

A DRY BONE STUDY OF THORACIC SPINE PEDICLE TRANSVERSE DIAMETERS IN A KENYAN POPULATION

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ABSTRACT

Background: The size of the pedicle screw utilized in spinal fixation is determined by the transverse diameter of the pedicle at the isthmus. This diameter has not been documented in dry bone specimens in an African population.

Objective: To determine the outer transverse diameter of the thoracic pedicles at the isthmus using a vernier caliper in a Kenyan population, and compare this with published literature.

Methods: One hundred thoracic spine cadaveric specimens were studied at the National Museums of Kenya. The diameters of both right and left pedicles at the isthmus of all the twelve thoracic vertebrae in each specimen were measured directly using a vernier caliper. The results were summarized with measures of central tendency and compared with results from previous studies using the student's t-test.

Results: The mean transverse diameter of the pedicle measured at the isthmus was: 7.2mm at T1, 5.3mm at T2, 4.3mm at T3, 3.7mm at T4, 3.7mm at T5, 4.0mm at T6, 4.4mm at T7, 4.3mm at T8, 5.0mm at T9, 5.9mm at T10, 7.4mm at T11 and 7.6mm at T12. The overall range was 1.3mm to 12.3mm. These measurements were much smaller than those of European and American studies; but were comparable to those in Indian studies.

Conclusions: The trend in diameter between T1 and T12 within a specimen is like in previous studies. The variability in pedicle diameter between specimens is marked, denoting heterogeneity in the study population.

Recommendations: The pedicle diameter variability precludes a recommendation of the appropriate pedicle screw diameter to be used in surgery. Further studies on the influence of demographic factors on pedicle transverse diameter are recommended.

Key words: Thoracic pedicle morphometry, Diameter

INTRODUCTION

The outer transverse diameter of the thoracic pedicle as measured at the isthmus has been documented in various studies, including American, Chinese, French, Malay, Korean, Greek and Indian populations among others (1-11). This transverse diameter of the pedicle at the isthmus determines the diameter of the pedicle screw to be used in spinal fixation surgery (12). Spinal fixation surgery has been on the increase in Africa in the last two decades. Despite this, no studies could be found that have documented the diameter of the thoracic spine pedicles in an African population as measured in dry bone specimens. Consequently, this study sought to determine the diameter of the thoracic spine pedicle in a Kenyan population and discuss this in relation to previous studies.

MATERIALS AND METHODS

Three hundred individual cadaveric thoracic spine specimens of Kenyan descent were available for study at the National Museums of Kenya. All the specimens had been examined by a pathologist prior to preservation at the museum. All adult specimens were eligible for the study. Institutional Research and Ethics Committee (IREC) approval was obtained. The specimens were handled with respect as required by the Kenyan Anatomy Act. Specimens that did not demonstrate all the 12 thoracic vertebrae or whose pedicle integrity was compromised were excluded from this study. One hundred thoracic specimens were found to be appropriate for study and were included in this study. Using a vernier caliper, both right and left pedicles diameters were obtained at the isthmus in all the twelve thoracic vertebrae of each cadaver, by one investigator (E.N.M.). This is shown in Figure 1.

Figure 1
Measurement technique



Pedicle measurements were summarized using measures of central tendency and presented in tables. Histogram and box plots were plotted to show the distribution of measurement values graphically. Statistical difference in measurements between right and left side pedicles was evaluated using t-test for paired samples. The results for both right and left pedicles were pooled and analyzed. The mean, median, standard deviation, range and interquartile range for each thoracic level was determined and summarized in table. These results were compared with similar studies published in literature by use of a t-test. The studies in literature chosen must have had pooled means for all the twelve thoracic vertebra levels and accompanying standard deviations. The authors of publications that did not document the standard deviations were contacted by email and asked to provide the same.

RESULTS

A total of 2400 measurements were made on one hundred thoracic spine cadaveric specimens. Test of normality for individual side of pedicle showed that most pedicles had values that assumed Gaussian distribution. Comparing Tables 1 and 2, only T5 and T7 had values that violated Gaussian distribution on both sides (right and left).

Table 1
Pedicle diameter measurement in millimeters

Vertebral level	Right		Left	
	Mean (SD)	Range	Mean (SD)	Range
T1	7.3(1.3)	3.9 - 10.7	7.2(1.2)	4 - 9.9
T2	5.4(1.1)	3.2 - 8.6	5.3(1.1)	3 - 8.1
T3	4.3(0.9)	2.2 - 6.8	4.3(1.0)	2.1 - 7.8
T4	3.7(0.9)	1.3 - 6.2	3.8(1.0)	1.7 - 6.8
T5	3.7(1.1)	1.6 - 8.2	3.6(1.1)	1.3 - 6.8
T6	4.1(1.1)	2.4 - 8.2	3.8(1.2)	1.7 - 7.5
T7	4.5(1.2)	2.2 - 8.2	4.3(1.3)	2.1 - 8.7
T8	4.7(1.2)	2.5 - 7.8	4.7(1.2)	2.0 - 8.0
T9	5.0(1.3)	2.3 - 8.1	4.9(1.3)	2.6 - 8.2
T10	6.0(1.5)	3.2 - 10.6	5.8(1.5)	2.7 - 11.3
T11	7.4(1.8)	3.7 - 12.1	7.4(1.9)	3.9 - 11.8
T12	7.6(1.6)	3.2 - 12.3	7.5(1.6)	4.2 - 12.3

Table 2
Difference in means between right and left pedicles

Vertebral level	Right side Mean (SD)	Left side Mean (SD)	t	P-value
T1	7.3(1.3)	7.2(1.2)	0.666	0.506
T2	5.4(1.1)	5.3(1.1)	1.292	0.199
T3	4.3(0.9)	4.3(1.0)	-0.565	0.572
T4	3.7(0.9)	3.8(1.0)	-0.391	0.696
T5	3.7(1.1)	3.6(1.1)	1.658	0.100
T6	4.1(1.1)	3.8(1.2)	4.536	0.000
T7	4.5(1.2)	4.3(1.3)	2.095	0.038
T8	4.7(1.2)	4.7(1.2)	0.464	0.643
T9	5.0(1.3)	4.9(1.3)	1.200	0.233
T10	6.0(1.5)	5.8(1.5)	2.055	0.042
T11	7.4(1.8)	7.4(1.9)	0.454	0.650
T12	7.6(1.6)	7.5(1.6)	1.002	0.318

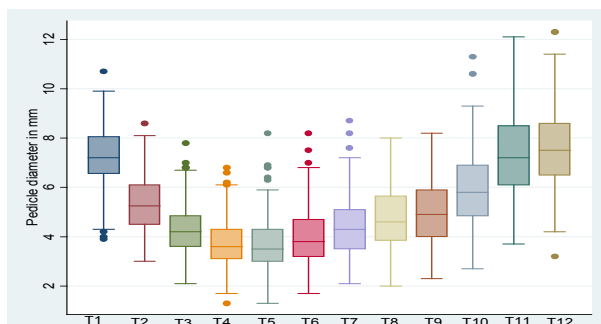
Generally, the right side had higher or equal mean values compared to the left, apart from T3 and T4 where left side had higher average measurements values. On average T6, T7 and T10 had right pedicles with significantly higher measurements compared to the left side ($p < 0.05$). Since the differences in pedicle diameter for left and right were judged to be clinically insignificant, pooled measurements were used to determine the average sizes of different pedicles.

Table 3
Summary statistics for pooled pedicle measurements

Vertebra	Observations	Mean (mm)	Std. Dev.	Median (mm)	IQR (mm)	Min (mm)	Max (mm)
T1	200	7.2	1.25	7.2	6.55, 8.05	3.9	10.7
T2	200	5.3	1.07	5.3	4.50, 6.10	3.0	8.6
T3	200	4.3	0.96	4.2	3.60, 4.85	2.1	7.8
T4	200	3.7	0.97	3.6	3.10, 4.30	1.3	6.8
T5	200	3.7	1.09	3.5	3.00, 4.30	1.3	8.2
T6	200	4.0	1.16	3.8	3.20, 4.70	1.7	8.2
T7	200	4.4	1.23	4.3	3.50, 5.10	2.1	8.7
T8	200	4.3	1.17	4.6	3.85, 5.65	2.0	8.0
T9	200	5.0	1.30	4.9	4.00, 5.90	2.3	8.2
T10	200	5.9	1.48	5.8	4.85, 6.90	2.7	11.3
T11	200	7.4	1.82	7.2	6.10, 8.50	3.7	12.1
T12	200	7.6	1.61	7.5	6.50, 8.60	3.2	12.3

The mean diameter of the thoracic pedicle was highest at T12 measuring 7.6mm (SD 1.61). This decreases gradually towards the middle reaching the lowest value of 3.7mm (SD 1.09) at T5 and 3.7mm (SD 0.97) at T4. Thereafter the mean pedicle diameter increases gradually to a maximum value of 7.2mm (SD 1.25) at T1.

Figure 2
Distribution of pooled pedicle measurements in millimeters



As shown in the box plot (Figure 2) most of the extreme (outliers) values were on the upper side of the average values for both right and left pedicles. In addition, the variation in measurements (measurement ranges) were highest at T10, T11, and T12.

The median value of pedicle diameter at T12 is 7.50 (IQR 6.50, 8.60) mm. This value decreases gradually to 3.50 (IQR 3.00, 4.30) mm at T5, and thereafter increases gradually to 7.2 (IQR 6.55, 8.05) mm at T1.

Results from five publications were found appropriate for comparison with the results of the current study. The mean diameters found by Panjabi *et al* (1), Yu *et al* (2,3), Zindrick *et al* (4) and Ugur *et al* (8) were significantly larger than those found in the current study. The results of Gangadhara (10) were not significantly different from our results as determined by the student's t-test. Standard deviations were not available in six studies and therefore the results could not be compared with those of the current study.

Table 4
Thoracic spine pedicle diameters from other studies and the current study

Study	Panjabi <i>et al</i> (1)	Yu <i>et al</i> (2,3)	Zindrick <i>et al</i> (4)	Liau <i>et al</i> (5)	Chaynes <i>et al</i> (13)	Kim <i>et al</i> (7)	Ugur <i>et al</i> (8)	Datir & Mitra(9)	Datir & Mitra(9)	Gangadhara(10)	Roop <i>et al</i> (11)	Current Study
Race	American	American	American	Malaysian	French	Korea	Turkish	Indian	Indian	Indian	Indian	Kenyan
Method	3-D morphometer	DIR	CT	CT	DIR	CT	DIR	DIR	CT	DIR	DIR	DIR
Cases	N=12	N=503	N=24-36	N=180	N=10	N=73	N=20	N= 18	N=18	N=20	N=100	N= 100
Thoracic Level												
T1	8.5*	8.65*	7.9*	7.97	8.3	8.1	6.5*	7.3	5.8	6.98**	7.72	7.2
T2	8.2*	7.08*	7.0*	6.69	6.5	6.1	5.9*	6.3	5.4	5.62**	6.22	5.3
T3	6.8*	5.77*	5.6*	5.32	5.9	4.6	5.1*	5.2	5.4	4.43**	5.03	4.3
T4	6.3*	5.10*	4.7*	4.27	5.4	4.2	4.5*	4.8	3.6	3.90**	4.53	3.7
T5	6.0*	5.07*	4.5*	4.42	4.9	4.3	4.6*	4.7	4.0	3.93**	4.22	3.7
T6	6.0*	5.38*	5.2*	4.64	5.1	4.7	4.9*	5.0	4.0	4.28**	4.58	4.0
T7	5.9*	5.66*	5.3*	4.77	5.7	4.8	5.4*	5.4	4.4	4.77**	4.82	4.4
T8	6.7*	5.98*	5.9*	4.87	6.4	5.1	5.6*	5.4	4.5	4.95*	4.82	4.3
T9	7.7*	6.53*	6.1*	5.27	6.4	5.2	6.1*	5.9	5.0	5.59**	5.33	5.0
T10	9.0*	7.78*	6.3**	5.99	7.4	6.3	6.2**	6.7	5.7	6.66*	6.10	5.9
T11	9.8*	9.31*	7.8**	6.78	9.3	7.9	7.4**	8.2	7.4	7.55**	7.36	7.4
T12	8.7*	9.19*	7.1**	7.16	8.9	7.9	7.6**	8.7	7.7	7.88**	7.94	7.6

Key: t-test *Significantly different **Not significantly different No asterisk - Significance test not done

DISCUSSION

The widest pedicles in the thoracic spine were found at T12, T11 and T1 vertebral areas, in decreasing order of size. This value decreases with cranial advancement from T12 toward the mid-thoracic spine, where the narrowest pedicles were located at the T5 and T4 areas. Progressive enlargement occurs from this area up to the T1 vertebra. This trend is like what has been found in published studies from other populations as demonstrated by Table 4.

The absolute mean values, however, are smaller than those found in American and European studies. The largest diameters have been recorded in the

American study by Panjabi *et al* (1) using a three-dimensional morphometer. The rest of the studies were either CT-based or used direct manual measurement using calipers. This difference may be attributable to this tool. CT scan has been reported to demonstrate smaller values than direct measurements. In spite of this, the findings in the current study are still smaller than the CT measurements found in the American and European studies. Direct measurement, as used in the current study, is considered the most accurate method of determining the transverse diameter of the thoracic pedicle. The Indian study by Gangadhara (10) gave similar values. Generally, the values recorded by Datir & Mitra (9), and Roop *et al* (11) closely approximate

our values. However, this could not be determined statistically in the absence of standard deviations. Similarly, the results of the Malaysian, French and Korean studies (recorded by Liao *et al* (5), Kim *et al* (7), Chaynes *et al* (13) and respectively) could not be subjected to statistical significance testing as shown in Table 4.

The specimens used in this study were of peoples that had died in the 1950s in one region of the country. Gender was only identified on half of study samples. Other demographic profiles could not be determined either. The causes of death were also unclear. The specimens had been boiled to remove soft tissues. These factors could have had an influence on the results. However, all distorted specimens were excluded from the current study to eliminate potential sources of error.

The high ranges between the minimum and maximum values on each pedicle could be an indication of heterogeneity in the population sampled. That is, some individuals having larger pedicles diameters than others, consistently across all pedicles. Therefore, use of the above calculated means to determine the size of screw for each pedicle is not practical. Further study of this heterogeneity using demographic information such as age, size (height, weight), and sex may help in discriminating the individual according to the pedicle sizes.

CONCLUSIONS AND RECOMMENDATIONS

The cranio-caudal trend in mean pedicle diameter between T12 and T1 within a specimen is like previous studies. The absolute mean pedicle diameters differ from studies done in Caucasian populations. The variability in pedicle diameter between specimens is marked, denoting heterogeneity in the study population. This variability precludes a recommendation of the appropriate pedicle screw diameter to be used in surgery. Further studies on the influence of demographic factors on pedicle transverse diameter are recommended.

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