MORPHOMETRIC ANALYSIS OF LUMBAR PEDICLES AMONG ADULT KENYANS USING COMPUTER TOMOGRAPHY SCANS AND DRY BONE SPECIMENS

V.O Misiani, MBChB, MMed (Ortho), **E.N. Muteti,** PhD, MMed, FCS(Ortho), Department of Orthopaedics and Rehabilitation, School of Medicine, Moi University/Moi Teaching and Referral Hospital, Eldoret, Kenya and **M.G.Y. ElBadawi,** PhD, (Human Anatomy), Department of Human Anatomy, School of Medicine, Moi University, Eldoret, Kenya.

Correspondence to: Dr. Oteki Misiani, P. O. Box 78516-00507, Nairobi, Kenya. Email: otekimisiani@yahoo.com

ABSTRACT

Background: The use of pedicle screws in the lumbar spine is guided by the dimension and orientation of the lumbar pedicle.
Objectives: To determine the width, angulation and chord length of the lumbar vertebrae pedicle from L1 to L5 in adult Kenyans using Computer tomography scans and dry bone specimens.
Methods: Three hundred and thirty dry bones, 100 samples were selected systematically, and 100 CT scans from 468 lumbar spine scans. Results from the analysis were summarized as means, standard deviations and presented in line and bar graphs**.**
Results: Pedicle width mean measurements were L1-8.6mm, L2-9.6mm, L3-11.4mm, L4-13.5mm, L5-16.3mm on dry bone specimens. On CT scan pedicle width mean measurements were L1-7.2mm, L2-7.6mm, L3-9.2mm, L4-10.8mm, L5-14. 6mm. The mean angle of insertion on CT scan was L1-19.7°, L2-20.5°, L3-22°, L4-24.1°, L5-29.8°. Pedicle chord length measurements obtained were L1-47.9mm, L2-48.9mm, L3-48.9mm, L4-47.7mm, and L5-47.0 mm on dry bone specimen. On CT scan it was, L1-48.6mm, L2-49.9mm, L3-50.1mm, L4-49.8mm, and L5-50.1 mm.
Conclusion: The pedicle width on CT scan measurements increased from 7.2mm to 14.6mm and on dry bone specimen it increased from 8.6mm to 16.3mm between L1 to L5. The angulation increased from L1 to L5 on CT scan measurements from 19.7° at L1 to 29.8° at L5**.** The chord length range measurement on dry bone specimen ranged from 47.9mm to 48.9mm and on CT scan from 48.6mm to 50.1mm.

Key words: Lumbar pedicle morphometry, Chord length

INTRODUCTION

The morphometric characteristics of the vertebrae, especially the pedicle, determine the size of pedicle screw length, shape, direction, and ideal angulation at the moment of introduction. Knowledge of this is important for the surgeon to avoid pedicle cortex violation that would lead to dural tears, nerve root injuries, viscera or adjacent vascular structure lesions due to poor placement or improper screw orientation (1). The success of the transpedicular screw fixation technique depends on the size of the pedicle, the trajectory, the screw size used and the quality of the vertebral body (2).

MATERIALS AND METHODS

At the National Museum of Kenya all the specimens had been examined by two pathologists prior to preservation. All adult specimens of vertebral spine bones 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. One hundred lumbar specimens were found to be appropriate for study and were included in this study. Inclusion criteria involved computerized scans of patients whose age ranged between 18 and 65 years and dry bones of fully ossified and well

preserved dry bones from the National Museums of Kenya, Nairobi. Exclusion criteria included computerized scans of patients with lumbosacral deformities such as scoliosis, spina bifida, traumatic fractures with damage to the middle and posterior columns, kyphosis and any other pathology that have destroyed the normal lumbar pedicle anatomy. Using a digital caliper, pedicle diameters were obtained in all the five lumbar vertebrae of each specimen by one investigator. The pedicle width was also obtained on computer tomography scans pedicle measurements were summarized using measures of central tendency and presented in Figures 1-4.

Figure 1

Dry bone pedicle width measurement

Figure 2

CT scan pedicle with measurement

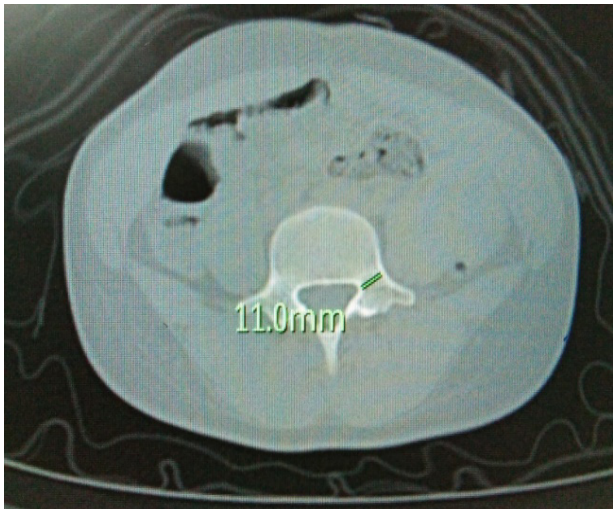
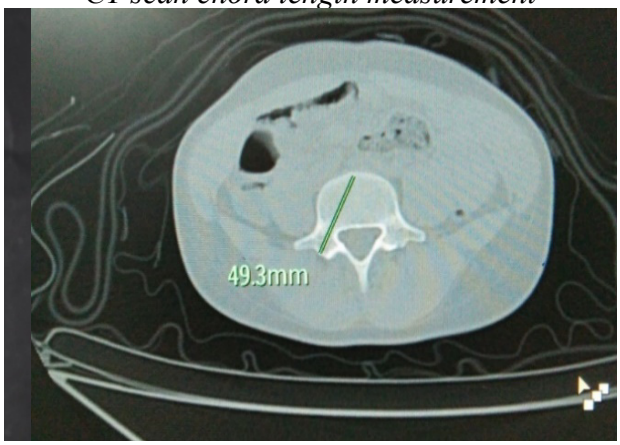


Figure 3

Dry bone chord length measurement

Figure 4

CT scan chord length measurement



Transverse dimension

Measuring of the transverse diameter: The transverse diameter which is the medial-lateral outer cortical width of the pedicle was measured both on dry bone specimens and computer tomography scans. The results obtained are represented in Tables 1 and 2. The mean, maximum and minimum measurements obtained on Computer tomography scans and dry bone measurements.

Chord length

Measuring the pedicle chord length: The best method of determining true pedicle dimensions is by direct and careful measurement of cadaveric specimens. Means, standard deviation, and minimum to maximum values for each were measured and tables were constructed using these data.

Chord length dimensions: The chord length measurements were obtained from 100 dry bone specimens and 100 Computer tomography scans. The mean was then obtained at each lumbar vertebral level and summarized in Tables 3 and 4.

Angulation measurement

The study established the angulation of the pedicle, measured from the midline to the mid-axis of the pedicle. The summary of the results is represented in Table 5**.**

RESULTS

A total of 1000 measurements were made on one hundred lumbar spine specimens.

The findings summarized in Table 1 revealed that Lumber five (L5) had the widest diameter with a maximum of 18mm, a minimum of 8.6mm and an average of 14.6mm based on CT scan measurements. A gradual increment was noted from L1 to L5 both on dry bone measurement and computerized tomography measurements.

Table 1

Transverse dimensions measured on CT scan in millimeters (mm)

	L1	L2	L3	L4	L5
Mean	7.2	7.6	9.2	10.8	14.6
[95% C. I]	[6.8, 7.6]	[7.2, 8.0]	[8.7, 9.6]	[10.3, 11.3]	[14.1, 15.2]
SD	1.5	1.5	1.6	1.8	2.1
Maximum	10.9	10.4	12.9	13.9	18
Minimum	4.8	4.9	5.5	7	8.6

Table 2

Transverse dimensions measured on dry bones in millimeters (mm)

	L1	L2	L3	L4	L5
Mean	8.6	9.6	11.4	13.5	16.3
[95% C. I]	[8.3, 8.9]	[9.2, 10.0]	[10.9, 11.9]	[13.0, 14.1]	[15.8,16.8]
SD	1.1	1.6	1.9	2.1	1.7
Maximum	10.8	12.8	14.8	16.3	20.2
Minimum	5.3	5.9	8	8	11.8

Table 2 shows there is an increment in the average transverse dimensions in the dry bones from 8.6mm to 16.3mm at L1 and L5 respectively. This was evident from the shortest minimum transverse dimensions of 5.3mm at L1 and the longest minimum transverse dimensions of 11.8mm at L5. In the same view, the maximum transverse dimensions were 10.8mm at L1 and the longest transverse dimensions was 20.2mm at L5.

Table 3

Average chord lengths of dry bone specimens using Vernier caliper in millimeters (mm)

Lumbar vertebrae	L1	L2	L3	L4	L5
Mean	47.99	48.9	48.9	47.7	47.0
[95% CI]	[47.3, 48.6]	[48.4, 49.5]	[48.4, 49.5]	[47.2, 48.2]	[46.5, 47.5]
SD	2.3	1.9	2.1	1.9	1.8
Longest	54	55	55	54	54
Shortest	43	46	44	44	43

From the data collected on the dry bone specimens the longest mean length obtained was at lumbar vertebrae 3 and lumbar vertebrae 2 with a mean of 48.9mm. The range obtained was from 55mm to 43mm.The longest being at lumbar vertebrae 2 and lumbar vertebra 3-55mm and the shortest being at lumbar vertebrae 1 and lumbar vertebrae 5-43mm.

Table 4

Average chord lengths based on computer tomography scans in millimeters (mm)

Lumbar vertebrae	L1	L2	L3	L4	L5
Mean	48.6 [47.4, 49.8] 4.2	49.9 [48.9, 50.9] 3.5	50.1 [49.3, 50.9] 2.8	49.8 [48.9, 50.7] 3.2	50.1 [49.1, 51.0] 3.3
Longest	59.5	59.9	58.5	57.3	57.4
Shortest	38	42.3	44.8	43.8	41.9

From the data collected on the Computer tomography scans the longest mean length obtained was at lumbar vertebrae 3 and lumbar vertebrae 5 with a mean of 50.1mm. The range obtained was 59.9mm to 38mm. The longest chord length was at lumbar vertebrae 2 with-59.9mm and the shortest lumbar vertebrae being at L1-38.0mm.

Table 5

Angle of insertion in degrees

	L1	L2	L3	L4	L5
Mean [95% C. I]	19.7 [19.1, 20.4]	20.5 [19.8, 21.1]	22 [21.4, 22.6]	24.1 [23.6, 24.7]	29.8 [29.0, 30.6]
SD	2.4	2.4	2.2	1.9	2.9
Maximum	25.4	25.9	26.9	28.3	36
Minimum	15.4	12.5	18.4	20.2	23.1

The study observed an average subsequent increment of 2^0 in subsequent lumbar vertebrae. Lumber five (L5) had the largest angle of insertion of 29.8^0 followed by lumber four (L4) had an average of 24.1^0. Lumber three (L3) had an average angle of insertion of 22.0^0. Lumber two (L2) had an average angle of insertion of 20.5^0 whereas lumber one had an average angle of insertion of 19.7^0. These measurements were based on CT scan.

Angle of insertion among male and female population

The study measured angle of insertion and recorded the differences and variations in different age groups of both sexes. The results are as shown in Table 6.

Table 6 shows that the female population has slightly wider angulations of the pedicle from the midpoint as compared to the male population. The angle of insertion in female pedicles range between 16^0 at L1 and 36^0 at L5. The angle of insertion in the male population had a range between 15.4^0 to 35.3^0 from L1 to L5.

Table 6

Comparison between angle of insertion among males and females

	L1		L2		L3		L4		L5	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	19.3	20.1	20.6	20.3	21.8	22.2	23.8	24.4	29.4	30.2
Max	15.4	23.3	24.4	25.9	26.9	26.8	28.2	28.3	35.3	36
Min	25.4	16	17	12.5	18.8	18.4	20.2	21.5	24.6	23.1

DISCUSSION

Morphometric analysis lumbar pedicles

The study evaluated lumbar vertebral pedicle width of the Kenyan population using Computed Tomography (CT) and dry bone measurement reporting a minimum mean value of 7.2mm and 8.6mm at L1 respectively and a mean maximum of 14.6mm and 16.3mm at L5 on CT scan based measurements and dry bone measurements respectively. In the same way it was shown that there was more variation in results from L1 to L5 vertebra. This was in agreement with findings demonstrated in other studies done by Kovacs *et al (*3).

The progressive increment noted both on CT scan measurement and dry bone measurement was very similar to another results obtained in various other studies on other population study by Kovacs *et al(*3). Findings are summarized in Tables 7 and 8. The results of pedicle cortical width in different populations are shown below. As can be seen, these studies showed a progressive increase in width from L1 to L5.

Table 7

Results of pedicle cortical width in different populations

Population (author, year)	Method	L1	L2	L3	L4	L5
Kenyan. (current study)	CT	7.2	7.6	9.2	10.8	14.6
Mexicans. (Fluoroscopía, 2009) (4)	CT	7.8	8.2	9.5	10.7	14.3
Koreans. (Kim, Lee, Chung, Kim, & Kim, 1994) (5)	CT	8.1	8.5	10.0	11.5	16.5
Israelites. (Castro-Reyes *et al.*, 2015)(6)	CT	5.6	7.7	8.9	11.4	13.7
Egyptians. (Maaly *et al.,* 2010) (7)	CT	6.6	8.8	10.1	12.9	18.9

Table 8

Results of pedicle cortical width in different populations

Population (author, year)	Method	L1	L2	L3	L4	L5
Kenyan (current study)	Dry bone	8.6	9.6	11.4	13.5	16.3
Turkish. (Morales-Avalos, *et al.,* 2015)(8)	Dry bone	6.4	6.6	8.6	10.8	12.4
Japanese. (Nojiri, Matsumoto, Chiba, & Toyama, 2005)(9)	Dry bone	7.4	7.8	9.1	10.1	11.1
Indians. (Acharya, Dorje, & Srivastava, 2010)(1)	Dry bone	7.2	7.6	8.9	11.1	13.9
Arabs. (El Sayed, Saab, El Shishtawy, & Hassan, 2014)(10)	Dry bone	8.7	9	10.5	11.1	12.5
Mexicans. (Castro-Reyes *et al.*, 2015)(11)	Dry bone	7.4	7.8	9.1	10.7	14.7

The results presented in Tables 7 and 8 are in agreement with other previous studies showing that there is an increase in pedicle width from L1 to L5 pedicle both on dry bone specimen and CT scan.

The chord length range measurement on dry bone specimen ranged from 47.9mm to 48.9mm and on CT scan from 48.6mm to 50.1mm. The male population has a longer mean chord length at each vertebral level as compared to the female population. These results are in agreement with those by Amonoo-Kuofi (2) who studied the lengths of pedicles on radiographs of 270 males and 270 females. He observed variations in different age groups and at different levels of lumbar spine. He also showed that there was a cephalocaudal increase of the length of pedicles from L1-L5 in males and females.

The angulation increased from L1 to L5 on CT scan measurements from 19.7^0 at L1 to 29.8^0 at L5. This increment as from L1 to L5 is in agreement to the study done by Gerszten *et al* (11). From the study the female population has slightly wider angulations of the pedicle from the midpoint as compared to the male population. The angle of insertion in female pedicles range between 160 at L1 and 36^0 at L5. The angle of insertion in the male population had a range between 15.4^0 to 35.3^0 from L1 to L5 as documented by Gerszten *et al* (11).

CONCLUSIONS

The present study accurately describes the dimension and orientation of the lumbar vertebral pedicle in Kenya. Based on the results, it can be stated that there exists a great variation in the

dimensions of the pedicle within the population and also in different populations. This necessitates the need to have appropriate and adequate imaging results prior to surgical approaches to the lumbar pedicle. However, a greater number of anatomical and imaging studies and a larger number of samples are necessary to analyze the morphometric characteristics of the lumbar vertebral pedicle in order to determine its true dimensions and establish variations according to age, gender, and vertebral level.

RECOMMENDATIONS

Significant differences exist between the pedicles of East Africans and other populations hence preoperative computed tomography scans of the patients must be evaluated and pedicle dimensions obtained in order to size the pedicle and determine its orientation. This will enable the operating surgeon know the most appropriate size of implant to use and avoid inadvertent complications.

Based on the variation there is need for measurements of the pedicle dimensions before trans-pedicular instrumentation to determine the appropriate screw size to use and trajectory. Intraoperative use of fluoroscopy is recommended as its use will guide the surgeon to know the position of the pedicle and its trajectory. Also intraoperative monitoring of neural electrical activities is recommended so as to avoid injury to the nerves. This can be done by placing electrodes at specific points that monitor neural activity and can be viewed as surgery continues. This will enable the surgeon know whether there is pedicle violation and make appropriate adjustments to prevent permanent neural damage.

Further research should be carried out to determine whether there exists a variation based on a persons age, weight and height.

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