Computerized Tomographic Measurement of Thoracic Vertebral Morphology in South Indian Population

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Research Article

Abstract: Knowledge of the vertebral morphology has been seen to be crucial for the safe placement of screws in pedicle screw fixation of the spine .An analysis of the morphometric parameters of the thoracic vertebrae was done in 229 patients using computed tomography scans in south Indian population .The results show significant variation in the morphology of the vertebral body and the pedicle in Indian population when compared to other races. The measurements were seen to be greater in males than in females with the exception of the transverse angle of the pedicle. The vertebral body height was found to be progressively increasing from T1 to T12 levels and ranged from 5.8mm(cumulative) at T1 to 22.3mm (cumulative) at T12.The vertebral body width was found to decrease from T1 to T5 and again increase from T6 to T12.The cephalo-caudal height of the pedicle ranged from 7.8mm at T1 to 13mm at T12.The medio-lateral width of the pedicle was found to decrease from T1 to T5 and increase from T6 to T12; the smallest cumulative value being 4.4 mm at T4 and the largest being 6mm at T12.The cord length ranged from 30.8mm at T1 to 40.4mm at T12.The mean transverse angle of the pedicle was observed to reduce from 26.8^0 at T1 to 1.8^0 at T12.The pedicle sagittal angulation was seen to be lowest at T12 with a cumulative value of 11.57^0 and highest at T3 with a cumulative value of 17.58^0. The study shows that medio-lateral width of the pedicle is smaller from T4 to T7 levels for the use of standard pedicle screws, thus making their use difficult and risky. The cord length measurements according to the study allow the use of standard screws ranging from 25mm to 35mm.A wide variation in the dimensions is also observed between different individuals, demonstrating the need for computed tomography as a preoperative evaluation tool in each patient for choosing the appropriate implant and also to prevent complications.

Keywords: Tomographic Measurement, Thoracic Vertebral Morphology, South India.

Introduction

Racial variations in skeleton are known to exist; hence the morphometry of the vertebrae also will show variations in different populations. The anatomical variations on the pedicle shape, size and angulation have already been reported[1,2,3] but most of the studies of the vertebral morphometry have been conducted on white population. Most of the previous studies chose cadaveric specimens which were old aged at death and may be osteoporotic or osteopenic[1,2,4] and soaking of the vertebrae of cadavers in formalin for a long duration make them friable and brittle resulting in broken deminaralised vertebrae, which interferes with their measurements. Hence, these pitfalls have to be considered in the study of the spine for the usage of thoracic pedicle screws and vertebral morphology .Advanced imaging modalities such as CT and MRI provide valuable information on vertebral morphometry. Importance regarding the vertebral morphology is important while planning for transpedicular screw fixation which is widely being used for the lumbar spine but due to the smaller pedicle diameter and the variability of the thoracic pedicle, its usage in the thoracic vertebrae has been restricted[1,2]. The breach rate still remains to be 7.5%, despite the emergence of navigation techniques to avoid misplacement[5]. The present study is therefore focused on measurements using accurate digital calipers; which records the radiological parameters of an Indian population and the study is unique because of the large sample size and is a single comprehensive study of all the parameters of each of the twelve thoracic vertebrae. The results also will play a major role in the planning and designing of the implants which further strengthen the reason behind an accurate study of pedicle and vertebral morphology. This study includes the evaluation of patients with stable thoracic spines.

Materials and methods

The thoracic Computed Tomography of 229 patients was evaluated, after obtaining the consent of the patients. The study was conducted between 2006 to 2010.The patients whose data were considered ranged from 20 to 60 years .Those with spine problems was excluded from the study. A computerized tomography (BRIGHT SPEED GE 16 Slice CT) was performed with 5mm slices from T1 to T12 levels and the mid Sagittal and mid axial measurements of each vertebra were taken from the system itself using computer software (ADW 4.4 WORK STATION) for distance and angle measurements The following

measurements were taken:

a) Vertebral body height (VBH) is taken as the smallest vertical distance from the upper margin to the lower margin of vertebral body in mid-Sagittal section.(figure 1)
b) Vertebral body width (VBW) is measured as the maximum distance of the body in the mid axial slice.(figure 2)
c) Pedicle Diameter Sagittal (PDS) Or Cephalo-Caudal Height is measured as the narrowest cephalo-caudal width in the midpoint of the left pedicle in a Sagittal section.(Figure 3)
d) Medio-Lateral Width of the Pedicle (PW) is measured as the medial-lateral width in the midpoint of the left pedicle in mid -axial section.(Figure4)
e) Cord length (CL): Measured from the posterior cortical entry point of the left pedicle to the anterior vertebral cortex in the line with the axis of the pedicle[7].(figure5)
f) Transverse angle of the pedicle (TA) was measured as the angle between a line perpendicular to the transverse isthmus (medio-lateral width of pedicle) and a sagittal midvertebral line[8].(figure6)
g) Pedicle Sagittal inclination angle (PSA) was measured by drawing a line along the axis of the pedicle and another line parallel to the superior border of vertebral body(figure7)

Results

Computer Tomography was done on 229 patients of whom there were 162 males and 67 females.

The mean vertebral body height was more in males than in females at all levels and in both groups the values progressively increased from T1 to T12.The VBH ranged from 15.8mm (cumulative) at T1 to 22.3mm at T12 (Table 1).The mean vertebral width is greater in males than in females at all levels, and decreased from T1 to T5, and again increased from T6 to T12 in both groups (Table 2). The mean cephalo-caudal pedicle diameter in the study showed higher values in males as compared to females and the value ranged from 7.8mm at T1 to 13mm at T12(Table3).The results showed higher mean Pedicle width values in males than in females and among the vertebraes the measurement decreased from T1to T5 and again increased from T6 to T12.The smallest cumulative value at T4 was 4.4mm and highest value was 6mm at T12 (Table4).The cord length is greater in males compared to females and it increases from T1 to T12 with a range of 30.8mm at T1 to 40.4mm at T12(Table 5). The mean transverse pedicle angle was found to be greater in females than in males and it reduced from T1 mean value of 26.8^0 to 1.8^0 at T12 (Table 6).The study result shows a decrease in the pedicle Sagittal Angle (cumulative) from T1 to T7 and gradually increased from T8to T11. T12 had a lower value compared to T11 in both males and females (Table 7). The observations in our study were compared with previous studies using a two tailed student *t test*. If the P value was found to be less than .05 the results were considered to be significant.

Discussion

Precise knowledge of the thoracic vertebral morphology is essential while using spinal instrumentations. Information about pedicle dimensions and the angulations at each level is crucial while using pedicle screws. Racial variations in the morphology of the vertebrae are a known fact so the utility of the implants which are designed for European population may not be suitable for Indian population[1, 3, 9].The vertebral body height (VBH) results were compared with Berry *et. al.*[10] and Scoles *et. al.*[4] observations (p value =0). The comparison showed significant difference in the vertebral body height, the size of the vertebrae was found to be smaller in Indian population as compared to the European populations. The results also showed a smaller vertebral body height in females at each level as compared to males. Similar observation was noted by Scoles *et. al.*[4] .Vertebral body width when compared to Scoles *et. al.*[4] and Berry *et. al.*[10] our studies showed that the width is significantly smaller in Indian population (p value =0.). As Scoles *et. al.*[4] study shows smaller width in females, the present study also showed similar outcome. The pedicle diameter sagittal, all studies showed similar trend in the sagittal diameter. The size gradually increased from T1 to T12 it was greater in males as compared to females at each levels. The morphometry study of pedicles in Indian population by Datir [3] also showed similar results .When compared to Berry *et. al.*[10], Zandrick *et. al.*[11], Vacarro *et. al.*[7] and Scoles *et. al.*[4] the pedicle diameter in our population was significantly smaller. The study on Chinese population by Hou *et. al.*[13] also showed higher values.The results when compared were smaller because of ethnic difference. Medio lateral width of the pedicle of the present study showed a decrease in the values from T1 to T5 followed by a gradual increase from T5 to T12.All other studies showed similar pattern. The results of the present study was compared with Berry *et. al.*[10],Zandrick *et. al.*[11],Vaccaro *et. al.*[7] (European population) ,Yong Soo[2](Korean),Hou[13](Chinese) and all of them showed a significant difference in the results(P value less than 0.05).Our study was comparable to the results by Datir *et. al.*[3] on Indian population (p value more than 0.05) from T1 to T8 levels though our values were less at each levels but from T9 to T12 the values showed significant difference may be because of the use of preserved human cadavers in their study. Our study shows no correlation with Chadha *et.*

al.[14] (Indian), but their sample size was only 31 patients. The cord length measurements in our study shows significantly smaller values (p value less than 0.05) when compared with the studies of the western population which include Vaccaro *et. al.*[7] and Zindrick[11]; and Chinese population by Hou *et. al.*[13]. The mean values of Datir *et. al.*[3] correlated with the current study at T2, T8 and T12 levels. The pedicle sagittal angle of the present study was compared with Zindrick[11] and Datir *et. al.*[3] there was a correlation with which the angle progressed. All the studies showed that the value of T1 was significantly smaller than T2 and the values reduced from T2 to T7 and from T8 to T12 there was a gradual increase. The current study measurements showed significant correlation (p value more than 0.05) with Zindrick *et. al.*[11], but no comparison could be made with Datir *et. al.*[3]The difference in values maybe due to the difference in the tool and sample size. The transverse angle of the pedicle in the current study showed a higher value in females than males. The same observation was made by Scoles *et. al.*[4].The values of the transverse angle progressively reduced from T1 to T12.The same observation was noted in all other studies[3,4,11,12,13, 14].Our study showed correlation with observation by Zandrick[11] in more than one level and Datir *et. al.*[3] and Chadha *et. al.*[14] in the upper and lower levels.

Conclusion

From the current study, after comparison with existing studies, we have noted that there is significant difference in the vertebral body and pedicle morphology of Indian population from that of other races. The individual measurements were smaller in females than in males except for the transverse pedicle angle which was found to be more in females. The medio-lateral width of the pedicle was significantly smaller from T4 to T7 making standard pedicle screws impossible (the smallest available standard screw is 4.5mm).The cord length of the current study showed range between 29.7mm at T1 to 40.6mm at T12, which allows the use of standard screws of length ranging from 25mm to 35mm.The greater variability in the measurements in the current study and other studies suggests the need for computed tomography as a basic tool prior to any spine stabilization surgeries so as to choose the appropriate implant and to prevent any complications.

The current study is the largest series of computed Tomographic assessment of vertebral morphology done so far on an Indian population.

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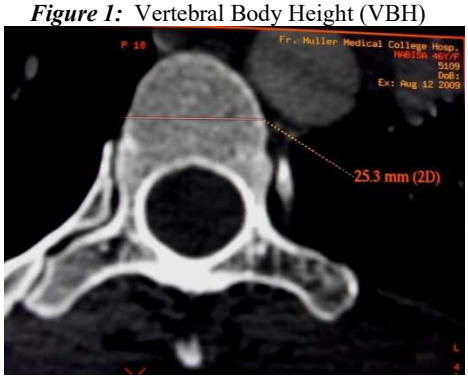
Figure 1: Vertebral Body Height (VBH)



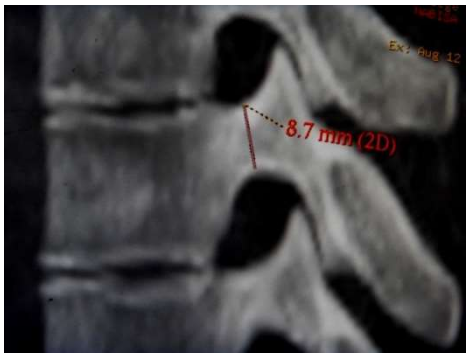


Figure 2: Vertebral Body Width (VBW)

Figure 3: Pedicle Diameter Sagittal (PDS) or Cephalo-Caudal Height
(Pedicle vertical diameter is measured as the narrowest cephalo-caudal width in the mid point of the left pedicle in a sagittal section)

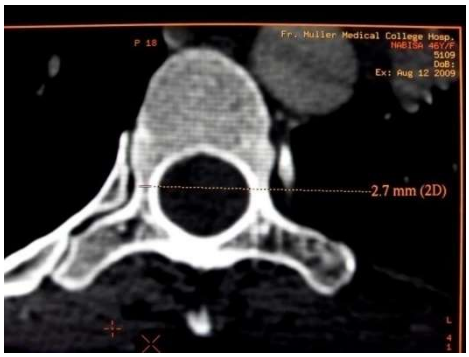


Figure 4: Medio-Lateral Width of The Pedicle (PW)
(Pedicle transverse diameter is measured as the medial-lateral width in the mid point of the left pedicle in mid -axial section)

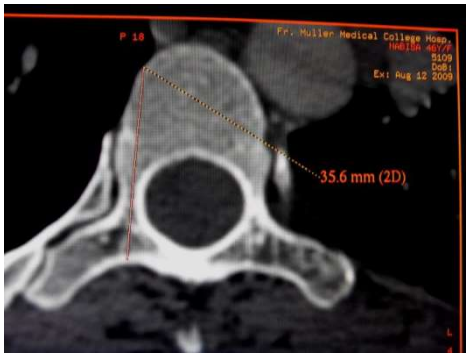


Figure 5: Cordlength (Cl)
(Measured from the posterior cortical entry point of the left pedicle to the anterior vertebral cortex in the line with the axis of the pedicle[7])

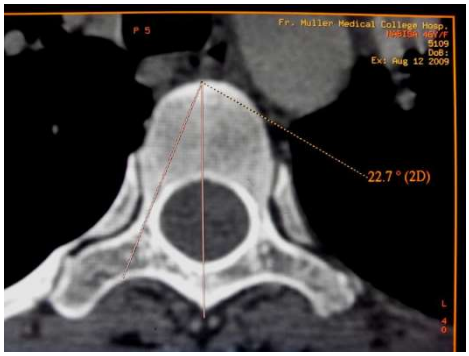


Figure 6: Transverse Angle of the Pedicle (TA)
(Transverse angle of the pedicle was measured as the angle between a line perpendicular to the transverse isthmus (medio-lateral width of pedicle) and a sagittal midvertebral line[8])

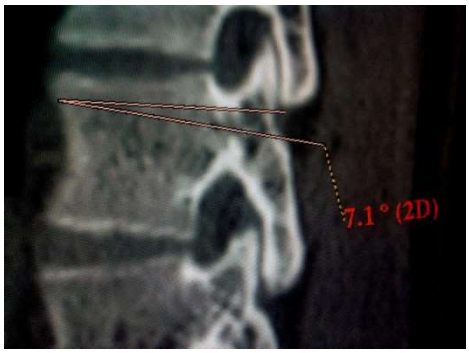


Figure 7: Pedicle Sagittal Angulation (PSA)
(Sagittal inclination angle of pedicle was measured by drawing a line along the axis of the pedicle and another line parallel to the superior border of vertebral body)

Table 1: Comparison of vertebral body height

VBH	CS*			Berry *et al*[10] (U.S)	Scoles *et al*[4](Canada)	
	Females	Males	Cumulative		Females	Males
T1	14.3±2.3	16.03±2.3	15.81 ± 2.44		15.7(0)	16.8(0)
T2	14.51±1.8	16.45±1.7	15.9 ±2	17.7(0)		
T3	14.71±1.6	16.28±1.6	15.82 ±1.8		17.6(0)	18.6(0)
T4	15.01±1.7	16.68±1.6	16.19±1.8			
T5	15.56±2.5	17.38±1.7	16.84±2.1			
T6	16.05±1.8	18.09±1.7	17.49±1.9		18.8(0)	19.8(0)
T7	16.34±1.6	18.4±1.8	17.8±2.0	20.2(0)		
T8	16.9±1.8	18.97±1.6	18.36±1.9			

T9	17.32±1.7	19.13±1.7	18.6±1.9		20.5(0)	21.8(0)
T10	18.22±2.2	20.26±1.9	19.66±2.2			
T11	19.46±2.2	21.3±1.8	20.75±2.1			
T12	21.12±2.8	22.8±1.9	22.31±2.3	23.9(0)	24.6(0)	25.9(0)

*Current Study

Note: value given in brackets stands for P value

Table 2: Comparison of vertebral body width

VBW	CS*				Scoles *et al*[4] (Canada)	
	Females	Males	Cumulative	Berry *et al*[10](U.S)	Females	Males
T1	25.22±2.6	28.125±2.5	27.27±2.8		26.7(0)	26.4(0)
T2	24.45±2.1	26.97±2.5	26.23±2.6	28.1(0)		
T3	23.45±3.2	26.46±2.4	25.58±3.0		24.1(0.1011)	27.6(0)
T4	22.88±1.9	27.22±2.4	25.94±2.4			
T5	22.41±3.0	26.09±2.1	25.01±2.9			
T6	23.17±2.3	26.75±2.3	25.7±2.8		26(0)	28.7(0)
T7	24.5±2.3	27.4±2.2	26.54±2.6	28(0)		
T8	24.73±2.0	27.97±2.5	27.03±2.8			
T9	25.8±2.5	28.51±2.4	27.71±2.7		29.3(0)	32.5(0)
T10	27.05±2.5	30.55±2.4	29.53±2.9			
T11	28.93±2.9	32.81±3.1	31.68±3.5			
T12	31.06±3.7	35.33±3.1	34.08±3.5	37.6(0)	37.5(0)	41.7(0)

Table 3: Comparison of Pedicle diameter cephalo-caudal (PDS)

TA	CS*			Scoles et al[4]					
	Females	Males	Cumulative	Females	Males	Yong Soo[12] (korean)	Datir et al[3]	Zindrick[11]	Chadha et al[14]
T1	26.42±2.1	27.83±2.5	26.8±2.7	26.4(0.8855)	29.8(0)	30.2(0)	27(0.2643)	27(0.2643)	
T2	18.72±2.3	18.95±1.5	18.4±2.1			18.4(1)	18(0.0043)	20(0)	
T3	15.03±1.9	14.97±1.8	14.6±2.0	15.5(0.0560)	15.3(0.697)	12.5(0)	10(0)	15(0.0028)	
T4	13.12±3.2	11.32±2.1	11.5±2.5			11(0)	7(0)	13(0.6023)	
T5	11.3±1.8	10.12±1.9	10.2±2.1			9.4(0)	5(0)	9(0)	
T6	9.52±2.3	8.47±2.6	8.5±2.5	10.9(0)	10.2(0)	8.8(0.0402)	5(0)	10(0)	
T7	8.32±3.1	7.42±3.5	7.5±3.2			8.7(0)	4(0)	9(0)	
T8	7.97±2.4	7.1±2.6	7.1±2.7			8.5(0)	2(0)	8(0)	
T9	7.2±2.5	6.67±2.1	6.6±2.5	10.3(0)	9.2(0)		2(0)	8(0)	5.42(0)
T10	5.53±2.6	5.19±1.9	5.1±2.5				3(0)	5(0.2273)	5.16(0.7168)
T11	2.21±3.1	2.16±2.7	2.1±3.1				0(0)	1(0)	-2.97(0)
T12	2.01±2.7	1.91±2.2	1.8±2.4	11.6(0)	9.5(0)		0(0)	4(0)	-3.0(0)

Table 4: Comparison of transverse angle of pedicle

TA	CS*				Scoles et al[4] (Canada)					
	Females	Males	Cumulative	Berry et al[10] (U.S)	Females	Males	Zindrick et al[11]	Shuxun Hou[13](Chinese)	Vaccaro et al[7]	Datir et al[3]
T1	6.57±1.4	7.3±1.2	7.08±1.3		8.4(0)	9.2(0)	9.9(0)			8.8(0)
T2	7.7±1.5	8.72±1.9	8.42±1.8	11.9(0)			12(0)			10.8(0)
T3	8.04±1.3	9±0.8	8.71±0.8		10.6(0)	11.8(0)	12.4(0)			10.6(0)
T4	7.99±1.3	9.29±1.5	8.91±1.6				12.1(0)		10.1(0)	10.3(0)
T5	8.02±1.3	9.24±1.5	8.88±1.6				11.9(0)		10(0)	10.8(0)
T6	8.3±1.0	9.38±1.4	9.06±1.2		10.6(0)	11.5(0)	12.2(0)		10.1(0)	10.4(0)
T7	8.56±1.4	9.68±16	9.35±1.6	11.9(0)			12.1(0)		10.8(0)	11.3(0)
T8	9.29±1.4	10.2±1.5	9.94±1.5				12.8(0)		11.1(0)	12.1(0)
T9	10.08±2.9	10.86±1.7	10.63±2.2		12(0)	12.9(0)	13.8(0)	12.9(0)	12.3(0)	13(0)
T10	10.74±2.0	11.88±2.1	11.54±2.1				15.2(0)	14.3(0)	14.1(0)	14.5(0)
T11	11.87±2.1	12.91±2.2	12.6±2.2				17.4(0)	16.2(0)	15(0)	15.9(0)
T12	11.88±1.7	13.3±2.0	12.89±2.1	17(0)	14.8(0)	16(0)	15.8(0)	16.6(0)	14.7(0)	17.1(0)

Table 5: Comparison of Medio-Lateral Width of thePedicle

PW	CS*			Berry et al[10](U.S)	Zindrick et al[11]	Yong Soo[12] (korean)	Shuxun Hou[13] (Chinese)	Vaccaro et al[7]	Datir et al[3]	Chadha et al[14]
	Females	Males	Cumulative							
T1	5.9±1.2	6.59±1.2	6.38±1.3		7.9(0)	7.66(0)			5.8(0)	
T2	5.13±1.0	5.6±1.2	5.5±2.8	6.3(0)**	7(0)	6.36(0)			5.4(0.5894)	
T3	4.19±0.9	4.63±1.5	4.5±1.4		5.6(0)	4.71(0.0241)			5.4(0)	
T4	3.9±0.8	4.23±0.9	4.13±2.8		4.7(0.0023)	4.38(0.1780)		4.5(0.0467)	3.6(0.0046)	
T5	3.71±0.7	4.25±1.0	4.09±0.9		4.5(0)	4.49(0)		4.4(0)	4(0.1316)	
T6	3.9±0.9	4.5±0.9	4.33±0.9		5.2(0)	4.67(0)		4.6(0)	4(0)	
T7	3.65±0.7	4.59±0.9	4.31±1.0	4.8(0)	5.3(0)	4.89(0)		4.9(0)	4.4(0.1746)	
T8	3.87±0.9	4.79±1.0	4.52±2.1		5.9(0)	5.23(0)		5.1(0)	4.5(0.8855)	
T9	4.03±0.8	4.73±1.1	4.52±1.1		6.1(0)		6(0)	5.8(0)	5(0)	5.02(0)
T10	4.53±1.0	5.33±1.3	5.1±1.3		6.3(0)		7(0)	6.7(0)	5.7(0)	6.34(0)
T11	5.01±1.1	5.9±1.4	5.64±1.4		7.8(0)		8.6(0)	8(0)	7.4(0)	6.51(0)
T12	5.41±1.3	6.25±1.5	6.01±1.5	7.6(0)	7.1(0)		8.8(0)	7.8(0)	7.7(0)	7.33(0)

Table 6: Comparison of Cord Length

CL	CS*			Scoles et al[4] (Canada)					
	Females	Males	Cumulative	Females	Males	Vaccaro et al[7]	Datir et al[3]	Zindrick[11]	Hou et al[13]
T1	27.63±2.8	30.56±3.3	29.7±3.5	29.1(0.0001)	32(0)		31.1(0)	36.9(0)	
T2	28.5±3.5	32.15±4.2	31.08±4.3				31(0.7786)	35.7(0)	
T3	31.16±3.1	34.37±2.9	33.43±3.3	30.1(0.0034)	31.6(0)		28.8(0)	37.7(0)	
T4	32.49±3.2	36.14±3.4	35.08±3.8			44.1(0)	31.8(0)	38.5(0)	
T5	34.51±2.9	38.15±2.9	37.09±3.3			39.3(0)	34.7(0)	41.9(0)	
T6	34.78±4.7	39.56±3.1	38.16±4.2	35.7(0.1139)	37.7(0)	38.9(0.0082)	36.1(0)	42.1(0)	
T7	35.63±5.0	40.15±2.9	38.83±4.2			43.6(0)	36.8(0)	42.6(0)	
T8	36.9±4.4	40.56±2.9	39.49±3.8			44.7(0)	39.8(0.2183)	45.4(0)	
T9	37.13±2.7	40.61±3.5	39.59±3.7	38.9(0)	41.9(0)	43.5(0)	40.6(0.0001)	45.2(0)	43.6(0)
T10	36.8±2.8	40.73±2.8	39.58±3.4			44.1(0)	38.8(0.0006)	44(0)	44.2(0)
T11	36.92±2.9	40.37±3.0	39.36±3.4			40.8(0)	38.6(0.0008)	41.8(0)	44.6(0)
T12	37.94±3.5	41.5±3.4	40.46±3.8	42(0)	43.3(0)	46.6(0)	40.1(0.1530)	38.6(0)	49.1(0)

Table 7: Comparison of Pedicle Sagittal Angulation

PSA	CS*		Cumulative	Datir et al[3]	Zindrick et al[11]
	Females	Males			
T1	12.44±6.4	13.17±6.8	12.95±6.7	7.7(0)	12.6(0.43)
T2	18.35±5.8	19.73±5.1	19.32±5.4	10.4(0)	17.5(0)
T3	17.12±5.9	17.77±4.8	17.58±5.1	9(0)	17.3(0.4069)
T4	14.8±4.9	15.87±4.2	15.56±4.4	8.6(0)	16.3(0.0116)
T5	14.06±2.7	14.73±3.5	14.53±3.3	8.2(0)	15(0.0322)
T6	14.54±4.1	14.83±2.6	14.74±3.1	7.6(0)	15(0)
T7	14.48±2.3	15.03±2.4	14.87±2.4	8.3(0)	15.7(0)
T8	15.9±2.8	16.59±2.3	16.38±2.5	7.2(0)	16.6(0.1843)
T9	15.83±2.4	16.01±2.3	15.95±2.4	6.7(0)	16(0.7528)
T10	16.0±3.0	16.34±2.4	16.24±2.6	5.5(0)	16.8(0.0013)
T11	15.17±2.6	15.47±2.9	15.38±2.8	6.1(0)	15.4(0.9140)
T12	10.95±3.0	11.83±3.0	11.57±3.0	7.5(0)	11.6(0.8799)