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Space Available for Sacroiliac Screws in the S1 Vertebral Body

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Abstract

Objectives: To define the maximal sagittal cross sectional dimensions of the S1 vertebral body and quantify the area available for safe placement of transverse sacroiliac (SI) screws.

Methods: A laboratory investigation was performed using twelve fresh, frozen, non-preserved cadaveric pelvic specimens (six males, six females). The sacrum was dissected and removed from each pelvis. After the gross height and widths were measured, the sacra were split in the midsagittal plane and the dimensions of the first sacral segment were recorded. Then, starting from the center, the vertebral bodies were sequentially reamed in a medial to lateral direction in increasing one millimeter increments until a cortical breech occurred in the narrowest portion of the ala at the first sacral neural foramina. Using the diameter of the largest reamer, the cross-sectional area of space available for a transverse sacroiliac screw in the S1 body was calculated.

Results: The cross-sectional area of space in the sagittal plane, corresponding to a transverse sacroiliac screw trajectory, of the first sacral vertebral body averaged 204 mm^2 (range, 153 mm^2 to 226 mm^2), corresponding to a mean maximum reamer diameter of 16.1 mm (SD 1.08). The male and female sacra did not differ significantly with respect to overall size (mean height, 15.6 cm, SD 1.02; mean width 10.7 cm; SD 0.75) and the dimensions of the S1 body (mean height 28.41 mm, SD 2.23, mean depth 27.17 mm, SD 3.69).

Conclusions: Our results improve upon our understanding of the surgical anatomic parameters of the upper sacral segment with respect to placement of transverse sacroiliac screw(s) by quantifying the cross-sectional area in the sagittal plane.

Keywords: Trauma; Sacrum; Sacral fracture; Sacroiliac screws; Pelvic fracture

Introduction

Pelvic instability resulting from the traumatic disruption of the posterior pelvic ring, in the form of sacral fractures or fracture-dislocations of the sacroiliac joint, may be encountered in a variety of clinical settings from both high and low energy mechanisms. When operative intervention is indicated, the goal of early reduction and stabilization of the posterior pelvic ring is necessary to prevent residual deformity and restore of the integrity of the posterior weight bearing sacroiliac arch, which may promote earlier rehabilitation and reduce morbidity [1-7]. Though other methods of posterior ring stabilization have been described, fluoroscopically-assisted, percutaneous sacroiliac (SI) screw fixation has gained popularity among surgeons secondary to advances in intraoperative imaging, improved understanding of biomechanics posterior pelvic ring fixation, and relatively low complication rates, especially regarding wound healing [8,9]. However, the complex and variable anatomy of the pelvis can make the procedure technically challenging for even the most experienced surgeons [1-4]. Mal placed screws, which have been reported to occur at rates from zero to 24%, may result in devastating complications due to the close proximity of surrounding neurovascular structures, with associated neurologic complication rates as high as 18% [1-3,10,11]. In the largest series of 244 SI screws by Routt, et al. two percent of screws were found to be malpositioned with a less than one percent incidence of neurovascular complications.

Although information has been published regarding the surrounding neurovascular anatomy in the posterior pelvis literature describing pertinent surgical anatomy regarding sacroiliac screw placement is relatively sparse. The goal of this study is to describe and quantify, using a cadaveric model, the cross-sectional area of the first sacral vertebral body and its anatomical confines about a simulated transverse sacroiliac screw trajectory. The results will help determine an anatomic parameter of safe space available in the first sacral vertebral body for transverse screw placement.

Methods

Twelve (six male and six female) adult pelvises were obtained as fresh frozen specimens from the bureau of anatomic services of Louisiana. The soft tissues from the anterior and posterior aspect of the specimens were dissected to expose the bony sacrum. The sacra were then carefully disarticulated from the pelvis at the sacroiliac joints and separated from the remaining specimen. The first measurement was from the center of the sacral promontory to the tip of the coccyx, which was defined as the height of the sacrum, and the second measurement was from sacral ala to ala across the first sacral vertebral body (S1), which was defined as the sacral width (Figure 1). The sacra were then split in a midline sagittal plane in the center of the superior endplate of the first sacral body (Figure 2).

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Next, gross anatomic parameters were measured of the first sacral vertebral bodies to include the central sagittal and central axial widths, defined as the respective S1 body heights and depths (Figure 1).

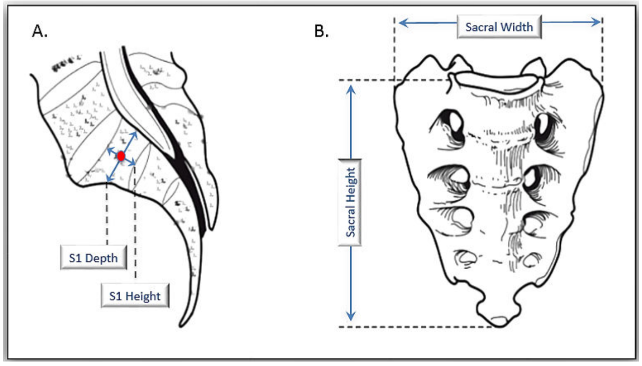

Figure 1: Illustration of the sacrum in a midsagittal section and anterior view in the coronal plane. Blue arrows in (A) and (B) are representative of the measured S1 height and depth and sacral height and width, respectively. The intersection of the measured height and depth (red circle) marks the starting point at which the S1 body was sequentially reamed.

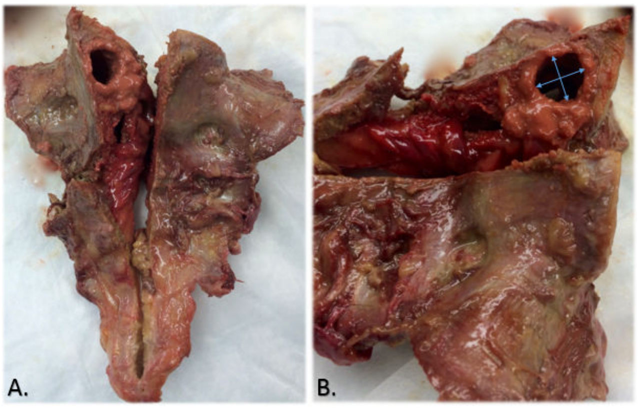

Figure 2: An example of one sacral specimen is shown following midline sagittal split (A) and reaming (B).

Once measurements were complete, the S1 vertebral body was sequentially reamed from medial to lateral in 1 mm increments starting at the midpoint (Figure 2), which was defined as the transection of the measured height and depth (Figure 1), until a breach of the sacral alar cortex occurred. The anatomical parameters of each sacrum were recorded and compared as well as the maximal diameter reamer that each body could accommodate. Using the maximal diameter of the reamer, the total area of space available in the sagittal plane of each vertebral body could be determined.

Results

The gross dimensions of each cadaveric specimen are shown in Figure 3. The average height of the sacrum was 15.6 cm (SD 1.02, p=0.27) and the average width measured 10.7 cm (SD 0.75, p=0.47).

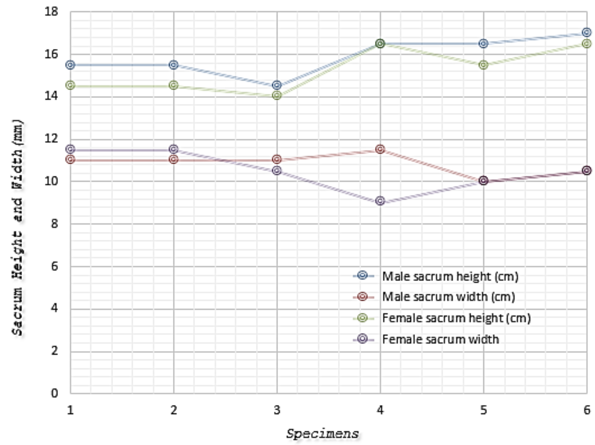

Figure 3: The measurements of the sacral heights and widths are depicted for male and female specimens. The average height was 15.6 mm (SD 1.02; p=0.28) and the average width was 10.7 mm (SD 0.75; p=0.47), with no significant differences between male and female specimens.

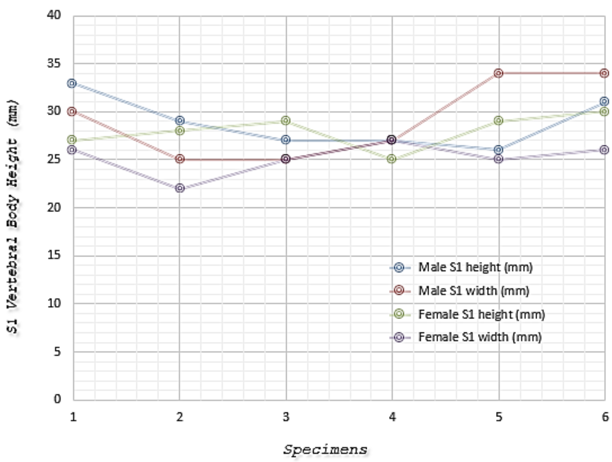

Figure 4: The measurements of the S1 vertebral body heights and depths are depicted for male and female specimens. The average height was 28.41 mm (SD 2.23; p=0.54) and the average width was 27.17 mm (SD 3.69; p=0.07), with no significant differences between male and female specimens.

The S1 vertebral body dimensions in the midsagittal and midaxial planes corresponding to heights and depths measured a mean 28.42 mm (SD 2.23, p=0.54) and 27.16 mm (SD=3.69, p=0.07), respectively, as shown in Figure 4. There were no significant differences in the anatomic parameters measured between the male and female specimens.

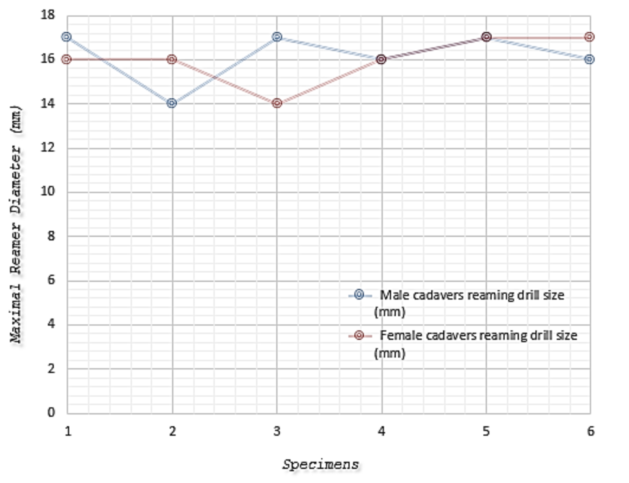

Figure 5: The maximal diameter reamer used in each specimen is shown for each male and female specimen. The mean maximal diameter was 16.1 mm (SD 1.08; p=0.80).

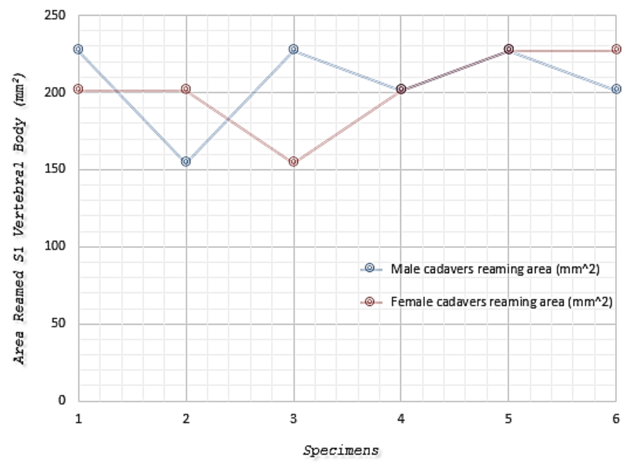

Figure 6: The maximal area that could be produced in the S1 body in the sagittal plane is shown for each specimen. The mean area was calculated to be 204 mm^2 (SD 26.45; p=0.79) with no significant differences between male and female specimens.

The maximal diameter reamer that could be accommodated in each specimen in the sagittal plane before cortical breech occurred is shown in Figure 5. The average maximal diameter was found to be 16.1 mm (SD 1.08, p=0.80), which also did not differ significantly between the male and female specimens. The corresponding average cross sectional area of space calculated was to be 204 mm^2 (SD 26.45, p=0.79) (Figure 6). The area of the vertebral body first breeched by an oversized drill bit in all specimens was the first sacral neural foramen.

Discussion

Percutaneous sacroiliac screw placement is a safe and well-described technique to stabilize posterior pelvic ring disruption [8-20]. The complex anatomy of the pelvis and proximity of neurovascular structures leave little room for error; therefore, identification of radiographic landmarks and relationships in the osseous screw corridor are of paramount importance [21-25]. Anatomic parameters of the upper sacral segments with regard to screw placement are not well described, especially in the setting of sacral dysmorphism [17,26-32]. Individual injury patterns and sacral morphology affect screw trajectory, length, and number, further complicating surgical decision making and technique. In our study, we sought to quantify at least one anatomical parameter of the upper sacral segment as it relates to screw placement by holding some of the variables constant, e.g. uniform screw trajectory in intact, non-dysmorphic upper sacral segments. To our knowledge, there are no reports which describe this anatomic parameter using a cadaveric model.

The three-dimensional trajectory of the screw can be defined by its chosen starting point, desired end-point, and passage through the bony corridor of the sacral ala. The corridor has the gross anatomical shape of two cones placed point to point, forming a space of maximal constriction of cross sectional area. This space, which has been described as the "vestibule" or the "bottleneck," is located in the mid-alar region, bound cranially by the cortical bone just below the fifth lumbar nerve root and caudally by the osseous tunnel of the first sacral neuroforamen [26,27,31].

Ovoid in shape, with a larger anterior-posterior plane diameter and smaller superior-inferior plane, the corridor is obliquely oriented to the sagittal plane of the first sacral vertebral body, coursing cranially and medially from the outer portion of the ala until becoming confluent with the body of the adjacent vertebra. Measuring the dimensions of this narrowest point in the bony corridor has been the subject of several excellent reports which have used computed tomography scans to create reconstructed images of the corridor in various planes, including those perpendicular to the narrowest point, in order to quantify its dimensions [6,7,27].

While these studies are extremely valuable in our understanding this anatomy as it relates to screw orientation and starting points, our results illustrate a slightly different perspective of the corridor's anatomy. While obtaining the dimensions of the corridor at its narrowest point has obviously useful implications, the measured area is still a two-dimensional, oblique plane through which the screw may pass at a large, but finite, number of angles as dictated by the screw's three-dimensional trajectory through the length of the corridor. By holding the screw trajectory constant, and using the center of the first sacral vertebral body as the starting point for a theoretical retrograde screw path, our results represent the cross-sectional area of an axially symmetric three dimensional "cylinder" of space connecting the vestibule of the corridor to the S1 body. As such, the space available for transverse screw placement in the S1 body in three dimensions is still confined by the vestibule, and smaller in cross sectional area than the greatest area of the invariably obliquely-oriented vestibule. Our results are most comparable to those published by Gardner et al. in which the authors used reconstructed images relative to the sacrum to simulate inlet (true axial) and outlet (true coronal) images recreating the three-dimensional landmarks used intraoperatively for determining screw trajectory. Simulated outlet views demonstrated the average transverse "safe zone" width to be 12.9 mm, and simulated inlet views averaged a transverse "safe zone" of 20.0 mm [32], which correlate with our results, considering the difference attributable to a cylindrical reamer crossing the ovoid "safe zone" at an oblique angle relative to the transverse screw trajectory.

Our results provide the surgeon with an anatomic parameter which may provide some guidance in decision making when planning one or more transversely oriented sacroiliac screws. A theoretical cylindrical space with a maximal cross sectional diameter of 204 mm^2 connecting the center of the S1 point to the vestibule, by comparison, is about 30% smaller than the surface area of the face of a penny. The external diameter of a standard 7.3 mm cannulated screw (7.3 mm) would occupy just over 40% of the total area and the shaft diameter (4.8 mm) would occupy about 18% of the area, making the placement of two screws tenuous, but still quite feasible. If two screws are placed within the described anatomical confines, one must consider the resultant biomechanical implications of the screw proximity.

There are several limitations in this study. First, the chosen screw path and trajectory utilized in this study provide only an idea of the cross-sectional area of the corridor from the S1 body to the alar vestibule, and should not take the place of careful study of the individual patients' anatomy and injury patterns pre-operatively. Likewise, the sacrums studied were classified as non-dysmorphic, though a spectrum of dysmorphism likely exists, and the small number of sacrums studied may have affected the results as patients may exhibit varying degrees of size differences with and without sacral dysmorphism or trauma [17,31,32]. Further research with the addition of dysmorphic sacrums, and similar measurements into the second sacral segment may help guide surgical decision making and technique further.

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