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A Cadaveric Morphometric Study of Lumbar Vertebrae in Zimbabwean Adult Males

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ABSTRACT

Background: Transpedicular screw fixation has been widely used for spinal reconstruction because of its good fusion results. However, pedicle walls can be damaged during fixation if diameter of the screw is too large or screw is misplaced. Knowledge of the morphometric dimensions of the pedicle is thus important for effective fixation and to avoid complications. The main objective of this study was to measure the Pedicle Transverse Diameter (PTD), Pedicle Vertical Diameter (PVD) and chord length of male adult cadavers from Zimbabwean population.

Material and Methods: It was a descriptive cross-sectional study carried out at the Department of Anatomy, University of Zimbabwe College of Health Sciences, Harare Zimbabwe, from June 2019 to December 2019. The lumbar vertebrae from 15 adult male cadavers were dissected out and Pedicle Transverse Diameter (PTD), Pedicle Vertical Diameter (PVD) and chord length was measured and compared (on right and left sides), using a Vernier caliper. The statistical analysis was done using SPSS version 20.0., with data expressed as means, standard deviation and ranges. Student's t-test was used to estimate the difference in pedicle dimensions of the right and left sides of the lumbar vertebrae.

Results: There was an insignificant difference between pedicle dimensions (PTD and PVD) of the right and left sides ($P > .05$). PTD steadily increased from vertebral level L1 to L5 followed by an abrupt increase at L5. PVD gradually decreased from L1 to L5 level. The chord length increased from a minimum at L1 to reach a maximum at L3 and then again decreased to L5 level.

Conclusions: Pedicle dimensions of the Zimbabwean population differ from those reported in previous studies for other population groups and can be useful while performing pedicle screw fixation for lumbar vertebral fractures. A screw length of 40-45 mm should be used for lumbar transpedicular screw fixation with minimal risk of implant failure in Zimbabwean population.

Key words: Chord length, Lumbar vertebrae, Pedicle transverse diameter, Pedicle vertical diameter

Authors' Contribution:
[1-2]Conception; Literature research; manuscript design and drafting; Critical analysis and manuscript review; Data analysis; Manuscript Editing.

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Introduction

The lumbar vertebral column consists of five vertebrae numbered from L1 to L5, articulating at inter-vertebral joints.[1] These vertebrae have a large kidney-shaped body for support and weight bearing. During weight transmission, lumbar vertebrae support much of the weight of the upper body and

are thus more prone to degenerative changes with advancing age. Therefore, surgical interventions are most commonly performed in this region to alleviate symptoms of backache caused by arthritic changes, deformities and fractures.[2]

The pedicles of a lumbar vertebrae arise near the upper border of the posterolateral aspect of the body. They are large, stout and strong, consisting almost entirely of cortical bone with a small core of cancellous bone.[3] Research in an Indian population has shown that pedicle width increases from L1 level and reaches maximum at L5, whereas pedicle height is maximum in the L1 and L2 vertebrae, then decreases from L3 down to L5.[4]

Transpedicular screw fixation of the lumbar vertebrae is performed surgically in patients with thoraco lumbar vertebral fractures, spondylolisthesis, kyphosis, posterolateral synostosis, vertebral collapse and canal stenosis.[5] These screws are commonly used for posterior fixation in spinal instability, but their insertion remains challenging. There is a misplacement rate of up to 11% even with navigation techniques. The diameter of the screw is determined by the horizontal diameter of the pedicle.[6] Successful fixation depends on detailed knowledge of the size and dimensions of the pedicles. The minimum width of the pedicle is an important factor to consider during screw selection. A screw of larger diameter can damage the pedicle and may end up causing injuries,[7] like dural tears, leakage of cerebrospinal fluid and damage to spinal nerve roots.[8]

Multiple researches have reported variations in pedicle morphometry between different ethnic groups.[9] Imaging techniques such as C-arm fluoroscopy can be employed to enhance accuracy during pedicle screw placement. However, this exposes both patient and surgeon to radiations along with increased cost and operative time.[10] A detailed study of dimensions of the pedicles of lumbar vertebrae is thus essential for proper fixation without complications. Therefore, the main objective of this study was to measure the Pedicle Transverse Diameter (PTD), Pedicle Vertical Diameter (PVD) and cord length of male adult cadavers from Zimbabwean population.

Material and Methods

This descriptive cross-sectional study was carried out in the Department of Anatomy, University of Zimbabwe College of Health Sciences Harare, Zimbabwe. The duration of the study was 6 months, from June 2019 to December 2019. The sample consisted of 15 adult black Zimbabwean male cadavers.[11] Non probability convenience sampling was used, where cadavers were selected according to their accessibility and proximity to the researcher. Approval of Joint Research Ethics Committee of the University of Zimbabwe was taken before carrying out the study. Adult black male cadavers, between the age group of 24 to 40 years with no obvious vertebral deformities were included in the study. Male cadavers with scoliosis or other gross vertebral malformations, injuries of lumbar vertebrae, Caucasians, females and children were excluded from this study. Osteoporotic changes were not ruled out, since only male cadavers, aged between 25 to 40 years were considered in this study.

Embalmed human cadavers were dissected using posterior approach to the lumbar spine. With the cadaver in prone position, the postaxial musculature was retracted as far as the tips of the transverse processes with scalpels and retractors. The lumbar vertebrae were then removed by cutting through intervertebral joints. After removal, the vertebrae were heated in a macerating tank for 36 hours at a constant temperature of 70^0C. The remaining soft tissues were removed by manual dissection[12] and the vertebrae were air dried. The pedicle width (transverse diameter), pedicle height (vertical diameter) and chord length were measured on both

sides of the lumbar vertebrae by using a sliding Vernier caliper[13] (Figures 1A and B). Pedicle height was measured at two sites; mid pedicle and at root of the pedicle (junction of pedicle with the vertebral body).[13] Chord length was measured from the posterior cortical entry point of the pedicle to the anterior vertebral cortex along the axis of the pedicle.[13]

Statistical analysis was done by IBM-SPSS version 20.0. Means, standard deviations and ranges were calculated. Student's t-test was used to estimate the difference in pedicle dimensions of the right and left sides.

Results

The mean PTD (width) and the mean PVD (height) for all lumbar vertebrae levels was 11.17 ± 4.11 mm (Table I) and 15.52 ± 1.31 mm (Table II), respectively. Using the Student's t-test, it was established that there was no significant difference in PTD and PVD between the right and left sides of the lumbar vertebrae ($P > .05$). The mean chord length was 47.36 ± 1.32 mm (Table III). Similarly, Student's t-test showed no significant difference in the chord length of the right and left sides ($P > .05$). No effect of weight was envisaged on the chord length.

Table I: Comparison of the mean Pedicle Transverse Diameter of the right and left sides of the lumbar vertebrae

Vertebral Level	Values	Left Pedicle Transverse Diameter (mm)	Right Pedicle Transverse Diameter (mm)	*P*-value*	Pooled Mean
L1	Mean	8.08	8.04	.766	8.06
	SD	1.45	1.32		1.36
	Range	5-9.8	5.6-9.8		5-9.08
L2	Mean	8.22	8.13	.673	8.18
	SD	1.14	1.28		1.19
	Range	6.25-9.6	5.25-9.65		5.25-9.65
L3	Mean	9.78	9.75	.877	9.81
	SD	1.05	1.32		1.17
	Range	7.6-11.4	6.85-12		6.85-12
L4	Mean	11.49	11.34	.535	11.41
	SD	1.37	1.26		1.29
	Range	9.8-13.6	8.7-13.1		8.7-13.6
L5	Mean	18.36	18.45	.807	18.41
	SD	2.13	2.46		2.25
	Range	13.7-21	13.2-22.15		13.2-22.15

*P-value < .05 was considered statistically significant

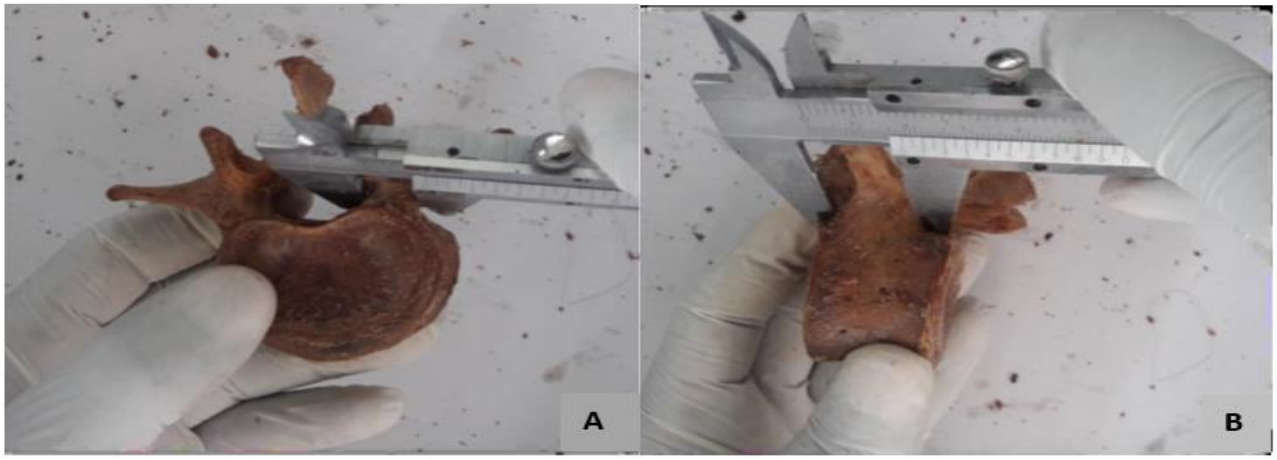

Figure 1: Photograph of lumbar vertebra showing pedicle measurement using sliding Vernier caliper. A: Pedicle transverse diameter, B: Pedicle vertical diameter.

Table II: Comparison of the mean Pedicle Vertical Diameter of the right and left sides of the lumbar vertebrae					
Vertebral Level	**Values**	**Left Pedicle Vertical Diameter (mm)**	**Right Pedicle Vertical Diameter (mm)**	***P*-value***	**Pooled Mean**
L1	Mean	16.28	16.57	.137	16.42
	SD	1.46	1.37		1.40
	Range	14.6-19.9	14.5-19.3		14.5-19.9
L2	Mean	15.54	15.85	.172	15.69
	SD	1.2	1.04		1.11
	Range	14-18.6	14.4-18.5		14-18.6
L3	Mean	15.36	15.54	.415	15.45
	SD	1.07	1.09		1.07
	Range	14.1-18.5	13.1-18.2		13.1-18.5
L4	Mean	14.99	15.18	.45	15.09
	SD	1.15	0.98		1.06
	Range	13.5-17.7	13.6-17		13.5-17.7
L5	Mean	14.68	15.21	.173	14.94
	SD	1.32	1.52		1.42
	Range	12.4-16.8	12.4-18.8		12.40-18.8

*P-value < .05 was considered statistically significant

Table III: Comparison of the mean chord length of the right and left sides of the lumbar vertebrae					
Vertebral Level	**Values**	**Left Chord Length (mm)**	**Right Chord Length (mm)**	***P*-value***	**Pooled Mean**
L1	Mean	46.29	46.34	.682	46.31
	SD	1.18	0.97		1.06
	Range	43.7-48.2	44.3-47.5		43.7-50
L2	Mean	46.91	47.86	.731	47.39
	SD	0.87	1.2		1.14
	Range	45.4-48.4	45.8-50		45.4-50
L3	Mean	48.33	48.63	.891	48.48
	SD	1.07	1		1.03
	Range	46.4-50	46.8-50.3		46.4-50.3
L4	Mean	47.89	47.17	.632	47.53
	SD	0.95	1.27		1.16
	Range	46.0-49.2	44.6-48.9		44.6-48.9
L5	Mean	47.36	46.85	.415	47.1
	SD	1.19	1.29		1.24
	Range	44.7-49.4	44.5-49.3		44.5-49.4

*P-value < .05 was considered statistically significant

Discussion

Lumbar region of the vertebral column plays an essential role in weight transmission and also permits a wide range of movement. Pedicles of the posterior arch of the vertebra are important in transmission of force between anterior and posterior elements of the vertebrae.[14] Any deformity of the pedicles can affect the weight transmission dynamics and can also compress neural structure. Pedicle screw fixation is a successful method of spine stabilization and has shown promising fusion results. The insertion of the screws remains challenging due to variations in width and height of pedicles and the proximity of the spinal nerve roots. PTD is an important factor that

determines the diameter of the screw used. Variations in pedicle morphometry has been reported in people of different ethnic groups.[12]

The present study showed that there is a steady increase in the pedicle transverse diameter from L1 to L4 followed by an abrupt increase at L5 level. This is consistent with the findings in studies done on Korean, American, and Indian populations.[15-17] A study done in the Saudi population showed a higher PTD between L1 and L4 and a smaller diameter of L5 as compared to other populations. Although there is a general increase in PTD, there is no abrupt increase in PTD at L5 level.[18] In the present study, the PTD is smaller than that found in American, Indian and Saudi populations.[16-18] In two studies conducted in an Indian population,[19,20] there was a general increase in PTD from L1 to L5 except at L2 level where minimum increase was seen.

In cross-section, PTD is the minimum thickness of the pedicle and hence dictates the maximum pedicle screw diameter. A study conducted in USA showed that PTD in the upper and lower lumbar vertebral levels was greater than 5 mm and 7 mm, thus pedicle screws of diameter 5 mm and 7 mm could be used in these regions respectively.[21] Based on the results obtained in the present study, where mean pedicle width is greater than 7 mm and 9 mm in the upper and lower lumbar regions respectively, it can be concluded that the maximum diameter of pedicle screw instrumented in the lumbar regions should be 7 mm and 9 mm in the respective vertebral segments.

The maximum PVD was obtained at L1 level and there was a steady decrease down to L5. This trend is similar to the ones found by the other researchers.[16,17,21] However, data of Saudi population showed minimum PVD at vertebral level L2 and a maximum at L5.[18] In cross section, the vertebral pedicle is oval in shape. It has been established that the pedicle vertical diameter is significantly greater than the transverse diameter.[22] Therefore, from a practical point of view, PVD carries lesser significance in selecting the pedicle screw diameter than PTD, and our study conforms to this theory.

In the present study, maximum chord length was recorded at L3 level and the minimum at L1. In a Turkish study, the longest chord length was obtained at level L1 and the shortest was at vertebral level L5, lower than those obtained in the current study.[22] Chord length determines the maximum length of any screw that can be safely used for pedicular screw fixation without anterior cortex violation.[23] Three other studies (American and Indian) reported that the longest chord length was at L2 while the shortest was at vertebral level L5.[16,24,25] The screw length should include 50% of the vertebral body in order to minimize instrument failure while allowing for effective screw fixation. A significantly longer screw can perforate the anterior cortex of the vertebral body causing damage to visceral organs and major blood vessels.[16] Currently, 40-43 mm screw length is used in Zimbabwe, but the results of present study showed that a screw length of 40-45 mm can be used in the lumbar region for effective fixation with minimal risk of implant failure.

The main limitation of the study is that it is a single center study with a limited sample size and hence the study may not reflect the morphometric characteristics of lumbar vertebrae pedicles of the entire male adult Zimbabwean population.

Conclusion

Morphometric studies of pedicles of lumbar vertebrae shows variations in different ethnic groups and their detailed knowledge is crucial for successful pedicle screw fixation. A screw length of 40-45 mm should be used for lumbar transpedicular

screw fixation with minimal risk of implant failure in Zimbabwean population.

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