An anatomical assessment of the pedicles of C3-C7 vertebrae and its implication for transpedicular screwing in the Ghanaian population

Ato Ampomah Brown, Gordon Kyei, Edward S. Gyimah, Eric Aidoo

Department of Anatomy and Cell Biology, School of Medical Sciences, University of Cape Coast, Ghana

SUMMARY

The aim of this study was to assess the sub-axial cervical pedicle and document its anatomical dimensions within the Ghanaian population. This knowledge is essential in determining dimensions of the screws to be used and the ideal trajectory in placing the screw within the pedicle without incidence. It has been suggested that the cervical spine pedicles may vary in different populations. It is important that each population have baseline measurements that will serve as a guide to surgeons.

The study was conducted using 187 sub-axial cervical vertebrae that were harvested from 20 cadavers. Vertebrae that had gross deformities, showed signs of degeneration or were damaged were excluded from the study. The measurements that were taken were the pedicle height, width, length and the posterior transverse angle.

The pedicle width ranged from 3.01-8.62 mm, the height from 4.15-10.18 mm and the length from 1.88-6.51 mm. There was no significant difference in the means of all the linear parameters when comparisons were made between the left and right side. A significant statistical difference in the mean pedicle width was however observed when comparisons were made between the different levels of cervical vertebrae

From the findings of our study, it is recommended that each pedicle should be assessed preoperatively to ascertain its suitability for pedicle screw placement. On the bases of dimension alone, it appears that C7 pedicles may be the safest in which to place screws.

Key words: Pedicle – Pedicle screws – Cervical vertebra – Ghana

INTRODUCTION

Compared to thoracic and lumbar transpedicular screw placement, cervical transpedicular screwing is a relatively recent medical procedure. The idea of placing screws in the pedicles of cervical vertebrae was not encouraged, as it was generally believed that the dimensions of the pedicles were small and the potential of damaging the vertebral artery or/and spinal cord was too high a risk to take (Abumi et al., 1994; Herrero et al., 2016).

Abumi et al. (1994) were the first to report the placement of screws within the pedicles of the cervical spine as a means of stabilizing injured spines. Since then, the use of transpedicular

Corresponding author:
Ato Ampomah Brown. Department of Anatomy and Cell Biology School of Medical Sciences University of Cape Coast, Cape Coast, Ghana. Phone: +233244648027. E-mail: a.a.brown@uccsms.edu.gh

Submitted: November 19, 2024. **Accepted:** August 18, 2025

https://doi.org/10.52083/SHNJ7649

screwing has greatly increased. One of the reasons why the placement of transpedicular screws has gained popularity is because it has been found to be biomechanically stronger than the use of lateral mass screws (Kotil et al., 2012; Tan et al., 2020).

Despite its growing popularity, the complication associated with cervical transpedicular screwing cannot be overlooked. The close proximity of the spinal cord, spinal nerve, and vertebral artery means that improper placement can result in life-threatening injury and can ultimately be fatal.

To avoid or minimize these complications, a detailed anatomical understanding of the sub-axial cervical pedicles, how they relate to the other parts of the vertebrae and surrounding structures cannot be overemphasized. This knowledge is essential in determining dimensions of the screws to be used and the ideal trajectory in placing the screw within the pedicle without incidence. The combination of good anatomical knowledge of the cervical pedicles and preoperative planning assisted by imaging have been found to reduce the incidence of the screw's breaching of the cervical pedicle considerably (Tan et al., 2020; Ludwig et al.; 2000; Kotil et al., 2012).

It has been suggested that the cervical spine pedicles may vary in different populations (Herrero et al., 2016). It is important that each population have baseline measurements that will serve as a guide to surgeons, particularly in this instance where minimal adjustments in the screw trajectory may lead to catastrophic consequences.

The aim of this study was to assess the sub-axial cervical pedicle and document its anatomical dimensions within the Ghanaian population.

MATERIALS AND METHODS

The study was conducted using 187 sub-axial cervical vertebrae that were harvested from 20 cadavers which had been donated to the Department of Anatomy and Cell Biology, School of Medical Sciences, University of Cape Coast for dissection and research. Vertebrae that had gross deformities, showed signs of degeneration or were damaged were excluded from the study. The ages of the specimens were unknown and the bones were not categorized according to gender.

The measurements that were taken were the pedicle height, width, length and the posterior transverse angle. These were defined as follows;

Pedicle width (PW): The distance between the medial and lateral border of the pedicle (Fig. 1).

Pedicle length (PL): The distance between the anterior limit of the superior articular facet and the posterior limit of the vertebral body (Fig. 1).

Pedicle height (PH): The vertical distance between the superior and inferior borders of the pedicle (Fig. 2).

Posterior Transverse Angle (PTA): the angle between the pedicle axis and the vertebral body midsagittal line in the transverse plane (Fig. 1).

All linear measurements of the pedicles were taken using a digital Vernier caliper at a precision of 0.01mm, with angles measured by means of a goniometer to 1^{o} precision.

The mean and standard deviation of all the various parameters were calculated. Difference in means for the left and right side of the vertebrae was carried out using a Student T-test, with a statistical significance at 0.05.

Statistical significance of the difference in means at the various levels was determined by using One-way analysis of variance (ANOVA) test. A Least Significant Difference (LSD) Post Hoc (multiple comparison) test was run to identify the levels at which these statistically significant difference(s) in means occurred at a p-value of 0.05.

Pearson correlation with a significant level of 0.05 (2-tailed) was also done to determine if there was a correlation between the measured parameters and the position they occupied on the cervical spine.

RESULTS

In the present study, the pedicle width ranged from 3.01-8.62 mm, the height from 4.15-10.18 mm and the length from 1.88-6.51 mm. The pedicle with the smallest mean width was C3 vertebra, while C7 vertebrae was found to have the largest width (Table1).

There was no significant difference in the means of all the linear parameters when compar-

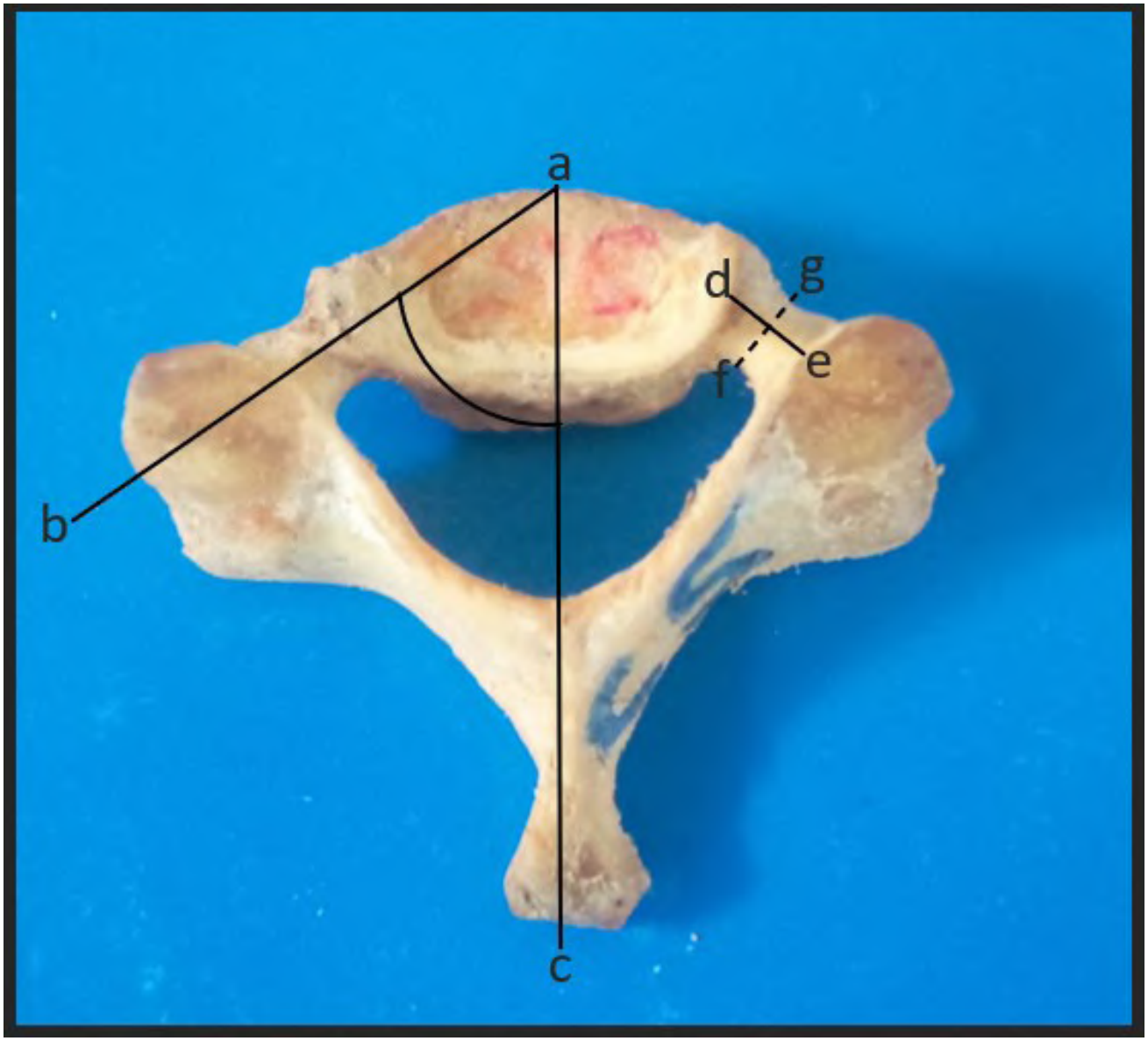

Fig. 1.- Picture showing the pedicle width (fg), pedicle length (de) and posterior transverse angle (bac).

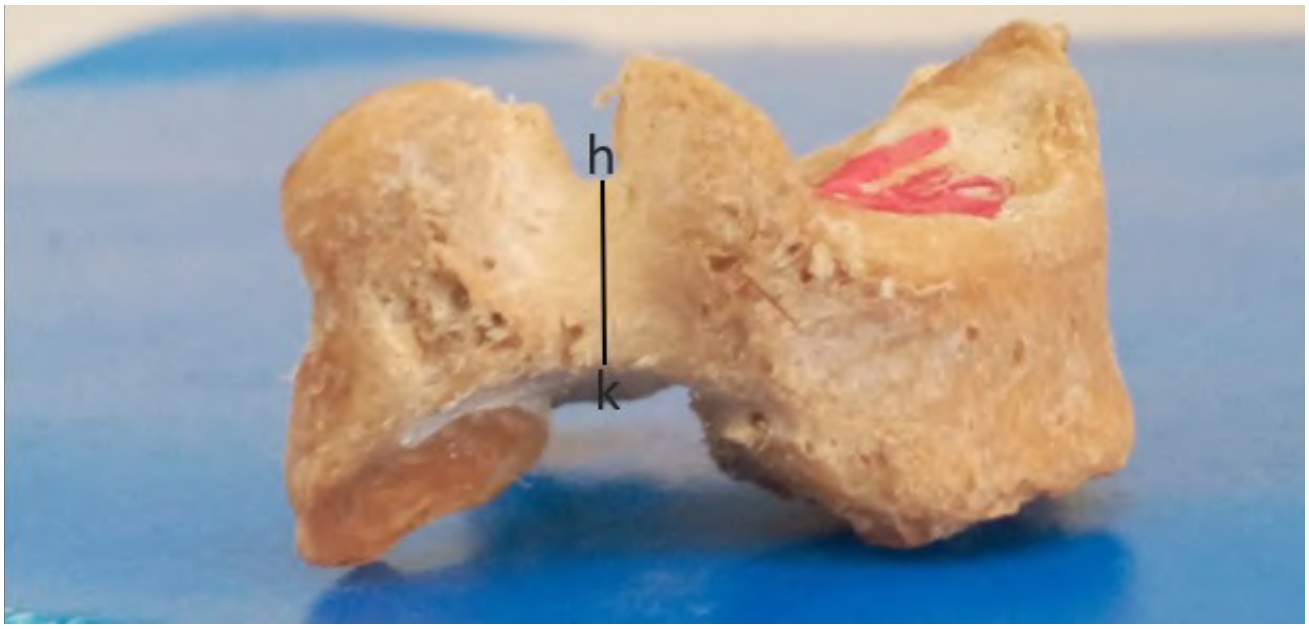

Fig. 2.- Picture showing pedicle height (hk).

isons were made between the left and right side. A significant statistical difference in the mean pedicle width was observed when comparisons were made between the different levels of cervical vertebrae (Table 2). This significant difference was however not observed in the pedicle length and height.

The posterior transverse angle ranged from 32-50º, the mean PTA was 43.0º ±4.08º, the mean PTA angel for the right sided pedicles was 42.88º while the mean angle for left sided pedicles was left 43.19. There was no statistically significant difference in the mean angles of right and left sided pedicles. The widest mean PTA was observed in the C7 vertebra while the least was found in the C3 vertebra (Table 4). When PTA was compared across spinal levels it was observed that there were significant differences between the PTA of C3 vertebrae and those of C6 and C7 (Table 5).

DISCUSSION

The mean pedicle length was 4.41 mm. There was no significant difference in the mean pedicle length when multiple comparisons were carried out between the various levels of the cervical vertebrae. No observable pattern of increasing or decreasing length was observed down the cervical spine. This was contrary to the findings of Kayalioglu et al. (2007), who described a decreasing pattern in the length of the pedicles as one moves down the spine. There was also no significant difference in the mean length of the pedicles when comparison was made between the various spinal levels. This contradicts findings of Rao et al. (2008). They reported that pedicle length was significantly smaller at C3 and C4 than it was at C5, C6, and C7.

The width of the pedicles ranged between 3.01-8.62 mm. The mean pedicle width of C7 was found to be the widest of the sub-axial cervical vertebrae, while the pedicle width of C3 was found to be the least. This observation is similar to those of previous studies which utilized direct observation (Ludwig et al., 2000; Uğur et al., 2000) and CT imaging (Chazono et al., 2006; Rao et al., 2008; Herrero et al., 2016). Although the least and highest means were observed at C3 and C7 respectively, there was no observable increasing pattern in the mean width as one progressed down the cervical, contrary to what has been reported in previous studies (Uğur et al., 2000; Chazono et al., 2006; Kayalioglu et al., 2007; Rao et al., 2008; Banerjee et al., 2012; Herrero et al., 2016) Comparison on the mean pedicle width between the different cervical levels showed a statistically significant difference between the C7 pedicle width and those of the other four superior sub-axial cervical vertebrae. Other researchers have reported similar findings (Ludwig et al., 2000; Xing-Guo et al., 2007).

The height of the pedicles ranged from 4.15-10.18 mm. The mean pedicle height was found to be highest in the C7 vertebrae and least in the C6 vertebrae. Previous findings from studies on the dimensions of pedicle height have been quite varied. While some researchers have observed the least mean pedicle height in the C3 vertebra (Uğur et al., 2000; Xing-Guo et al., 2007; Kayalioglu et al., 2007; Rao et al., 2008), others found the C3 pedicle height to be the largest (Bazaldúa et al., 2011; Prabavathy et al., 2017). Some studies have reported a progressive decrease in pedicle height as one moves from C3 to C7 (Bazaldúa et al., 2011; Prabavathy et al., 2017); others have also reported a reverse pattern (Rao et al., 2008). Neither increasing nor decreasing patterns of pedicle height were observed in this study. There was also no significant difference in the mean pedicle height when they were compared across the different levels.

The successful placement of cervical screws in any particular pedicle is partly dependent on the availability of adequate bone tissue; this is estimated partly by its dimensions. However, it is very much appreciated that the pedicle is not a regular cylindrical structure but exhibits a complex three-dimensional architecture along its length (Shin et al., 2000, Panjabi et al., 2000). Its diameter prior to surgery is for the most part determined by measuring its width and height using various imaging modalities. The diameters of cervical pedicle screws most often used are 3.5, 4.0 and 4.5 mm. An outer pedicle diameter less than 4 mm makes cervical placement screw insertion challenging (Tan et al., 2020).

The mean pedicle height at all cervical levels

Table 1. Pedicle width, height and length

	PW(Rt)	PW(Lt)	PW(Pool)	PH(Rt)	PH(Lt)	PH(Pool)	PL(Rt)	PL(Lt)	PL(Pool)
C3	4.77±0.99	4.76±0.99	4.76±0.98	6.63±1.17	6.84±1.10	6.73±1.12	4.34±0.92	4.37±0.97	4.36±0.93
C4	5.12±0.91	5.15±0.81	5.13±0.85	6.88±1.24	6.98±1.00	6.93±1.11	4.23±0.89	4.19±0.90	4.21±0.85
C5	5.12±0.97	5.04±0.93	5.08±0.94	6.77±1.30	6.99±1.19	6.88±1.24	4.32±1.02	4.50±1.01	4.41±1.00
C6	5.09±1.17	5.25±0.92	5.17±1.04	6.65±1.33	6.64±1.40	6.60±1.35	4.50±0.76	4.54±0.72	4.57±0.70
C7	6.52±0.90	6.06±1.17	6.30±1.05	7.21±1.15	7.23±1.34	7.22±1.22	4.61±0.79	4.43±0.96	4.52±0.87

Table 2. Multiple comparison of mean pedicle width between the various spinal levels

Vertebrae	Vertebrae	Mean Difference	P-value
C4	C3	.36719	.156
C5	C3	.31778	.212
	C4	-.04941	.846
C6	C3	.31469	.223
	C4	-.05250	.839
	C5	-.00309	.990
	C3	1.51939*	.000
	C4	1.15220*	.000
	C5	1.20161*	.000
	C6	1.20470*	.000

*Significant at the level of 0.05

Table 3. Percentage distribution of pedicle width

Vertebrae	3 mm	4 mm	5 mm	6 mm	7 mm	8 mm
C3	25	41.66	22.22	8.33	2.78	
C4	5.56	38.89	41.66	11.11	2.78	
C5	8.33	41.68	30.56	16.67	2.78	
C6	8.57	31.43	45.71	8.57	5.71	
C7	0	6.90	37.93	27.59	20.69	6.90

Table **4.** Posterior transverse angle at various spinal levels

	C3	C4	C5	C5	C7
Mean±Std.	41.71º±4.36	42.42º±4.10	43.18º±3.86	43.84º±3.94	44.00º±3.87

T**able 5.** Multiple comparison of PTA between the various spinal level

Cervical Vertebrae		Mean Difference	p-value
C3	C4	0.71053	0.444
	C5	-1.46447	0.111
	C6	-2.13158*	0.022
	C7	-2.28947*	0.019
C4	C5	0.75395	0.411
	C6	-1.42105	0.127
	C7	-1.57895	0.105
C5	C6	0.66711	0.467
	C7	0.82500	0.390
C6	C7	0.15789	0.871

*Significance at the level of 0.05

was > 6 mm, suggesting that in terms of height, most pedicles in the Ghanaian populace may safely accommodate the placement of screws. The challenge however appears to be with the pedicle width. In this study, the incidence of pedicles width was < 4 mm and was found to be 9.71% compared to the 1.7% reported by Rao et al. (2008). The incidence at each spinal level was as follows: C3; 25%, C4; 5.56%, C5; 8.33% and C6; 8.57%; all pedicles at C7 had widths > 4 mm. These frequencies are much higher than those reported by Chazono et al. (2006), who found an incidence of 8.5% at C-3, 7.9% at C-4, 1.6% at C-5, and 0% at C-6 and C-7. The findings suggest that the standard screws used for transpediclartranspedicular insertion may not be suitable for placement within the C3 pedicles of a significant number of Ghanaians. Thus, a careful evaluation of the C3 pedicle for its suitability for the placement of cervical screws must be done preoperatively. Surgeons must also consider the use of smaller screws when placing cervical placement screws within the C3 pedicle. Based on the diameter of the pedicles alone, C7 pedicles appear to be the safest within which cervical screws may be placed.

The PTA in the present study ranged between 32º and 50º, with a mean of 43.0º±4.08º. The mean PTA ranged from 37.1° to 45.4° (Nishinome et al., 2013). There was no statistically significant difference in the mean angles for the right and left side. The PTA was found to increase from C3 to C7 in conformity with the notion that PTA generally increases from C3 to C7 (Tan et al., 2020). When the mean PTA of one level was compared to the others, it was observed that there were significant differences between the PTA of C3 vertebrae and those of C6 and C7. Other studies have also reported significant differences between the various vertebral levels (Rao et al., 2008; Nishinome et al., 2013). Rao et al. (2008) observed that pedicle transverse angulation was significantly dependent on spinal level. Based on these observations, it appears that standardized angles have from little to no value for transpedicular screw placement. It is however recommended that PTA for each level must be assessed preoperatively using CT imaging in order to establish an ideal convergence angle trajectory for the successful placement of the screw.

One limitation of this study was the inability to segregate the data by sex and age. There is some evidence in literature that points to the fact that pedicle dimensions and orientation are influenced by both factors. Future studies in the Ghanaian population must endeavor to segregate specimen by sex and gender.

In conclusion, the information from this study will help to add to the body of knowledge already available and will give spinal surgeons in Ghana a good three-dimensional appreciation of pedicle anatomy to help mitigate the risk associated with pedicle screw insertion. The findings of our study compared to other studies highlights the high degree of variability in dimensions and angulation of the cervical pedicles across different populations. There may be many reasons for these differences, which may including genetics, nutrition and the presence of some endemic infectious diseases (Brown et al., 2020a; Brown et al., 2020b). From the findings of our study, it is recommended that each pedicle should be assessed preoperatively to ascertain its suitability for pedicle screw placement. On the bases of dimension alone, it may appear that C7 pedicles are the safest in which to place screws, while C3 pedicle carry the most risk.

REFERENCES

ABUMI K, ITOH H, TANEICHI H, KANEDA K (1994) Transpedicular screw fixation for traumatic lesions of the middle and lower cervical spine: description of the techniques and preliminary report. Clin Spine Surg, 7 (1) :19-28.

BANERJEE PS, ROYCHOUDHURY A, KARMAKAR SK (2012) Morphometric analysis of the cervical spine of Indian population by using computerized tomography. J Med Allied Sci, 2(2): 66.

BAZALDÚA CJ, GONZÁLEZ LA, GÓMEZ SA, VILLARREAL SE, VELÁZQUEZ GS, SÁNCHEZ UA, ELIZONDO-OMAÑA RE, GUZMÁN LS (2011) Morphometric study of cervical vertebrae C3-C7 in a population from northeastern Mexico. Int J Morphol, 29(2): 325-30.

BROWN AA, DERKYI-KWARTENG L, ABAIDOO CS (2020a) The effect of malaria-induced serum tumor necrosis factor-alpha on epiphyseal bone formation of rats. Acta Med Int, 7(1): 39-43.

BROWN AA, DIKE NO, DERKYI-KWARTENG L, ABAIDOO CS (2020b) The effect of recurrent malaria infections on bone and cartilage at the distal femoral epiphysis of rats: A histological study. J Curr Res Sci Med, 6(1): 51-56.

CHAZONO M, SOSHI S, INOUE T, KIDA Y, USHIKU C (2006) Anatomical considerations for cervical pedicle screw insertion: the use of multiplanar computerized tomography reconstruction measurements. J Neurosurg Spine, 4(6): 472-477.

HERRERO CF, DO NASCIMENTO AL, MARANHO DA, FERREIRA-FILHO NM, NOGUEIRA CP, NOGUEIRA-BARBOSA MH, DEFINO HL (2016) Cervical pedicle morphometry in a Latin American population: A Brazilian study. Medicine, 95(25): e3947.

KAYALIOGLU G, ERTURK M, VAROL T, CEZAYIRLI E (2007) Morphometry of the cervical vertebral pedicles as a guide for transpedicular screw fixation. Neurol Med Chir, 47: 102-108.

KOTIL K, AKÇETIN MA, SAVAS Y (2012) Neurovascular complications of cervical pedicle screw fixation. J Clin Neurosci, 19: 546-551.

LUDWIG SC, KRAMER DL, BALDERSTON RA, VACCARO AR, FOLEY KF, ALBERT TJ (2000) Placement of pedicle screws in the human cadaveric cervical spine: comparative accuracy of three techniques. Spine, 25: 1655-1667.

NISHINOME M, IIZUKA H, IIZUKA Y, TAKAGISHI K (2013) An analysis of the anatomic features of the cervical spine using computed tomography to select safer screw insertion techniques. Eur Spine J, 22: 2526-2531.

PANJABI MM, SHIN EK, CHEN NC, WANG JL (2000) Internal morphology of human cervical pedicles. Spine, 25(10): 1197-1205.

PRABAVATHY G, PHILIP XC, ARTHI G, SADEESH T (2017) Morphometric study of cervical vertebrae C3-C7 in South Indian population–A clinico-anatomical approach. Ital J Anat Embryol, 11: 49-57.

RAO RD, MARAWAR SV, STEMPER BD, YOGANANDAN N, SHENDER BS (2008) Computerized tomographic morphometric analysis of subaxial cervical spine pedicles in young asymptomatic volunteers. J Bone Joint Surg, 90: 1914-1921.

SHIN EK, PANJABI, MM, CHEN NC, WANG JL (2000) The anatomic variability of human cervical pedicles: considerations for transpedicular screw fixation in the middle and lower cervical spine. Eur Spine J, 9: 61-66.

TAN KA, LIN S, CHIN BZ, THADANI VN, HEY HW (2020) Anatomic techniques for cervical pedicle screw placement. J Spine Surg, 6(1): 262.

UĞUR HÇ, ATTAR A, UZ A, TEKDEMIR I, EGEMEN N, ÇAĞLAR S, GENÇ Y (2000) Surgical anatomic evaluation of the cervical pedicle and adjacent neural structures. Neurosurgery, 47: 1162-1169.

XING-GUO L, YUN H, YAN Z, ZHI-RONG Z, PENG Z, JI-HONG L, YONG-FU G, YANG-JIE Z, YU-RAN Z, ZONG-LIANG L (2007) Applied anatomy of the lower cervical pedicle screw insertion. Chin J Traumatol, 10(05): 299-305.