L4	10.81±1.17	ND	ND	15.39±5.69	ND	46.27±8.28
		L5	13.47±1.78	ND	ND	24.33±6.93	ND	49.45±6.20
5	Mistri *et al.* [17] (2006, CT based)	L1	5.82±1.21	12.22±1.11	29.65±4.81	11.16±2.00	4.34±1.45	ND
		L2	6.58±1.45	14.03±1.15	32.15±5.53	13.06±1.65	5.58±1.69	ND
		L3	8.36±1.75	13.08±0.83	35.72±5.80	16.59±2.52	5.45±1.59	ND
		L4	10.2±2.35	14.19±0.64	41.52±4.80	20.81±3.23	12.64±3.52	ND
		L5	12.86±2.25	15.12±0.19	49.86±7.81	26.98±1.61	32.67±8.48	ND
6	Seema *et al.* [18] (2016, Radiographic measurements)	L1	9.42±0.34	17.4±0.43	24.2±0.43	ND	ND	ND
		L2	10.21±0.55	18.45±0.43	25.13±0.32	ND	ND	ND
		L3	11.72±0.39	17.12±0.26	20.78±0.24	ND	ND	ND
		L4	12.87±0.45	17.56±0.32	27.98±0.38	ND	ND	ND
		L5	14.23±0.3	17.07±0.5	30.98±.025	ND	ND	ND
7	Choubisa [19] (2018, direct measurement)	L1	8.30±0.90	15.14±2.30	ND	ND	ND	ND
		L2	8.93±1.33	15.47±2.43	ND	ND	ND	ND
		L3	9.51±1.34	14.70±2.11	ND	ND	ND	ND
		L4	10.73±1.91	13.62±1.89	ND	ND	ND	ND
		L5	12.14±2.90	13.55±2.10	ND	ND	ND	ND

Table 8: Comparison of pedicle dimensions of our study with the western population *ND-No Data

S. No	Study	Level	PW	PH	IPD	TPA	SPA	PAL
1	Our study	L1	6.00±1.232	11.87±0.860	21.55±1.764	23±1.912	14.27±1.437	51.53±2.224
		L2	6.53±1.502	11.17±0.913	22.30±2.054	23.03±1.608	14.40±1.329	51.13±2.113
		L3	7.70±1.932	10.17±0.834	22.30±1.725	24.73±1.837	14.37±1.217	50.93±2.449
		L4	10.21±1.626	9.37±0.928	25.00±1.894	27.00±2.407	14.52±1.243	49.45±2.558
		L5	12.88±1.166	8.03±0.765	28.03±2.606	32.07±5.085	14.50±1.614	47.90±2.537
2	Zindrick *et al.* [27] (1986; CT based study)	L1	8.7± 2.3	15.4±2.8	ND	10.9±2.2	2.4±5.3	44.7±4.5
		L2	8.9±2.2	15.0±1.5	ND	12.0±3.5	1.8±5.5	45.5±3.7
		L3	10.3±2.6	14.9±2.4	ND	14.4±3.8	0.2±3.9	44.4±5.1
		L4	12.9±2.1	14.8±2.1	ND	17.7±5.2	0.2±3.9	40.7±4.3
		L5	18.0±4.1	14.0±2.3	ND	20.8±6.3	-1.8±3.5	33.7±5.6
3	Berry *et al.* [23] (1986; direct measurement)	L1	7.0±1.9	15.6±1.4	22.1±2.3	7.5±8	18±6	ND
		L2	7.4±1.6	15.4±1.0	23.0±2.3	11.5±3	14±	ND
		L3	9.2±1.3	14.6±1.2	22.7±1.7	14.0±4	17±5	ND
		L4	10.3±1.6	13.0±1.3	22.0±1.8	20.0±5	14±3	ND
		L5	10.9±3.4	13.8±2.5	26.0±2.5	31.5±5	20±6	ND
4	Seemans *et al.* [24]	L1	7.0	15.8	22.4±2.6	2.8	-8.0	48.2
		L2	7.2	15.3	22.6±1.9	1.7	-8.8	48.9

		L3	8.6	14.8	23.1±1.8	2.7	-11.5	49.2
		L4	9.4	15.9	24.7±3.2	1.7	-15.5	49.1
		L5	10.3	21.3	27.1±0.9	1.4	23.6	47.2
5	Scole *et al.* [28] (1987; direct measurement)	L1	21.2±1.6	ND	21.2±1.6	12.3±2.0	ND	46.9±3.5
		L2		ND	ND	ND	ND	ND
		L3	22.2±1.4	ND	22.2±1.4	15.1±2.0	ND	48.2±3.1
		L4		ND	ND	ND	ND	ND
		L5	26.02±2.6	ND	26.0±2.6	24.1±3.7	ND	48.6±4.6

Table 9: Comparison of pedicle dimensions of our study with the other countries *ND-No Data

S. No	Study	Level	PW	PH	IPD	TPA	SPA	PAL
1.	Our study	L1	6.00±1.232	11.87±0.860	21.55±1.764	23±1.912	14.27±1.437	51.53±2.224
		L2	6.53±1.502	11.17±0.913	22.30±2.054	23.03±1.608	14.40±1.329	51.13±2.113
		L3	7.70±1.932	10.17±0.834	22.30±1.725	24.73±1.837	14.37±1.217	50.93±2.449
		L4	10.21±1.626	9.37±0.928	25.00±1.894	27.00±2.407	14.52±1.243	49.45±2.558
		L5	12.88±1.166	8.03±0.765	28.03±2.606	32.07±5.085	14.50±1.614	47.90±2.537
2.	Punjabi *et al.* [25] (Japanese, 1991, radiographic measurements)	L1	8.0±0.95	15.9±0.81	ND	ND	ND	ND
		L2	7.8±0.57	15.0±0.53	ND	ND	ND	ND
		L3	10.2±0.67	14.2±0.64	ND	ND	ND	ND
		L4	13.4±0.18	15.7±0.57	ND	ND	ND	ND
		L5	18.0±1.03	19.6±0.74	ND	ND	ND	ND
3.	Kadioglu *et al.* [8] (Turkey, 2003 CT based study)	L1	8.8±0.4	14.7±1.7	22.7±1.7	13.0±0.7	14.0±2.6	42.7±2.7
		L2	9.7±2.0	14.5±2.4	22.5±1.4	15.1±1.5	13.8±2.7	42.5±3.4
		L3	10.3±2.0	13.6±1.6	22.5±1.6	13.4±4.4	13.7±2.8	41.6±3.1
		L4	10.8±2.5	13.6±1.8	24.5±2.1	15.3±3.1	14.2±3.1	41.3±2.1
		L5	14.6±3.8	13.4±1.7	27.6±3.9	16.8±2.5	14.9±3.2	40.8±3.0
4.	Hou *et al*. [20] (Chienes, 1994; radiographic measurements)	L1	7.2±1.3	15.9±1.4	ND	ND	ND	50.7±3.4
		L2	7.6±1.2	15. ±1.6	ND	ND	ND	50.3±3.9
		L3	9.4±1.6	15.3±1.7	ND	ND	ND	49.7±3.8
		L4	10.8±1.4	15.3±1.9	ND	ND	ND	47.9±3.9
		L5	12.8±2.7	20.0±3.6	ND	ND	ND	43.9±4.1
5.	Amono Kuofi [21] (Saudi Arabia, 1994 radiographic measurements)	L1	9.6	17.2	ND	ND	ND	ND
		L2	10.3	17.5	ND	ND	ND	ND
		L3	11.8	17.0	ND	ND	ND	ND
		L4	12.8	17.7	ND	ND	ND	ND
		L5	13.7	18.8	ND	ND	ND	ND
6.	Mansur *et al.* [22] (Nepali, 2020; CT based)	L1	6.82±1.47	14.28±1.63	ND	ND	ND	44.7±4.05
		L2	7.21±1.28	13.60±1.58	ND	ND	ND	44.58±4.04
		L3	8.67±1.84	13.30±1.89	ND	ND	ND	44.37±3.85
		L4	9.61±2.23	11.76±1.87	ND	ND	ND	43.46±3.78
		L5	10.21±3.75	10.66±2.05	ND	ND	ND	42.32±3.78
7.	Abdelaziz [26] (Egypt, 2010; CT based)	L1	7.7±1.6	ND	ND	17±3.9	ND	ND
		L2	8.7±1.4	ND	ND	19±3.2	ND	ND
		L3	10.6±1.6	ND	ND	20±3.9	ND	ND
		L4	13.6±1.9	ND	ND	24±2.6	ND	ND
		L5	18.3±2.5	ND	ND	30±3.5	ND	ND

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 [9]. It requires surgical fixation for its activity to be regained and for the normal functioning of the affected individuals. Spinal fusion began in early 19th century and screw use began in the 1940. In 1970, Roy Camille was the first person to use screws and plates, since then it is the most popular method of internal fixation associated with spinal fusion [10]. The success of the technique determined, among other factors, by the accuracy of choice of screw, size of the pedicle and the quality of the bone of the pedicle. Selection of a suitable diameter of transpedicular screw is an important issue for safe surgical placement [11, 12].

Various authors have documented that the Cross-section of the pedicles is oval; hence, the Sagital Pedicle isthmus width is always greater than the transverse pedicle isthmus width, which is the limiting factor in choosing the diameter of the pedicle screws. Use of a larger size screw will lead to the violation of the medial or lateral cortex of the pedicle and may lead to neurologic deficit. In such situations, if cement is used to enhance the pullout strength in osteoporotic bone, the cement can leak through the damaged wall and cause further injury [13].

Many authors have described the morphometric aspects of the thoracic and lumbar spines and the details of the pedicle sizes and dimensions by means of varied techniques such as direct specimen measurement, plain radiology image, CT scan etc. In the present study, the same measurements were taken only in lumbar vertebrae. However, we examined the pedicle anatomy of lumbar vertebrae by CT data. We obtained all the measurements in young or middle-aged subjects because we aimed to exclude spinal degenerative disorders and to take consistent measurements. Pedicle dimensions in this study were consistent with those of previous studies in the literature.

The narrowest dimension of the ovoid shaped pedicle is in the transverse plane, it progressively increases craniocaudally [13]. The average width in this plane was reported to mean range from 6 mm to in the L1 vertebra to 12.86 mm in the L5 vertebra. Similar results were observed in all the previous studies conducted in India, Mitra *et al*. [14] (7mm to 14mm), Acharya *et al*. 15(7.20mm to 13mm), Chadha *et al*. 16 (6.69mm to 13mm), Mistri *et al*. [17] (5.82mm to 12.86mm), Seema *et al*. [18] (9.42mm to 14mm), Choubsia *et al*. [19] (8.30mm to 12.4mm).

Studies from other countries also showed the similar progressive increase of Pedicle width from L1 to L5, Kadioglu *et al*. [8] (Turkey population, mean range 8.8mm to 14.38mm), Hou *et al*. [20] (Chienes, mean range 7.2mm to 12.8mm), Amono Kuofi [21] (Saudi Arabia, mean range 9.6mm to 13.7mm), Mansur *et al*. [22] (Nepalese, mean range 6.8mm to 10.21mm), including 2 western studies Berry *et al*. [23] (mean 7.00mm to 10.9mm), Seemans *et al*. [24] (7.00mm to 10.3mm).

Some countries also showed the similar trend but revealed pedicles are more thicker than Indians, Punjabi *et al*. [25] (Japanese, range 8mm to 18mm), Abdelaziz 26 (Egypt, range 7.7mm to 18.3mm, including 2 western studies Zindrick *et al*. [27] (8.7mm to 18.00mm), Scole *et al*. [28] (21mm to 26mm).

It is interesting note that the thickness of pedicles was progressively increasing from L1 to L4 and increased suddenly at L5 as load has to pass through the pedicles against gravity at L5 level [7, 19, 28]. Therefore, the transfer of load from the body to the laminae in L5 will be upwards against gravity, making L5 possess the strongest pedicles with maximum thickness [3]. In the present study also the thickness of pedicles is maximum at L5 level on both sides and in both genders [22].

In our study, it was reported that the pedicle height was gradually decreasing from L1 to L5 on both sides in both genders. The average height in this plane was reported to mean range from 11.82 mm in the L1 vertebra to 8.03 mm in the L5 vertebra. Similar results were obtained from Kadioglu *et al*. [8] (range 14.2 to 13.2mm), Mansur *et al*. [22] (14.8mm to 10.6mm). few studies showed the similar trend but length of pedicle height was more compared to Indians, Zindrick *et al*. [27] (15.4mm to 14.00mm), Berry *et al*. [23] (15.6mm to 13.00mm). Studies from Japan (Punjabi *et al*.) [25] and China (Hou *et al*.) [20], India (Mitra *et al*.) [14] showed Progressive decrease in PH from L1 to L4 and sudden increase at L5. In contrast our study Amono Kuofi [21] (Saudi Arabia) showed progressive increase in PH from L1 to L5 (mean value 17.00mm to 18mm).

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Many Indian studies showed variation in PH from L1 to L5. Mistri *et al*. [17] (increase from L1 to L2, short at L3 again increase at L4 L5), Seema *et al*. [18] (L2 being the highest, then decreasing progressively).

The larger vertical diameter of the pedicle of the 1st Lumbar vertebra (as Compared with the vertical diameters of the 2nd and 3rd lumbar pedicles could also be explained by the Weight-bearing function. The 1st lumbar pedicle is located at the thoracolumbar transitional junction. A report by Davis (1955) demonstrated that this junction was the site of a complex zygapophyseal joint which was adapted to withstand marked compressive forces transmitted from the relatively immobile thoracic segment to the highly mobile lumbar segment of the vertebral column. He showed that the vertebrae and pedicles at this junction were reinforced to withstand the forces that had to be transmitted across this junction [21].

In our study Inter pedicle distance progressively increased from L1 to L5 Range (21.93mm to 28.40mm). Similar findings were observed in the previous Indian studies, Seema Et [18] (mean range 24.2mm to 30.98mm), Choubsia *et al*. [19] (mean range 20.32mm to 25mm), However Mistri *et al*. 14 observed the same trend but was associated with higher IPD of range 29.65mm to 49.86mm.

Similar findings were observed in western population, (Seemans *et al*. [24], mean range 22.4mm to 27.1mm, Berry *et al*. 23 mean range 22.1mm to 26.0mm), Turkey population (Kadioglu *et al*. [8] mean range 22.7mm to 27.6mm).

The depth of penetration should be 50% to 80% of the AP distance, without any attempt being made to engage the anterior cortex [29].

The "Pedicle Axis Length", because these dictate the upper limit to transpedicular screw diameter and length. [16]. In our Study PAL progressively decreased from L1 to L5, with mean range of 52mm at L1 to 48.93mm at L5.

Similar observations were made in Chinese population, Hou *et al*. [20] (mean range 50.7mm to 43.9mm), Nepalese and Turkey population has similar trend but with lower mean values of PAL (Kadioglu *et al*. [8] 42.7mm to 40.87mm, Mansur *et al*. [22] 44.7mm to 42.32mm).

In contrast to our study many Indian and western studies showed, L2 being longest PAL, constant value at L3 and L4 and again decrease or increase at L5, as compared in tables 7 and 9.

Transverse Pedicle Angle followed the trend of other previous studies at lumbar Level all the TPA was medially angulated. The angle gradually increased medially as we moved caudal, with the maximum medial angulations at L5 vertebrae, in this study 32° at L5. This suggests that pedicles are more converging in the Indian population. This is similar to Indian studies noted.

Above (table 8) as well as in a studies on Western population (table 9) but angle of inclination was smaller from L1 to L4 and comparable at L5. Sagital Pedicle Angle in our study ranged from 11° at L1 to 19° at L5 with mean value of 14.50°. Other studies from India Mitra *et al*. [14] showed progressive increase from L1 to L4 (range 4° to 11°) and decrease at L5 (-8° to 15°), Mistri *et al*. observed progressive increase from L1 to L4 (4° to 12°) and suddenly increasing at L5(26.9°). Similar results were obtained by Kadioglu *et al*. [8] in turkey population (12° to 17°). Results from western population were similar to Mitra *et al*. [14] but magnitude of angulation was less Zindrick *et al*. [27] (2.4° to -0.8°).

Conclusion

The transverse diameter values were smaller in the Indian population than in the white population. Comparable within Indian population and other countries like Chinese, Japanese, Tourkey and Saudi Arabian population. The results suggest that a 5-mm screw would be safer at the upper lumbar levels (L1 and L2) and that a 6-mm screw would be safer at the lower lumbar levels (L3-L5).

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Pedicle Axis Angle was fairly constant between individuals and between vertebral levels. A screw length of 40 mm appeared to be safer for all lumbar levels. The pedicle axis was oriented anteromedially and more obliquely at L5 (_30°), markedly differing from that of the white population at L1-L4. Pedicle height and Sagital pedicle angle varied in different studies of the same population.

Drawbacks of the study

No analysis of the correlation between the sizes of investigated population or height and pedicle morphometry was done in this study.

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