Original communication

MORPHOMETRY OF THE PEDICLE OF FIRST SACRAL VERTEBRAE AND ITS APPLICATION IN POSTERIOR TRANSPEDICULAR SCREW FIXATION

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RESUMEN

Los objetivos del presente estudio fueron determinar los parámetros anatómicos del pedículo S1 en la población India del sur para comparar los datos con respecto a los géneros masculinos y femeninos. El estudio incluyó 50 sacros secos (25 hombres y 25 mujeres) que se obtuvieron en el laboratorio de anatomía de nuestra institución. En el presente estudio se observa que la longitud media del pedículo S1 fue 49.9± 3,6 mm para los hombres y 46.3± 4,8 mm para las mujeres. La altura céfalo-caudal del pedículo S1 fue 27.2±4.0 mm y 23.9±3.7 mm para el varón y la hembra respectivamente. La anchura antero-posterior del pedículo S1 fue 7.5± 1,3 mm, 7.5± 1.7 mm en varones y mujeres, respectivamente. La distancia antero-posterior de S1, desde el promontorio sacro a la apófisis espinosa de S1 fue 52.9± 5.2 mm y 50.4± 6.8 mm en los géneros masculino y femenino respectivamente. El presente estudio demostró que la longitud y la altura de céfalo-caudal eran más altos (p0.05) en varones que en mujeres. Los datos de mujeres y varones con respecto a la anchura antero-posterior y la distancia antero-posterior de S1 no eran estadísticamente diferentes. El presente estudio ha proporcionado datos morfométricos importantes del pedículo de la primera vértebra sacra de la muestra anatómica de la población India del sur. El conocimiento de los diámetros del pedículo de S1 es crucial para la colocación segura de tornillos para la fijación transpedicular posterior.

Palabras clave: *Pedículo, sacro, columna vertebral, tornillo, vértebra*

ABSTRACT

Objectives of the present study were to determine the anatomical parameters of the S1 pedicle in South Indian population and to compare the data, with respect to male and female genders. The study included 50 dry sacra (25 male and 25 female), which were obtained from the anatomy laboratory of our institution. It is observed in the present study that the mean S1 pedicle length was 49.9± 3.6 mm for male and 46.3± 4.8 mm for the female. The cephalocaudal heights of S1 pedicle were 27.2±4.0 mms and 23.9±3.7 mms for the male and female respectively. The anteroposterior width of S1 pedicle was 7.5± 1.3 mms, 7.5± 1.7 mms in males and females respectively. The anteroposterior distances of S1, from the sacral promontory to the spinous process of S1 were 52.9± 5.2 mms and 50.4± 6.8 mms respectively for the male and female genders. The present study observed that the mean S1 pedicle length and the cephalocaudal height were higher ($p<0.05$) for the males than that of females. The data (male vs female) were not found statistically different ($p>0.05$), with respect to the anteroposterior width of the S1 pedicle and the anteroposterior distances of S1 from the sacral promontory to the spinous process of S1. The present study has provided important morphometric data onto the pedicle of the first sacral vertebrae, from the anatomical samples of the South Indian population. The knowledge of pedicle diameters of S1 is crucial to the safe placement of screws in the posterior transpedicular screw fixation.

Key words: *pedicle, sacrum, spine, screw, vertebra*

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INTRODUCTION

The low back pain affects approximately 60-85% of adults during some part of their life (Frymoyer, 1988). The back ache and leg pain may occur due to some injury, where the lumbar spine and the sacral region connect, because of stress and rotation during activities like sports and sitting in a chair for long periods of time. Sacral pain could be characterized as aching or sharp pain, usually a pain in the lower back, or in the buttocks. The sacrum is a large, triangular flat bone situated between the lumbar and coccygeal portions of the spine. It consists of five vertebrae, which are fused both anteriorly and posteriorly (Diel et al, 2001). Ala is the wing-shaped part of sacrum, which is found lateral to the body of first sacral vertebra (S1). S1 vertebra is the largest among all the sacral vertebral bodies (*Peretz et al, 1998)*. S1 body shows a prominent antero-superior lip, named as sacral promontory. The S1 is designed to provide support, during the weight bearing on the axial skeleton. The posterior transpedicular screw fixation has been the most widely used procedure **(**Okutan et al, 2003), to treat the unstable lumbosacral spine, due by trauma, degenerative diseases, congenital anomalies and malignancies. The spinal external fixation is the best surgical procedure performed to treat the lumbosacral spondylosis (Elizondo-Omaña and Guzmán-López, 2012).

The knowledge of pedicle morphometry of first sacral vertebra is important to the safe placement of screws. It has been reported that pedicle screw instrumentation, could result in injury to the pedicle cortex, nerve roots, facet joint and the adjacent vital structures because of the mis-placed pedicle screw (Kostuik, 1986). Okutan et al. (2003) suggested it is better to know the bony landmarks of the S1 and its pedicular anatomy for a safer pedicle screw placement,. There are reports, available in the literature about the morphometry of pedicle of S1 (Misenhimer et al, 1989; Brantley et al, 1994; Okutan et al, 2003), but not from Indian population. Hence, the objectives to perform the present study were to determine the anatomical parameters of the pedicle of S1 in the South Indian population. The present study has also compared the parameters with respect to male and female samples.

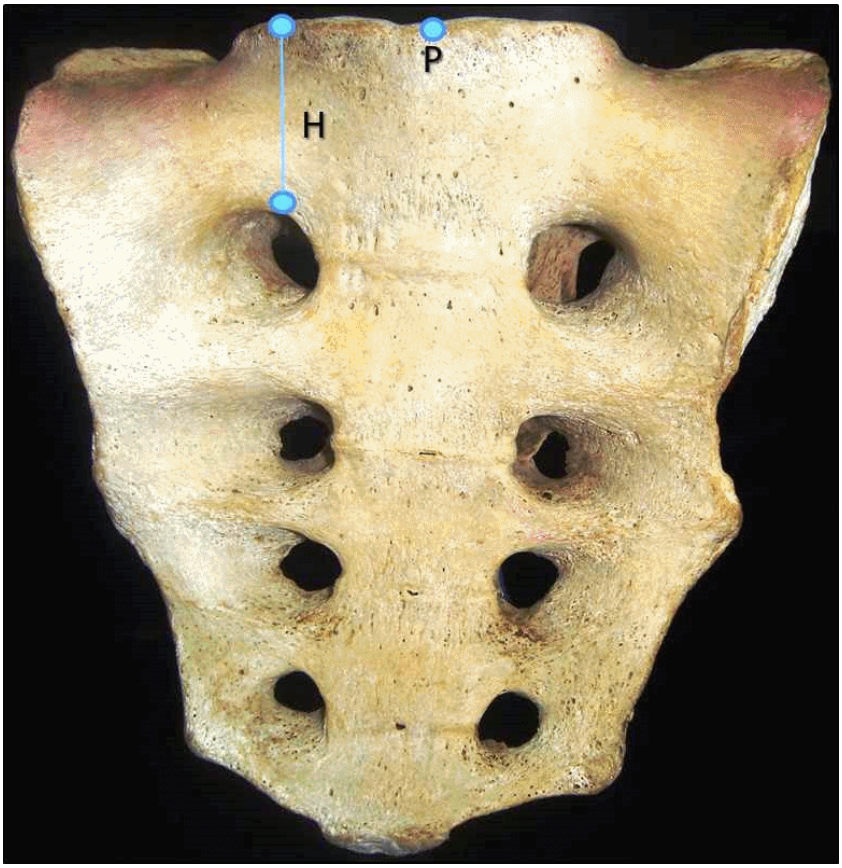

Figure 1– Photograph showing the anterior view of sacrum. H distance (cephalo-caudal height of S1 pedicle) was measured between the most superior border of the S1 foramen and superior surface of body of S1. P point – sacral promontory.

MATERIAL AND METHODS

The present study included 50 dry sacra, which were obtained from the anatomy laboratory of our institution. There were 25 male and 25 female specimens; all among them were belonged to South Indian population. The samples of the present study did not exhibit any pathological change or deformity. The gender determination of the vertebrae was done with the assistance of the forensic pathologist. The gender determination was performed by using the following features as given in the text books of human forensic medicine (Krogman and Iscan, 1986; Vij, 2011). The sacrum was considered of male gender, if the breadth of the S1 body is bigger than the breadth of its ala. It is considered as female, if the breadth is smaller than the breadth of its ala (Krogman and Iscan, 1986; Vij, 2011). The male sacra exhibited uniformly curved inner curvature and female sacra were abruptly curved at the last two segments. The parameters were measured on both the right and left sides by using the vernier caliper of 0.01 mm accuracy. The measurements in the entire vertebra have been performed by the same person.

The following parameters were measured in the present study:

1. Cephalo caudal height of pedicle of S1 (H distance): measured between the superior border of S1 foramen and the superior surface of the body of S1 (Fig. 1)
2. Anteroposterior width of pedicle of S1 (W distance): measured between the anterior and posterior cortex of S1 pedicle (Fig. 2)
3. XP distance (pedicle length): distance from the X point to the sacral promontory (P) (Fig. 2); X point- a point inferior and lateral to the inferior tip of superior articular process of S1 and represents the entrance point of S1 screw insertion in surgical practice (Fig. 2)
4. AP distance: anteroposterior distance of S1 from the sacral promontory until the spinous process of S1 (Fig. 2)

The data were tabulated and presented as mean ± SD. The statistical analysis between the genders (male vs female) was performed by using the independent samples test. Two tailed p-values <0.05 (α=0.05) were considered significant. The SPSS 15.0 program was used to perform the statistical analysis.

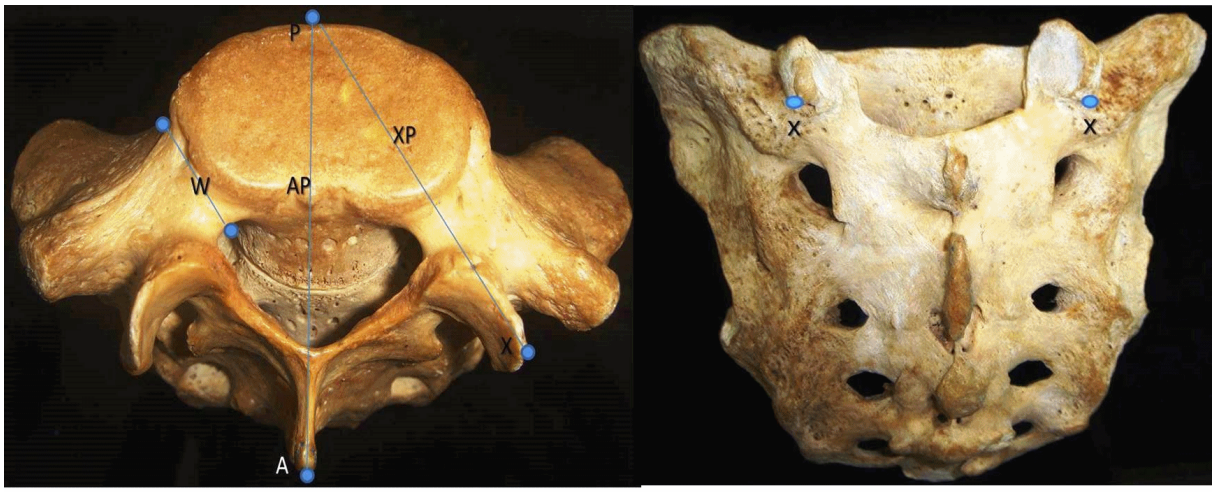

Figure 2– Photograph showing the superior and posterior views of the sacrum. P point- sacral promontory; XP distance-pedicle length (the distance from entrance point, X to sacral promontory, P); W distance-anteroposterior width of S1 pedicle, measured between the anterior and posterior cortex of S1 pedicle; X point- a landmark that shows a point inferior and lateral to the inferior tip of the superior articular process of S1 and represents the entrance point of S1 screw insertion; AP distance-anteroposterior distance of S1 from the sacral promontory until the spinous process of S1.

RESULTS

The present study has performed the gender based comparison of morphometric parameters. The morphometric data of the present study are represented in Table 1. The values for the male and female samples were given separately. It is observed that, there were some differences in the parameters with respect to the male and female. These data were found statistically significant ($p<0.05$). In the present study (Table 1), the mean S1 pedicle length and the cephalocaudal heights were greater ($p<0.05$) for the males than that of the females. However the data (male vs

female), were not found statistically significant (p>0.05) with respect to the anteroposterior width of S1 pedicle and the anteroposterior distances of S1 from the sacral promontory until the spinous process of S1.

measurement in mm	males (n=25)	females (n=25)
cephalocaudal height*	27.2 ± 4.0	23.9 ±3.7
anteroposterior width	7.5 ± 1.3	7.5 ± 1.7
XP distance*	49.9 ± 3.6	46.3 ± 4.8
AP distance	52.9 ± 5.2	50.4 ± 6.8

Table 1- Gender wise comparison of dimensions of S1 pedicle (n=50) values are mean ± SD, statistical significance (independent samples test) *p<0.05.

DISCUSSION

Sacrum resembles an inverted triangle and has a concave anterior surface and convex posterior surface. It is designed to support the lumbar vertebral column and to transmit loads from the trunk to the pelvic girdle and into the lower limbs **(**Bogduk, 2005)**.** The sacrum superiorly articulates with L5, inferiorly with the coccyx and laterally with the iliac bones at the sacroiliac joints (Diel et al, 2001). In the lateral view of the spine, the sacrum is noted to project posteriorly, forming the lumbosacral angle. As a result of this angle, the articulation is subjected to the shearing forces. Posteriorly, the fused spinous processes of the sacrum form the median sacral crest, which extends caudally to the sacral hiatus. The sacral hiatus is a defect in the posterior wall of the sacrum at the S5 level (Diel et al, 2001). The pedicle of S1 differs from that of cervical, thoracic or lumbar region vertebrae (Okutan et al, 2003; Arman et al, 2009). In the neurosurgical practice, sacral screw fixation remains a challenging clinical problem because of the unique anatomy of the first sacral vertebra (Xu et al, 1995). It was reported that, fracture of the pedicle may occur if increasingly bigger screws are placed into an already expanded pedicle or when a screw, larger than the outer diameter of the pedicle, is passed through the pedicle in cervical, thoracic or lumbar spines. This would lead to compression of the medially passing spinal nerve (Okutan et al, 2003). Okutan et al (2003) reported that the height and width of the pedicle of S1 is larger than all the available screw diameters which are presently in surgical use. It was also opined that, there is always a risk of nerve root compression in the S1 foramen, if the screw is placed more medially. The anterior vascular structures could be compressed, if the screw is directed very laterally from the entrance point, which is labeled X in the present study.

In neurosurgical practice, achieving the fusion across the lumbosacral region is a significant challenge, while extending fusion levels into the sacrum bone. The detailed knowledge of the S1 pedicle morphometry, is important while using the pedicle to gain access into the vertebra (Okutan et al, 2003). Fixing the S1 screw appropriately without injuring the adjacent vital structures depends on the entrance point of screw insertion and the direction of the screw. Unfortunately, there are only a very few reports available in the literature regarding S1 pedicle morphometry and the morphology. Harrington and Dickenson (1976) suggested that, the most secure screw fixation to the S1 passes through the S1 pedicle to the sacral promontory. The measurement of the pedicular depth is important in the posterior sacral screw placement surgery (Okutan et al, 2003).

There are a few problems associated with the inserti**on of** screws, unless the surge**on** is well experienced and adheres to the principles **of** operative technique. Lonstein et al (1999) reported that, there is a low rate **of** postoperative complicati**on**s with the pedicle screws. The posterior transpedicular screw fixation has been widely used in the management of unstable lumbosacral spine caused by the traumatic injuries, degenerative diseases, congenital anomalies and cancers (Okutan et al, 2003). It has been described that the pediculo-corporeal insertion of the screw is the best and the most reliable method for lumbo-sacral fusion (Harrington and Dickenson, 1976). It is accepted

that the morphometry of the pedicle of S1 is important in the pedicle corporal screw placement. The surgeon has to make sure that, if the screw which has to be inserted is of optimum length before performing the fixation. It is crucial to determine the optimum screw length for both the unicortical and bicortical screw placement to achieve the strongest biomechanical stability. This would avoid injury to the anterior sacral structures for anteromedial insertion of the posterior transpedicular screw to the S1 (Okutan et al, 2004). Ebraheim et al (1997) reported that the mean anterior and posterior pedicular heights in their specimen were 30.2 and 26.1 mm respectively. In their specimens, the depths of pedicle and ala were reported as 27.8 and 45.8 mm. The mean posterior alar height was 28.7 mm and the mean first sacral pedicular height measured on the radiograph was 20 mm, which was significantly smaller than the real anatomical pedicular height. Ebraheim et al performed a study on 50 bony spines and they published that the S1 pedicle height was 21.2 mm in males and 20.2 mm in females (Xu et al, 1995). In contrast, Arman et al (2009) found that the anterior pedicle height of 14.81 ± 2.32 mm and a posterior pedicle height of 20.98 ± 2.34 mm. They reported that these distances reflect the vertical limits for the screw placement without the risk at S1. Esses et al (1991) reported that the distances from the upper part of the first sacral body to the upper border of first sacral foramen was 22.7 mm anteriorly and 23.07 mm posteriorly.

Okutan et al (2004) described an easy method to determine the length of anteromedial screw by measuring the outer interforaminal distance of S1 vertebra on anteroposterior radiograph of the sacrum. Using an entry point just inferolateral to the S1 facet, a study by Arman et al (2009) determined the distance between the entry point of a screw in the dorsal surface of the sacrum and anteromedial cortex of the S1 promontory, as well as the distance between the same dorsal point and the anterolateral cortex of the sacral wing. According to Arman et al (2009), there are two main screw trajectories for posterior sacral fixation, the anteromedial trajectory through the pedicle to the promontory and the anterolateral trajectory to the sacral wing. In their study, the measured anteromedial distance was 51 mm and the anterolateral distance was 50 mm.

Morales-Avalos et al (2012b) reported that there exist significant differences in the morphometric data of the vertebrae among the different ethnic groups, races, genders and ages. Okutan et al (2003) reported that the S1 anteromedial length was 50.7 ± 3.7 mm in females and 51.8 ± 3.5 mm in males. Okutan et al (2004) also found that S1 pedicle screw distance was 52.3 ± 3.1 mm on the right and 52.3 ± 3.9 mm on the left for men, whereas the same length was 50.9 ± 3.9 mm on the right and 51.1 ± 3.7 mm on the left for women. According to Arman et al (2009), the distance between the S1 pedicle entry point and the anteromedial point of S1 vertebra was 51.12 ± 4.83 mm on the right and 51.26 ± 4.72 mm on the left. Xu et al (1995) reported the mean S1 pedicle length was 43.7 mm for men and 41.7 mm for women. The height of S1 vertebral body has been reported to be 28.9 mm for men and 27.7 mm for women (Xu et al, 1995). According to Arman et al (2009), the length of the pedicle was found to be 8-10 mm longer than that from Xu et al (1995). They reported that S1 pedicle height is greater than other pedicles. In Arman et al (2009) study, the mean height of the S1 vertebral body was 30.22 ± 2.35 mm.

The measurements of the present study were performed according to Okutan et al (2003), Okutan et al (2003) measured the cephalocaudal height, anteroposterior width, pedicle length, transverse angle and sagittal angle of the first sacral pedicle from a Turkish population. They compared the measurements statistically among the males and females; however they didn't found any statistical differences for any of the measurements. In a study from Mexican population by Morales-Avalos et al (2012a), the S1 pedicle average length was 25 ± 2.41 mms, the S1 pedicle anterior and posterior average height was 20.68 ± 3.40 mms and 24.64 ± 3.77 mms respectively. They also performed the sacral canal dimensions on its superior opening, which were 15.13 ± 2.4 mms in the sagital diameter and 31.07 ± 2.65 mms for the transverse diameter. In the present study, the mean S1 pedicle length was 49.9 ± 3.6 mm for men and 46.3 ± 4.8 mm for the women. The cephalocaudal heights of S1 pedicle were 27.2 ± 4.0 mm and 23.9 ± 3.7 mm respectively for the male and female. Our study also compared the anteroposterior width of S1 pedicle which was 7.5 ± 1.3 mm, 7.5 ± 1.7 mm in males and females respectively. The anteroposterior distances of S1 from the sacral promontory until the spinous process of S1 were 52.9 ± 5.2 mm and 50.4 ± 6.8 mm respectively for the man and woman. The difference in the data of the present study with respect to the previous report is may be because of racial variations. The present study has observed that the data are different for males and females. This is different from the observations of Okutan et al (2003) study, as there was no statistically significant difference observed in their study with respect to any of the parameters measured with respect to the genders.

In conclusion, we opine that the present study has provided important morphometric data of the

S1 pedicle from the anatomical samples of South Indian population. This data is important for the safe approach during the placement and orientation of the screws while performing the lumbosacral instrumentation. The data of this study is also important for the procedures involving the sacral region as a diagnostic and surgical target. The morphometric details of the vertebrae, particularly of the pedicle, will determine the size of pedicular implants, including the length and width (Morales-Avalos et al, 2012a; Morales-Avalos et al, 2012b). This would also dictate the shape and direction of the screw and its ideal angulation at the time of insertion. Knowing the morphometric data is important to prevent injuries to adjacent neurovascular structures. This helps in decreasing the postoperative complication rate (Morales-Avalos et al, 2012b). This is especially important because the number of patients with spine diseases has increased in the recent years, requiring an increase in the number of surgical interventions. Spinal fixation through the transpedicular approach is being most commonly used to manage any kind of spinal disease (Morales-Avalos et al, 2012b). It has been opined that the anatomical data is more accurate than that from the radiological values. It is believed that the data of the present study is enlightening to the neurosurgeons and orthopedic surgeons.

REFERENCES

Arman C, Naderi S, Kiray A, Aksu FT, Yılmaz HS, Tetik S, Korman E. 2009. The human sacrum and safe approaches for screw placement. J Clin Neurosc 16: 1046-49.

Bogduk N. 2005. Clinical anatomy of the lumbar spine and sacrum**.** 4th edn. London: Churchill Livingstone, 59.

Brantley AG, Mayfield JK, Koeneman JB, Clark KR. 1994. The effects of pedicle screw fit. An in vitro study. Spine 19: 1752-58.

Diel J, Ortiz O, Losada RA, Price DB, Hayt MW, Katz DS. 2001. The sacrum: pathologic spectrum, multimodality imaging, and subspecialty approach. Radiographics 21: 83-104.

Ebraheim NA, Xu R, Biyani A, Nadaud MC. 1997. Morphologic considerations of the first sacral pedicle for iliosacral screw placement. Spine 22: 841-46.

Esses SI, Botsford DJ, Huler RJ, Rauschning W. 1991. Surgical anatomy of the sacrum: A guide for rational screw fixation. Spine 16: S283–88.

Frymoyer JW. 1988. Back pain and sciatica. N Engl J Med 318: 291–300.

Harrington PR, Dickson JH. 1976. Spinal instrumentation in the treatment of severe progressive spondylolisthesis. Clin Orthop 117: 157-63.

Kostuik JP. 1986. Techniques of internal fixation for degenerative conditions of the spine. Clin Orthop 203: 219-31.

Krogman WM, Iscan MY. 1986. The Human Skeleton in Forensic Medicine. 2nd edn. Springfield, Illinois: Charles C Thomas.

Lonstein JE, Denis F, Perra JH, Pinto MR, Smith MD, Winter RB. 1999. Complications associated with pedicle screws. J Bone Joint Surg Am 81: 1519-28.

Misenhimer GR, Peek RD, Wiltse LL, Rothman SLG, Widell EH. 1989. Anatomic analysis of pedicle cortical and cancellous diameter as related to screw size. Spine 11: 367-72.

Morales-Ávalos R, Leyva-Villegas JI, Vílchez-Cavazos F, Martínez-Ponce de León ÁR, Elizondo-Omaña RE, Guzmán-López S. 2012. Morphometric characteristics of the sacrum in Mexican population. Its importance in lumbosacral fusion and fixation procedures. Cir Cir 80: 528-35.

Morales-Avalos R, Re Elizondo-Omaña RE, Vílchez-Cavazos F, Martínez-Ponce de León AR, Elizondo-Riojas G, Delgado-Brito M, Cortés -González P, Guzmán-Avilán RI, Pinales-Razo R, de la Garza-Castro O, Guzmán-López S. 2012. Vertebral fixation with a transpedicular approach. Relevance of anatomical and imaging studies. Acta Ortop Mex 26: 402-11.

Okutan O, Kaptanoglu E, Solaroglu I, Beskonakli E, Tekdemir I. 2003. Pedicle morphology of the first sacral vertebra. Neuroanatomy 2: 16-19.

Okutan O, Kaptanoglu E, Solaroglu I, Beskonakli E, Tekdemir I. 2004. Determination of the length of anteromedial screw trajectory by measuring interforaminal distance in the first sacral vertebra. Spine 29: 1608-11.

Peretz AM, Hipp JA, Heggeness MH. 1998. The internal bony architecture of the sacrum. Spine 23*:* 971-*974.*

Vij K. 2011. Textbook of Forensic Medicine and Toxicology. Principles and Practice. 5th edn. New Delhi: Elsevier.

Xu R, Ebraheim NA, Yeasting RA, Wong FY, Jackson WT. 1995. Morphometric evaluation of the first sacral vertebra and the projection of its pedicle on the posterior aspect of the sacrum. Spine 20: 936-40.

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