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Pedicle morphology of the first sacral vertebra

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ABSTRACT
Posterior transpedicular screw fixation has been widely used for the management of unstable lumbosacral spine caused by trauma, degenerative conditions, congenital defects and neoplasms. Knowledge of the pedicle diameters of the first sacral vertebra is crucial for safe placement of the screws. Thirty dry sacral specimens (18 male, 12 female) were used for study of the first sacral pedicles. Cephalad-caudad height, anterior-posterior width, transverse and sagittal angles, and depth of S1 pedicle were presented. The mean width of the pedicles were estimated as 22.5±2.6 mm and 22.2±2.8 mm; the heights were 13.6±2.3 mm and 13.6±2.7 mm; the depths were 50.7±3.7 mm and 51.8±3.5 mm for female and male, respectively. The mean transverse angles were 43°±2.3 and 41°±2.2; the sagittal angles were 19°±2.9 and 19°±3.7 for female and male, respectively. The depth and the angle of screw trajectory is as important as entrance point for pedicular screw placement to the S1 to avoid injury to the vascular structures anteriorly and nerve roots medially.

Key words: pedicle, sacrum, spine, screw, anatomy, morphology

Introduction

Spinal fusion has been used successfully for many years in the management of segmental instability resulting from various conditions [1-3]. With the recent increased use of various pedicle screw instrumentations, there is concern about injuries to the pedicle cortex, nerve root, facet joint, and adjacent vital structures by a misplaced or misdirected pedicle screw [4]. For safer pedicle screw placement, it is critical to understand the exact posterior aspect of the first sacral vertebra (S1) and its pedicular anatomy. Description of the anatomy of the pedicles has been performed based on direct anatomic measures of normal samples. Several studies of pedicular anatomy exist, but these have generally been reported on European population, and have dictated many of the decisions in instrument and screw design [5, 6]. The purpose of this anatomic study was to determine the outlines of the anatomy of the S1 pedicle in the Turkish population, and to gain a better understanding of its structure and the clinical implication of these findings.

Materials and Methods

In this anatomic study, thirty adult dry sacra were used. These specimens were obtained from the Department of Anatomy at the Medical Faculty of Ankara University. There were 18 male and 12 female specimens. The sacra did not have any bony disease or deformity. All parameters were measured bilaterally using calipers accurate to 0.1 mm and a goniometer accurate to 1°.

DESCRIPTION OF LANDMARKS AND DISTANCES OF LINEAR AND ANGULAR MEASUREMENT

H distance: Cephalad-caudad height of S1 pedicle. H distance was measured between the most superior border of the S1 foramen and superior surface of body of S1 (Fig. 1).

W distance: Anterior-posterior widht of S1 pedicle was measured between anterior and posterior cortex of S1 pedicle (Fig. 2).

X point: This is a landmark that shows a point below and lateral to the inferior tip of the superior articular process of S1 and represents the entrance point of S1 screw insertion (Fig. 3).

P point: Promontorium (Fig. 1 and Fig. 2).

XP distance: Pedicle length is the distance from entrance point (X) to promontorium (P) (Fig. 2 and Fig. 4).

T angle: Transverse angle of S1 pedicle. T angle represents the angle between vertebral anteroposterior midline of S1 and XP line on transverse plane (Fig. 2).

S angle: Sagittal angle of S1 pedicle. S angle represents the angle between transverse plane of superior surface of S1 and XP line on sagittal plane (Fig. 4).

The measurements between male and female specimens for each parameter were compared with a two-tailed Student t test. Statistical significance was determined at $P \leq 0.05$.

Results

Thirty specimens were measured, distinguishing between male and female specimens for each paramater. Differences in measures of male and female specimens, including cephalad-caudad height and anterior-posterior widht of S1 pedicle, sagittal and transverse angles of S1 pedicle, and depth of S1 pedicle were not found to stastically significant ($p>0.05$).

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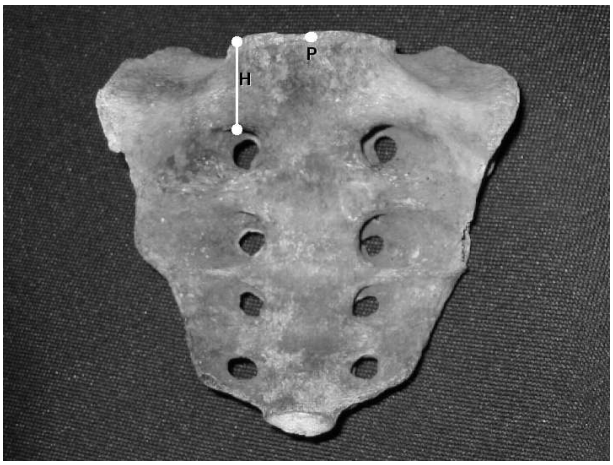

Figure 1 | Figure shows anterior view of the sacrum. H distance (Cephalad-caudad height of S1 pedicle) was measured between the most superior border of the S1 foramen and superior surface of body of S1. P point; Promontorium

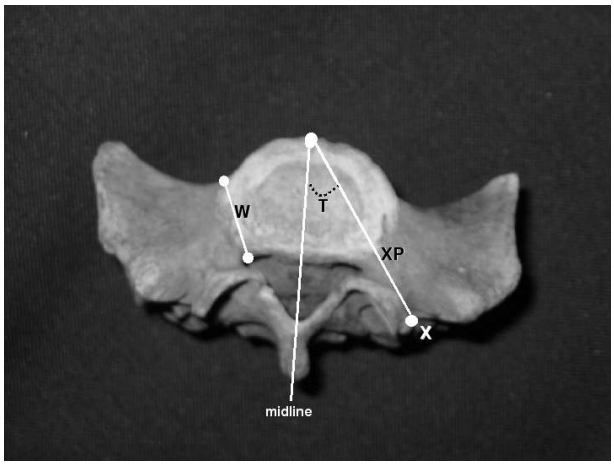

Figure 2 | Figure shows axial view of the sacrum. P point; Promontorium, XP distance; Pedicle length is the distance from entrance point (X) to promontorium (P), T angle; Transverse angle of S1 pedicle. T angle represents the angle between vertebral anteroposterior midline of S1 and XP line on transverse plane.

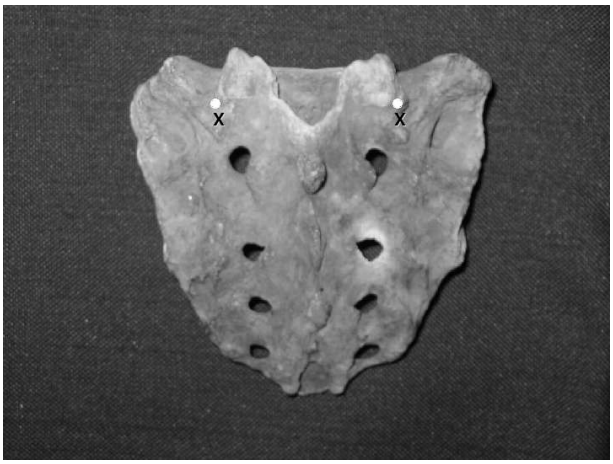

Figure 3 | Figure shows posterior view of the sacrum. X point is a landmark that shows a point below and lateral to the inferior tip of the superior articular process of S1 and represents the entrance point of S1 screw insertion.

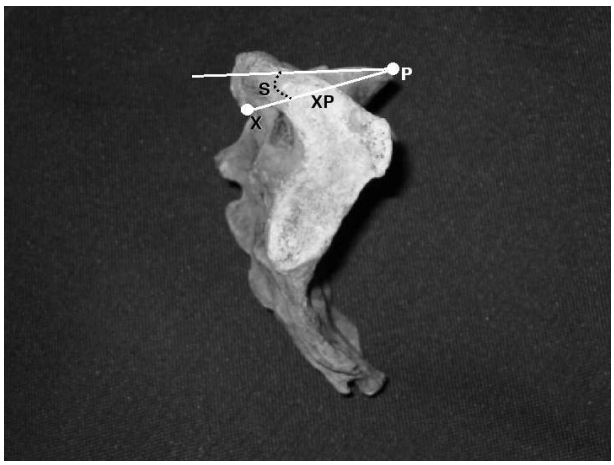

Figure 4 | Figure shows lateral view of the sacrum. XP distance; Pedicle length is the distance from entrence point (X) to promontorium (P), S angle; Sagittal angle of S1 pedicle.

Anterior-posterior widht of the S1 pedicle was measured as 22.5±2.6 mm on an avarage in the female. In the male, widht was measured as 22.2±2.8 mm on an avarage. Pedicle cephalad-caudad height mean diameters were measured 13.6±2.3 mm in the female. The mean diameters of height of S1 pedicle were measured 13.6±2.7 mm in the male. S1 pedicle length mean diameters were measured 50.7±3.7 mm in the female. In the male, this measure was 51.8±3.5 mm. The mean S and T angles of S1 pedicle were measured 19°±2.9 and 43°±2.3, respectively in the female. In the male, the mean S and T angles were 19°±3.7 and 41°±2.2, respectively. The data was summarised in Table 1.

Discussion

Achieving fusion across the lumbosacral junction is a significant challange when extending fusion levels to the sacrum. A detailed knowledge of pedicle of the first sacral vertebra measures is crucial when using the pedicle to gain purchase to the vertebra. There is no enough studies regarding S1 pedicle in the literature. Harrington and Dickenson suggested that pediculo-corporeal insertion of the screw is the best and the most guarantee method for

Table 1 | The table shows the results of dry-bone measurements, which were presented as milimeters (H, W, XP) and degrees (S, T). H distance; Cephalad-caudad height of S1 pedicle. H distance was measured between the most superior border of the S1 foramen and superior surface of body of S1. W distance; Anterior-posterior widht of S1 pedicle was measured between anterior and posterior cortex of S1 pedicle. X point; This is a landmark that shows a point below and lateral to the inferior tip of the superior articular process of S1 and represents the entrance point of S1 screw insertion. P point; Promontorium. XP distance; Pedicle length is the distance from entrence point (X) to promontorium (P). T angle; Transverse angle of S1 pedicle. T angle represents the angle between vertebral anteroposterior midline of S1 and XP line on transverse plane. S angle; Sagittal angle of S1 pedicle. S angle represents the angle between transverse plane of superior surface of S1 and XP line on sagittal plane.

	H	W	XP	S	T
FEMALE (n= 12)	13.6±2.3	22.5±2.6	50.7±3.7	19±2.9	43±2.3
MALE (n= 18)	13.6±2.7	22.2±2.8	51.8±3.5	19±3.7	41±2.2

lumbosacral fusion [7]. The pedicle of S1 differs from cervical, thoracal or lumbar pedicles. It is important to describe the unique anatomic structure of S1 pedicle.

Many authors have studied vertebral pedicle morphological characteristics in the axial, sagittal and angular dimensions [4-6, 8-10]. It appears that some authors have regarded the dimensions of the pedicle at its isthmus to be the most important diameter in relation to screw size for fixation for thoracolumbar vertebrae [4, 6, 8, 9]. Pedicle fracture may occur when increasingly larger screws were placed into an already expanded pedicle or when a screw, larger than the outer diameter of the pedicle, was passed through the pedicle in cervical, thoracic or lumbar vertebrae. This could easily lead to neurologic compromise of a medially passing spinal nerve. In the present study, we found that S1 pedicular heigh and width are larger than all available screw diameter in surgical use. Although there is no discordance between screw and pedicle diameter, there is always risk to damage the nerve root in the S1 foramen if the screw placed very medially and anterior vascular structures if the screw directed very laterally from the widely accepted enterance point (represented as legend X in the present study).

Hou et al. and Zindrick et al. describe that pedicle antero-posterior widht (W) and cephalo-caudal height (H) diameter is narrowest section of the pedicular isthmus of thoracic and lumbar vertebra [9, 11]. Robertson et al. reported the margins of the antero-posterior widht (W) and cephalo-caudal height (H) of S1 pedicle [10], but they have not performed any measurements. To our knowledge, S1 pedicle has not beed defined and measured yet. We define that W distance is the anterior-posterior widht of S1 pedicle which was measured between anterior and posterior cortex of S1 pedicle. H distance is defined as cephalad-caudal height of S1 pedicle. H distance was measured between the most superior border of the S1 foramen and superior surface of body of S1. These measuruments and definitions are the critical steps of the surgical procedures.

Marchesi et al. and Ebraheim et al. described the total length of the pedicle as the distance from the most posterior aspect of the junction of the superior articular facet and the anterior cortex of the vertebral body for the lumbar vertebrae [12]. Hou et al. also described two pedicle depths. The first depth is parallel to the midline from posterior cortex to anterior cortex for lumbar vertebra. The second definition of the pedicle depth is from posterior cortex to midline along the pedicle in thoracal and lumbar vertebrae [11]. We define S1 pedicular depth as the screw entrance point which is the below and lateral to the inferior tip of the articular process of S1 (X) to the promontory (P) as XP distance, shown in Figures 2 and 4. Harrington and Dickenson suggested that most secure first sacral screw placement passes through the first sacral pedicle to the sacral promontory [7]. For this reason, anatomical measurement of the pedicular depth has crucial importance in posterior sacral screw placement surgery.

Appropriate S1 screw placement, without injury to the adjacent vital structures, mainly depends not only entrance point of S1 screw insertion but also the direction of the screw. The anterior medial safe zone was described as promontory medially, internal iliac vein laterally (22-27 mm wide) and 2 cm superiorly to promontory [13]. For proper screw placement, screw direction should be oblique forward and inward. Peretti et al. notified that the oblique forward and inward degrees of S1 are 15° and 30°, respectively [14]. Louis also recommended inward screw insertion at an angle of 30-45 degrees [15]. Othervise, longer screws may penetrate anterior cortex lateral to promontorium and this may be hazardous to great vessels situated closely lateral to promontorium [13]. In the present study, the ideal angulations from the entrance point (X) were found to be about 41°±2.2 in a medial direction (T angle) and 19°±3.7 in a sagittal direction (S angle) for males, and 43°±2.3 medial and 19°±2.9 sagittal for females to target the promontorium.

Zindrick et al., Ebraheim et al., and Olsewski et al. have demonstrated the differences between pedicle dimensions of thoracic and lumbar vertebrae in both sex [4, 9, 16]. Although we have not found any sex comparison study of S1 pedicle in the literature, we found no statistical differences between male and female in S1 for any measurements.

As summary, the knowledge of the pedicular anatomy of the first sacral vertebra has crucial importance in the pediculocorporeal screw placement. Screw placement will be safe if the screw has the proper length and proper angulation. Pedicular depths are 51.8±3.5 mm for males and 50.7±3.7 mm for females and screws longer than these measures will penetrate the anterior cortex of S1. Transverse angles are 41°±2.2 for males and 43°±2.3 for females. The angle bigger than these measures may result in injury to spinal nerve with penetration of medial cortex of the foramen. Smaller angles may cause targeting more laterally from the promontorium and carries the risk of injury to the vital vascular structures.

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