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Comparative study of CT scan and dissection measurements of pedicle width, screw path length and screw path angle in thoracolumbar spines of cadavers

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Abstract:

Objective:

Pedicle screw fixation is a method of choice for spinal instabilities. A detailed knowledge of anatomy of the pedicles is essential for preoperative planning. CT scan measurements form the main mode of assessing the morphometry of pedicles. Even with the preoperative measurements on CT scans, pedicle screws sometimes not match with the pedicle measurements during the surgery. This can lead to violation of the pedicles leading to breaches causing increased risk of vascular or neurological damage. The available studies focus mainly on anatomy of pedicles in Caucasian populations, with only a few studies that documentpedicle anatomy in Indian populations. The main objectives of this study were to measure the pedicle width, screw path length and screw path angle on axial section in CT scan and dissection in thoracolumbar spines of cadavers and to compare the findings of the CT scan measurements and the actual dissection measurements.

Methods:

The study was done on 10 formalin fixed cadavers. The cadavers were subjected to CT scan of their thoracolumbar spine. Pedicle width, screw path angle and screw path length were measured on the axial section for all the thoracic and lumbar vertebrae. Following this the cadaveric spine was sliced using band saw to obtain an axial section. The measurements of the pedicles were taken. Mean and standard deviations were obtained for all the measurements taken (CT scan and dissection).

Result:

The comparison study of the CT scan and dissection data for the thoracolumbar pedicles showed that bilateralpedicle widthswere measured higher on dissecting. The mean bilateral screw path lengths of thoracic vertebrae measured higher on the CT scanwhereas on the lumbar vertebrae, higher measurements were seen on dissecting. The Screw path angles of bilateral pedicles showed almost no difference in

the thoracic vertebrae, but lumbar vertebrae measured higher on dissection measurements.
Conclusion:
The pedicle morphology measured on a CT scan and on dissection shows significant difference statistically. But, the differences don't seem to result in a severe breach during the pedicle screw fixation. The differences fall into the Grade0 to grade 2 on the Gertzbein scale. Also the pedicle measurements in the Indian population needs documentation, as they measure lesser than the Caucasian counterparts.
Keywords: Pedicle screw fixation; pedicle morphology; cadaveric; CT scan; dissection

Abbreviations:
T: thoracic vertebrae
L: lumbar vertebrae
CT: computed tomography
PW: pedicle width
SPL: screw path length
SPA: Screw path angle

Introduction:
Spine stabilization using pedicle screws is one of the most widely used techniques[1-3]. The success of the procedure depends largely on the understanding of the anatomy of the pedicles like its breadth, length of the screws and the angle of the pedicles for screw entry. It has been established that the variation in the anatomy of the pedicles in an individual is high[4]. The variations among the races and gender are also very high[5]. Although a detailed study of the spines, especially the thoracolumbar spines, can be found in the literature, they are mostly of Caucasian population. A morphometric study on the Indian population is rare[6]. A detailed understanding of the anatomy of pedicles and by the clear knowledge of the pedicle screw systems, the complications of an erroneous screw placement can be reduced[7].
An ideally placed screw is well contained in the pedicle and the body of the vertebrae, with absolutely no breach[8]. Breaches are caused by abnormally placed screws in the pedicles resulting in breaking of the cortical bone in the pedicle or the body of the vertebrae. This can be medially, laterally or in a vertical orientation. The most used scale to assess the breaches in the Gertzbein's scale[9].
A preoperative planning regarding the measurements of the pedicle are studied to be beneficial in the decisions of the screw sizes and hence reduces the intraoperative time [9]. CT scan measurements have been used as gold standard for this purpose [10]. A study has reported a significant difference between the measurements done on CT scans when compared to the manual measurements[11].
In this study the thoracolumbar spines of cadavers were studied to find out three important measurements of pedicle morphology; pedicle width (PW), pedicle screw path length (SPL) and the pedicle screw path angle (SPA) on manual dissection and CT scans. These two measurements would be compared to see if the CT scans measurements are accurate and can be used to prevent the breaches efficiently.

Material and method:
The study was done on ten formalin fixed cadavers of Indian origin. The study was carried out after obtaining the Institutional Ethical committee approval.
Inclusion and exclusion criteria:
Indian cadavers with intact thoracic and lumbar vertebrae of any gender were included in the study. Cadavers having broken or disfigured bony parts of the vertebrae were excluded.
Statistical method: Means and standard deviation of the measurements and paired T-test to compare the means of the two groups.

Detailed description of procedure
The study involved the CT scans of the thoracolumbar spines of ten formalin fixed cadavers which were dissected later on. Three measurements were obtained for boththe CT scan and

dissected specimen (figure 1); screw path length(SPL),screw path angle(SPA)and pedicle width (PW).

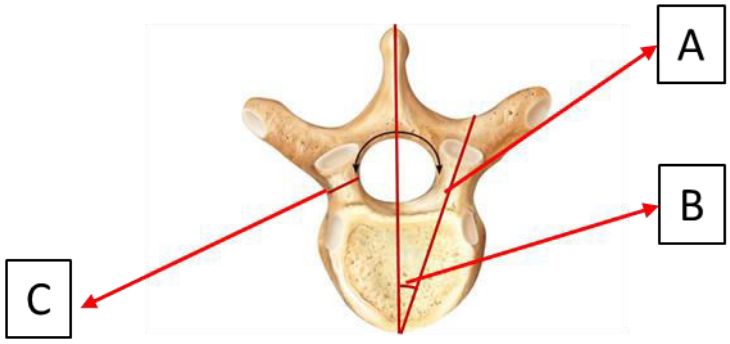

Figure 1: Measurements taken on the vertebrae; A: SPL, B: SPA, C:PW

a. CT scan of cadavers:

Formalin fixed cadavers with intact vertebral anatomy were subjected to a CT scan (after ethical committee clearance to use CT scan facility). CT scan axial section at the junction between the lower 2/3rd and upper 1/3rd of the vertebral bodies were to be obtained for all the thoracic (T1 to T12) and lumbar (L1 to L5) vertebrae. Three measurements of the pedicles were takenon the software (figure 2).

Figure 2: CT scan of T4 (fourth thoracic) vertebra with the measurements

b. Dissection of the cadavers

Cadavers with intact vertebral anatomy, used for the CT scan study, were dissected to remove the muscles of the back (figure 3a). The spines were cleaned and a count was done to ensure the number of vertebrae. A section of the vertebral bodies (T1 to T12 and L1 to L5) at the junction between lower 2/3rd and upper 1/3rd were taken using an electric band saw (figure 3b). Three measurements of the pedicles were taken using calipers, rulers and protractor (figure 4).

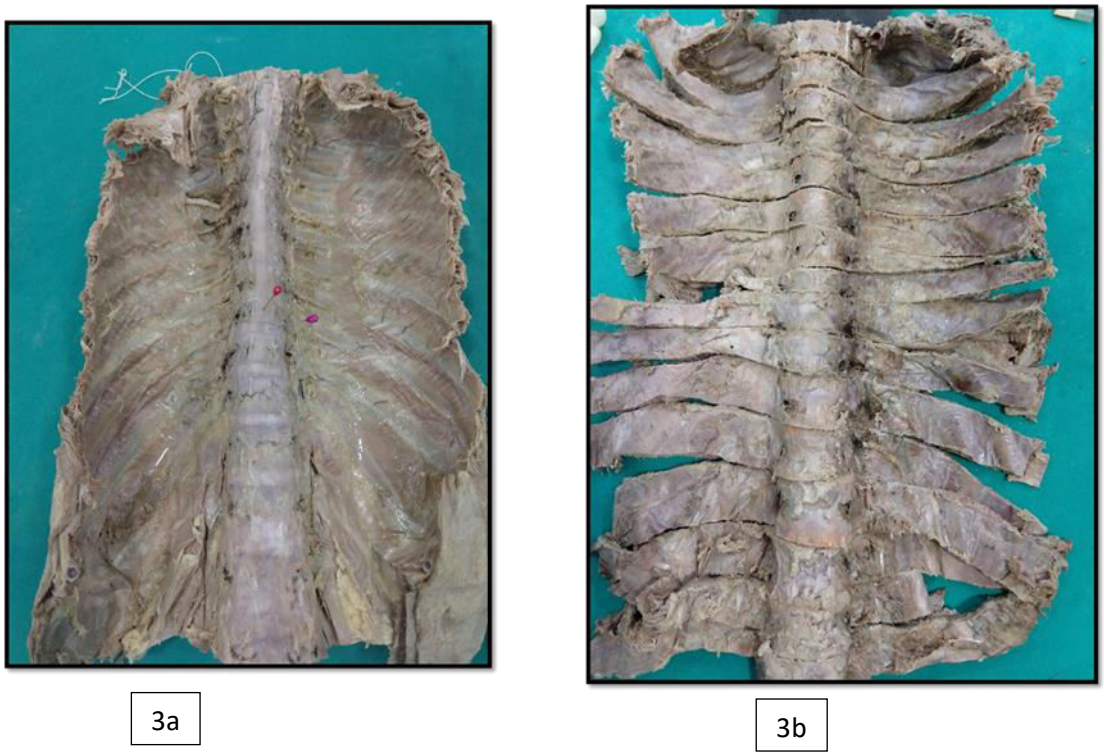

Figure 3: Dissected(3a) and sectioned (3B) thoracolumbar spine

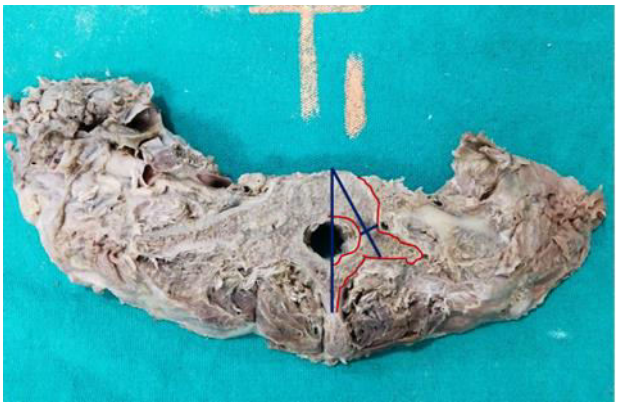

Figure 4: Axial section for dissection manual measurements

c. Comparison between the CT scan and dissected axial sections:
A comparison of measurements was done for each vertebral level of all the cadavers (figure 5)

Figure 5: A comparision of measurements on the CT scan and Dissection at T1 (First thoracic) vertebra in cadaver

Results:

A total of 240 (120 right side and 120 left side)and 100 (50 right side and 50 left side) thoracic pedicles and lumbar pedicles were measured. The CT scans of axial sections were measured and recorded on the software whereas the dissection measurements were done by the Vernier callipers, rulers and protractor. Mean and standard deviation were calculated for each vertebral level among the cadavers both in CT scan and dissections. The results are tabulated as a mean of bilateral pedicle measurements (SPL: screw path length, PW: pedicle width and SPA: screw path angle) on CT scans and dissection. Mean and standard deviation were calculated for each vertebral level among the cadavers both in CT scan and dissections. Comparisons between two methods of assessment on right and left side were conducted using paired samples t test.

Vertebrae Number	Assessment method	Left side		Right side	
		Mean (cms)± SD*	P value**	Mean (cms) ± SD	P value**
T1	Dissection	3.550±.207	.415	3.560±.217	.486
	CT scan	3.630±.220		3.630±.220	
T2	Dissection	3.500±.115	.000	3.500±.115	.000
	CT scan	3.864±.178		3.874±.176	
T3	Dissection	3.680±.193	.000	3.680±.162	.000
	CT scan	4.038±.124		4.027±.132	
T4	Dissection	4.010±.213	.013	4.010±.213	.013
	CT scan	4.260±.155		4.260±.155	
T5	Dissection	4.100±.194	.002	4.080±.193	.001
	CT scan	4.408±.158		4.430±.192	
T6	Dissection	4.190±.292	.004	4.180±.297	.005
	CT scan	4.623±.214		4.580±.168	
T7	Dissection	4.270±.406	.165	4.290±.354	.165
	CT scan	4.539±.368		4.539±.368	
T8	Dissection	4.390±.407	.614	4.370±.386	.515
	CT scan	4.470±.392		4.470±.392	

T9	**Dissection**	4.570±.340	.179	4.580±.322	.251
	CT scan	4.745±.324		4.723±.284	
T10	**Dissection**	4.700±.392	.036	4.680±.388	.024
	CT scan	5.000±.279		5.000±.279	
T11	**Dissection**	4.910±.420	.190	4.840±.395	.100
	CT scan	5.114±.318		5.114±.318	
T12	**Dissection**	5.100±.440	.780	5.060±.499	.558
	CT scan	5.144±.322		5.154±.315	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-1.Comparison of mean screw path length in the pedicles of the all left thoracic vertebrae of cadavers evaluated by Dissection and CT scan

Screw path length

Considering measurement of screw path length in the pedicles, it was observed that the anatomic measurements of thoracic vertebrae showed lower values as compared to CT scan measurements on both right and left sides. The least values were recorded for T2 (L-3.500±.115cm, R-3.500±.115cm) using dissection method and T1(L-3.630±.220cm, R-3.630±.220cm) in the case of CT scan but highest values were recorded for T12 using both methods. There was a steady increase in measurements from T1 to T12 with a small dip at T7 and T8 in the case of CT scan whereas for dissection method an initial dip was observed at T2 with consistent increase towards T12. A statistically significant difference ($p<0.05$) was observed between the two assessment methods for T2, T3, T4, T5, T6 and T10 on both right and left sides. (Table-1)

In the case of lumbar vertebrae, on the contrary, it was observed that the anatomic measurements showed higher values as compared to CT scan measurements and there was a steady increase in the values from L1 to L5, on both right and left sides. In case of dissection method, the mean values obtained for L1 were (L-5.260±.470cms, R-5.290±.431cms) and for L5 were(L-6.100±.258cms, R-6.050±.317cms).Similarly the corresponding mean values in CT scan method were obtained as (L-5.190±.398cms,R- 5.138±.396cms) for L1 and (L-5.650±.251cms,R-5.650±.232cms) for L5. Both sides showed statistically significant differences($p<0.05$) in measurements assessed by Dissection method and CT scan for lumbar vertebrae L3, L4 and L5.(Table-2)

Vertebrae Number	Assessment method	Left side		Right side	
		Mean (cms)± SD*	P value**	Mean (cms) ± SD	P value**
L1	Dissection	5.260±.470	.673	5.290±.431	.145
	CT scan	5.190±.398		5.138±.396	
L2	Dissection	5.460±.474	.213	5.450±.465	.068
	CT scan	5.289±.374		5.239±.342	
L3	Dissection	5.580±.413	.051	5.590±.409	.038
	CT scan	5.390±.401		5.408±.386	
L4	Dissection	5.800±.383	.000	5.760±.427	.000
	CT scan	5.558±.305		5.558±.305	
L5	Dissection	6.100±.258	.000	6.050±.317	.005
	CT scan	5.650±.251		5.650±.232	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-2. Comparison of mean screw path length in the pedicles of the all left and right lumbar vertebrae of cadavers evaluated by Dissection and CT scan

Vertebrae Number	Assessment method	Left side		Right side	
		Mean (cms)± SD*	P value**	Mean (cms) ± SD	P value**
T1	Dissection	.800±.133	.228	.780±.132	.378
	CT scan	.735±.082		.740±.088	
T2	Dissection	.760±.107	.001	.770±.095	.001
	CT scan	.598±.066		.604±.069	
T3	Dissection	.680±.079	.000	.680±.079	.001
	CT scan	.547±.019		.551±.023	
T4	Dissection	.560±.117	.303	.570±.116	.241
	CT scan	.508±.076		.513±.078	
T5	Dissection	.720±.155	.002	.710±.166	.004
	CT scan	.510±.042		.510±.042	
T6	Dissection	.700±.163	.029	.740±.143	.004
	CT scan	.576±.067		.576±.067	
T7	Dissection	.730±.082	.000	.750±.085	.000
	CT scan	.562±.093		.559±.097	
T8	Dissection	.780±.079	.001	.780±.103	.002
	CT scan	.599±.114		.597±.115	
T9	Dissection	.860±.117	.001	.860±.107	.000
	CT scan	.626±.125		.629±.127	
T10	Dissection	.900±.156	.000	.890±.173	.000
	CT scan	.594±.074		.605±.084	

T11	**Dissection**	.960±.165	.000	.980±.169	.000
	CT scan	.600±.055		.600±.055	
T12	**Dissection**	.950±.085	.000	.970±.095	.000
	CT scan	.676±.091		.670±.084	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-3.Comparison of mean width of pedicles in all the left and right thoracic vertebrae of cadavers evaluated by Dissection and CT scan

Pedicle width

Considering the width of the pedicles for left side, it was observed that the anatomic measurements of thoracic vertebrae showed higher values as compared to CT scan measurements. Maximum mean pedicle width values in dissection method was for T11 (0.96 ±.165cm) and least was observed in T4 (0.56±.117cm). The corresponding values assessed by CT scan were noted for T1 (0.735±.082cms) and T5 (0.50±.042cms) The right side showed great similarities with the left side; it was observed that the anatomic measurements of right thoracic vertebrae also showed higher values as compared to CT scan measurements. Maximum mean pedicle width values in dissection method was for T11 (0.98±.169 cms) and least was observed in T4 (0.57±.078cm). The corresponding values assessed by CT scan were noted for T1 (0.74±.088cms) and T5 (0.51±.042cms). A statistically significant difference ($p<0.05$) was observed between the two assessment methods for all thoracic vertebrae except for T1 and T4 (Table-3)

As in the case of thoracic vertebrae, Descriptive statistics for width of pedicles in all the left lumbar vertebrae of cadavers, evaluated by Dissection and CT scan showed greater mean values when assessed by dissection rather than CT scan. Maximum mean pedicle width values in dissection method was for L5 (1.480±.140cms) and least was observed in L1 (1.050±.097cms). The corresponding values assessed by CT scan were also noted for L5 (1.294±.210cms) and L1(.821±.210cms).Likewise on right side, Maximum mean pedicle width values in dissection method was for L5 (1.500±.149cms) and least was observed in L1 (1.060±.084cms). The corresponding values assessed by CT scan were also noted for L5 (1.324±.223cms) and L1(.821±.140cms). It was also observed that there was a steady increase in mean with of pedicles from L1 to L5 irrespective of the method or side of assessment. Comparison of mean width of pedicles in all the right lumbar vertebrae of cadavers evaluated by Dissection and CT scan using paired samples t test showed statistically significant differences($p\leq0.05$) only for L1 and L2.(Table-4)

Vertebrae Number	Assessment method	Left side Mean (cms)± SD*	P value **	Right side Mean (cms) ± SD	P value **
L1	Dissection	1.050±.097	.000	1.060±.084	.001
	CT scan	.821±.210		.821±.140	
L2	Dissection	1.100±.082	.001	1.110±.099	.001
	CT scan	.963±.129		.963±.129	
L3	Dissection	1.150±.165	.443	1.160±.165	.498
	CT scan	1.09±5.230		1.101±.240	
L4	Dissection	1.260±.107	.869	1.290±.120	.771
	CT scan	1.245±.236		1.265±.231	
L5	Dissection	1.480±.140	.076	1.500±.149	.089
	CT scan	1.294±.210		1.324±.223	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-4.Comparison of mean width of pedicles in all the left and right lumbar vertebrae of cadavers evaluated by Dissection and CT scan

Vertebrae Number	Assessment method	Left side Mean (degrees)± SD*	P value**	Right side Mean (degrees) ± SD	P value**
T1	Dissection	25.430±4.679	.009	25.500±4.767	.009
	CT scan	28.200±3.676		28.380±3.848	
T2	Dissection	23.980±4.106	.319	23.980±4.106	.319
	CT scan	24.780±2.703		24.780±2.703	
T3	Dissection	23.940±3.859	.064	23.900±3.835	.059
	CT scan	22.210±2.166		22.110±1.931	
T4	Dissection	23.410±3.103	.197	23.420±3.235	.137
	CT scan	21.880±2.120		21.740±2.115	
T5	Dissection	22.910±3.208	.052	22.850±3.199	.060
	CT scan	21.270±1.731		21.270±1.731	
T6	Dissection	22.360±2.744	.006	22.310±2.786	.007
	CT scan	19.580±1.414		19.530±1.386	
T7	Dissection	20.980±2.943	.216	20.910±3.098	.255
	CT scan	20.100±1.826		20.100±1.826	
T8	Dissection	20.990±2.787	.846	21.090±2.806	.646
	CT scan	20.840±1.289		20.750±1.394	
T9	Dissection	20.850±3.481	.946	20.670±3.659	.797
	CT scan	20.930±1.862		20.970±1.882	
T10	Dissection	21.500±3.257	.973	21.620±3.053	.963
	CT scan	21.540±1.599		21.670±1.517	

T11	**Dissection**	21.830±3.322	.942	21.750±3.234	.993
	CT scan	21.740±1.033		21.740±1.033	
T12	**Dissection**	22.020±3.131	.508	21.960±3.343	.505
	CT scan	22.780±1.004		22.760±.958	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-5. Comparison of mean screw path angle in the pedicles of the all left and right thoracic vertebrae of cadavers evaluated by Dissection and CT scan

Screwpath angle

Based on descriptive statistics for screw path angles for thoracic vertebrae on left and right side, it was understood that the measurements did not follow any definite pattern that could probably predict the method of assessment. The highest values for both methods were observed for T1. For dissection method it was (L-25.430±4.679degrees, R-25.500±4.767degrees) and CT scan it was (L-28.200±3.676 degrees, R-28.380±3.848degrees); the lowest mean values were observed for T9 in Dissection method (L-20.850±3.481degrees 20.670±3.659degrees) and for T6 in CT scan method(L-19.580±1.414 degrees,R-19.530±1.386degrees).There was a statistically significant difference($p<0.05$) between the values obtained by the two assessment methods which was noted on the left side for T1, T5 and T6; whereas on right side it was observed only for T1 and T6. (Table-5)

In the case of lumbar vertebrae, it was observed that there was an increase in mean screw path angle from L1 to L5 for both assessment methods. In dissection method the mean screw path angle measurements for L1were (L-22.220±2.992degrees, R-22.220±2.992degrees) and in CT scan they were (L-23.110±1.508degrees, 23.110±1.508degrees). In the case of L5, mean values were (L-25.280±2.240degrees, R-25.410±2.273degrees) and (L-27.670±1.063degrees, R-27.700±1.036 degrees) for dissection and CT scans respectively. For all lumbar vertebrae, CT scan values of screw path angle were higher than dissection method values and showed statistical significance($p<0.05$) for L4 and L5 on left side and only for L5 on the right side. (Table-6)

Vertebrae Number	**Assessment method**	**Left side**		**Right side**	
		Mean (degrees)± SD*	**P value****	**Mean (degrees) ± SD**	**P value****
L1	**Dissection**	22.220±2.992	.402	22.220±2.992	.402
	CT scan	23.110±1.508		23.110±1.508	
L2	**Dissection**	22.790±2.906	.218	22.810±2.924	.236
	CT scan	24.440±1.407		24.410±1.409	
L3	**Dissection**	23.480±2.663	.103	23.280±2.855	.083
	CT scan	25.680±1.380		25.720±1.446	
L4	**Dissection**	24.270±2.360	.051	24.250±2.518	.056
	CT scan	26.540±1.193		26.590±1.187	
L5	**Dissection**	25.280±2.240	.028	25.410±2.273	.035
	CT scan	27.670±1.063		27.700±1.036	

*SD- Standard deviation, **p value≤0.05 considered statistically significant based on paired samples t test

Table-6. Comparison of mean screw path angle in the pedicles of the all left and right lumbar vertebrae of cadavers evaluated by Dissection and CT scan

Discussion:

The measurements in this study have been done twice to reduce the observer variations which may impact the outcome of the preoperative planning when done in a real scenario[10]. We have observed statistically significant differences in the CT scan and dissection measurements. The differences in the CT scan measurements and the dissection measurements are in congruence with Datir and Mitra[11]. The reasons for this could be because of the angulations of the pedicles, both sagittal and transverse[13].

The CT scan measurements of pedicle width in this study are lower as was observed by other researchers[11,13,14,15]. The PW measurement in this study for the thoracic vertebrae is the lowest at the T4 level. From T5 to T12 the width consistently increases. This is in congruence with the other studies [6,11]. Studies[6,11,16]have suggested that the smallest screws with a diameter of 4.5 mm in accordance to the Caucasian population, must be used with caution at the mid thoracic levels. And our study supports that finding. Bilateral measurement differences of the PW are very low.

In the present study the lowest SPL is seen at the T1 (CT) and T2 (dissection)level bilaterally. The SPL is important assessment to be made for a better pullout strength of the screws. This means that the screws must be long enough to reach the cortical layer of the body of the vertebrae and not breach through it[17,18].

The transverse pedicle angle or the SPA in our study is least the T9(dissection) and T6(CT) level. If the CT scan measurements are considered, it means that the mid thoracic pedicles are closer to being horizontal anteroposteriorly and the lower pedicles are more antero-medially directed. This finding supports the findings of other researchers[16]. An analysis of the SPAhas been found to be of importance. The angulations of the pedicles can be a determinant to misplaced screws[19,20].

The Ct scans and dissection measurements show statistically significant differences at all the levels of the thoracolumbar spine. But the differences in all the parameters fall between Grade0 to grade 2 on the Gertzbein scale. These differences are less likely to cause a breach.

Conclusion: To conclude, our study haslow sample size and even though the differences in the pedicle measurements by the two methods are statistically significant, the CT scan measurements can't be marked off as non-real. CT scans can continue to be the method of choice preoperative planning and measurements of the pedicles. The differences may also not result in a significant breach during pedicle screw placement.But, for a robust preoperative planning in the Indian population, a computerized data of pedicle measurements is a must. This will fill in the research gap in the ethnic studies in India

Limitations: Sample size of our study is small. Gender and age factors will make the study more conclusive.

Declarations

Ethical Approval

Ethical approval (IEC:721/2020) has been obtained for the study from the Kasturba Medical College and Hospital Institutional Ethics Committee (Registration No. ECR/146/Ins/KA/2013/RR-19 and DHR Registration No. EC/NEW/INST/2019/374)

Competing interests
The authors have no conflict of interest(s)

Ms. Snigdha Mishra	Conception, design, drafting and statistical analysis in the article Collection, assembly, analysis and interpretation of the data
Dr. Mamatha H	Conception, design and revision of manuscript
Dr. Shyamasunder N. Bhat	Conception, design and final approval of article. Provision of study materials and administrative support

Authors' contributions

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