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# Posterior Wall Defect of Sacrum: An Anatomical Study of Sacral Spina Bifida

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## ABSTRACT

**AIM:** To investigate the incidence, types, morphological and morphometric properties of spina bifida on dry sacral bones.

**MATERIAL and METHODS:** 110 dry adult sacrums gathered from the bone collections of the Laboratory of the Anatomy Department of Dokuz Eylul University School of Medicine were examined. The parameters analysed were: 1) results of parameters related to the posterior sacral wall; 2) classification and rate of the closure defects; 3) classification of the top sacral vertebrae according to the shape of its superior surface; 4) presence of sacralisation and lumbalisation among sacrums with dorsal wall defects; 5) vertebral levels of apex of the sacral hiatus; and 6) vertebral levels of closure defects of the sacrums.

**RESULTS:** We determined 22/110 (20%) sacrums demonstrated spina bifida. Of these 22 sacrums, 4 (18.18%) showed complete and 18 (81.82%) showed incomplete spina bifida. We noted the coexistence of spina bifida with sacralisation (6/22 [27.27%]) and lumbalisation (5/22 [22.73%]). The types of defects were described and grouped as 'V' (Type 1), inverse 'V' (Type 2), window (Type 3), foramen (hole) (Type 4), sand watch (Type 5), narrow linear (Type 6), wide linear (Type 7), and bridged (Type 8). The shape of upper surfaces of the sacrums with spina bifida was grouped as: cavity (20/22, 90.9%), hump (1/22, 4.5%), and flat (1/22, 4.5%).

**CONCLUSION:** A precise definition of the anatomical variations of sacrums is essential for surgeons, particularly when operating using endoscopic techniques and for anaesthesiologists applying caudal epidural block.

**KEYWORDS:** Defect, Sacral hiatus, Sacrum, Spina bifida

## INTRODUCTION

The worldwide incidence of spina bifida has declined in recent years. However, a larger proportion of new patients present with more distal lesions (i.e. sacral) (2,10,35). The incomplete closure of the sacral canal is known as spina bifida occulta (SBO) and is comprise of anomalies ranging from the partial defect of the posterior arch of the sacral vertebrae top to sacral S1-S5 spina bifida (16).

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**Table I:** The Results of Parameters Related to Posterior Sacral Wall

| | n | Minimum-Maximum (mm) | Mean ± SD (mm) |
|---|---|---|---|
| Horizontal diameter of the sacral canal superiorly (**A**) | 22 | 22.68-34.33 | 29.50 ± 3.51 |
| Anteroposterior diameter of the sacral canal superiorly (**B**) | 20 | 7.97-22.28 | 14.59 ± 4.47 |
| posterior height of the sacrum (**C**) | 21 | 97.23-137.13 | 113.00 ± 11.21 |
| The distance between the median sacral crest and the upper margin of the sacrum (**D**) | 18 | 19.51-48.75 | 32.19 ± 9.53 |
| The length of the median sacral crest (**E**) | 18 | 27.31-93.14 | 61.04 ± 20.24 |
| The height of apex of the sacral hiatus (**F**) | 20 | 3.54-47.12 | 24.51 ± 11.30 |
| The distance between sacral corns at sacral hiatus (**G**) | 22 | 10.54-22.22 | 16.47 ± 2.90 |
| The A-P distance at apex of sacral hiatus (**H**) | 20 | 1.37-11.89 | 5.63 ± 2.51 |

**Table II:** The Classification and the Rate of Posterior Sacral Wall Closure Defects

| | Shape | Case (Rate) |
|---|---|---|
| Incomplete | "V" shaped (Type 1) | 4 (18.18%) |
| | Inverse "V" shaped (Type 2) | 4 (18.18%) |
| | Window shaped (Type 3) | 4 (18.18%) |
| | Foramen shaped (Type 4) | 2 (9.09%) |
| | Sand watch shaped (Type 5) | 0 (0%) |
| | Type 3+Type 5 | 1 (4.55%) |
| | Narrow linear (Type 6) | 1 (4.55%) |
| | Type 1+Type 4 | 1 (4.55%) |
| | Type 3+Type 6 | 1 (4.55%) |
| Complete | Wide linear (Type 7) | 1 (4.55%) |
| | Bridged (Type 8) | 1 (4.55%) |
| | Type 5+Type 6 | 1 (4.55%) |
| | Type 1+Type 2+Type 3+Type 6 | 1 (4.55%) |

The rate of sacral SBO (SSBO) alone has been observed in healthy populations as 12.4% to 21.4% (16,33). Degenerative calcification may cause the filling of some bone defects in the elderly population. Therefore, the prevalence of SBO tends to decrease with age (8,19). This age-related decrease in the prevalence of SBO has been documented many studies (8, 19,48,65,69).

It has been determined that 90% to 100% of cases with sacral level lesions are outpatients (1,9,20,30,58). The clinical spectrum of SBO ranges from insignificant cases with minimal anatomical variation to more severe cases of neurological deficits with meningomyelocele (1,9,31,44,46,51,58,59,73). The skin and nervous system malformations may coincidentally be observed together owing to their common ectodermic origin (28). Sacral skin lesions such as dimples, focal hypertrichosis, nevus, or lipomas are observed in 51% to 100% of cases with occult spinal dysraphism and appear to be the most important clinical predictors (24,28).

In cases without external manifestations, SBO of the sacrum may cause backache, posterior disc herniation, enuresis, functional disorders of the lower urinary tract, and neurological foot abnormalities (1,18,22). Depending on the level of the lesion, erectile dysfunction is observed in approximately 75% of adult males with spina bifida (14,23). Before performing any surgical procedure on the sacrum (i.e. caudal epidural block, internal fixation via transpedicular and lateral mass screws), the surgeon must consider the congenital defects of the sacrum to help prevent serious surgical complications (61,62,64)

The objective of the present study is to investigate the incidence, types and morphological and morphometric properties of spina bifida on dry sacral bones.

## MATERIAL and METHODS

We examined 110 dry adult sacrums gathered from bone samples in the Laboratory of the Anatomy Department of Dokuz Eylul University School of Medicine. The bone samples were obtained from the West Anatolian region. The sex and age of the bones were unknown. Permission for this investigation was obtained from Dokuz Eylul University School of Medicine. The sacrums were macroscopically evaluated for the presence of dorsal wall closure defects (spina bifida), as well as the levels and types of these defects.

In the present study, the parameters analysed were: 1) results of parameters related to posterior sacral wall (Table I, Figure 1A-C); 2) classification and rate of closure defects (Table II, Figure 2); 3) classification of the top sacral vertebrae according to the shape of its superior surface (cavity, hump, or flat) (Figure 3A-C); 4) presence and rate of sacralisation and lumbalisation among sacrums with dorsal wall defects (Figure 4A, B); 5) vertebral levels of apex of the sacral hiatus (Table III, Figure 5A-F); and 6) vertebral levels of closure defects of the sacrums (Table IV).

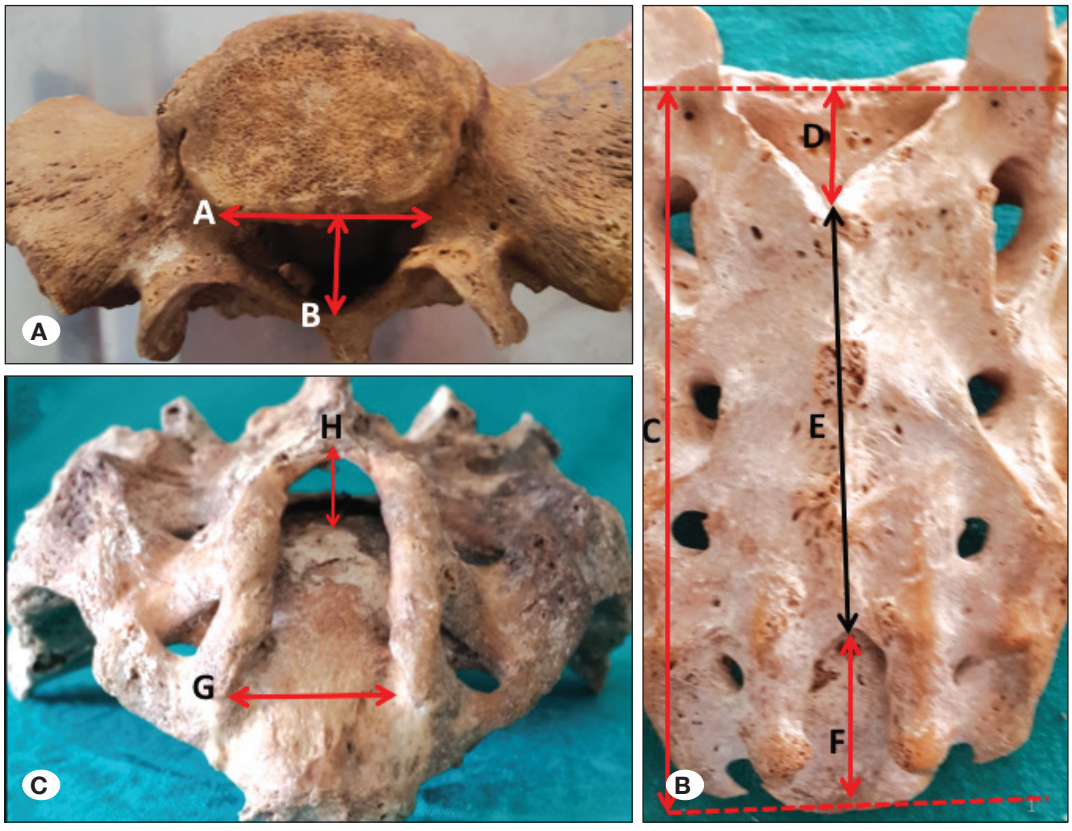


**Figure 1:** Measured parameters.
**1A)** horizontal (**A**) and anteroposterior (**B**) diameter of the sacral canal superiorly,
**1B)** posterior height of the sacrum (**C**), the distance between the median sacral crest and the upper margin of the sacrum (**D**), the length of the median sacral crest (**E**), the height of apex of the sacral hiatus (**F**),
**1C)** the distance between sacral corns at sacral hiatus (**G**), the antero-posterior distance at apex of sacral hiatus (**H**).

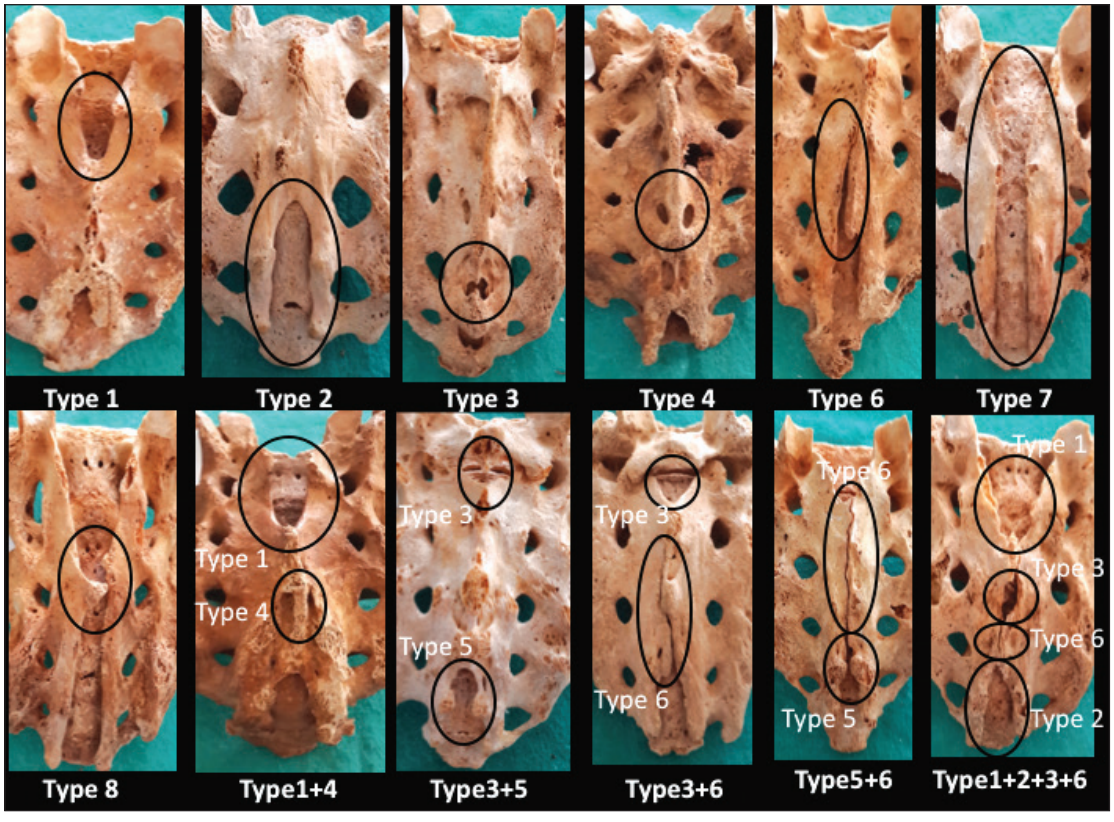


**Figure 2:** The types of posterior sacral wall closed defects. "V" shaped (**Type 1**), inverse "V" shaped (**Type 2**), window shaped (**Type 3**), foramen (hole) shaped (**Type 4**), sand watch shaped (**Type 5**), narrow linear (**Type 6**), wide linear (**Type 7**), and bridged (**Type 8**).

**Table III**: The Vertebral Level of Apex of the Sacral Hiatus

| Level | Completed Open Posterior Wall | Sacral 2 vertebra | Sacral 3 vertebra | Sacral 4 vertebra | Sacral 5 vertebra | Completed Close Sacral Hiatus |
|---|---|---|---|---|---|---|
| Case N (rate) | 4 (18.18%) | 1 (4.54%) | 7 (31.82%) | 7 (31.82%) | 1 (4.54%) | 2 (9.09%) |

**Table IV:** The Vertebral Level of Closure Defect of the Sacrums

| Level | L5 vertebra | S1 vertebra | S2 vertebra | S3 vertebra | S4 vertebra | S5 vertebra |
|---|---|---|---|---|---|---|
| Case N (rate) | 3 (3.6%) | 13 (15.5%) | 12 (14.3%) | 14 (16.7%) | 22 (26.2%) | 20 (23.8%) |

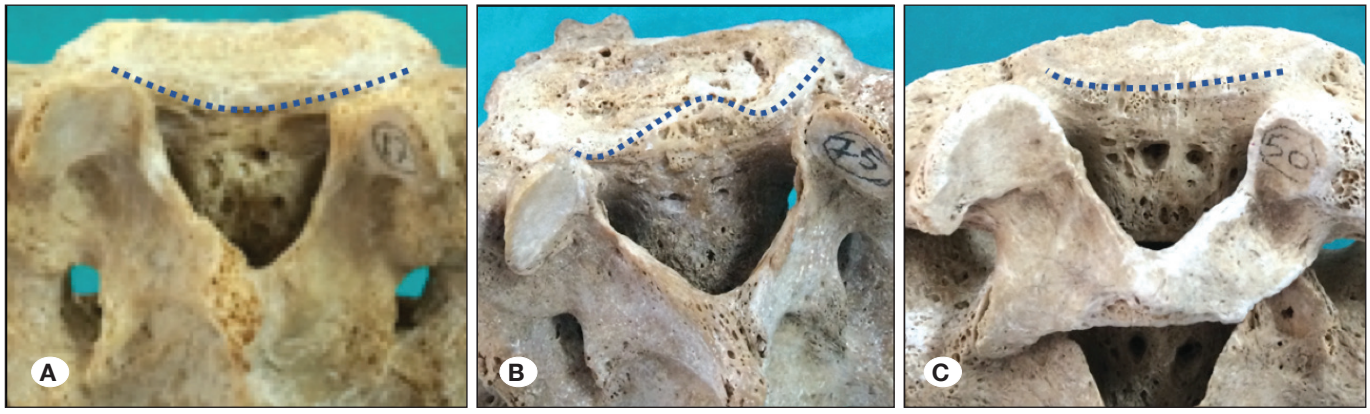


**Figure 3:** The superior surface of corpus of the first sacral vertebrae were classified according to their shape. **A)** cavity, **B)** hump, **C)** flat.

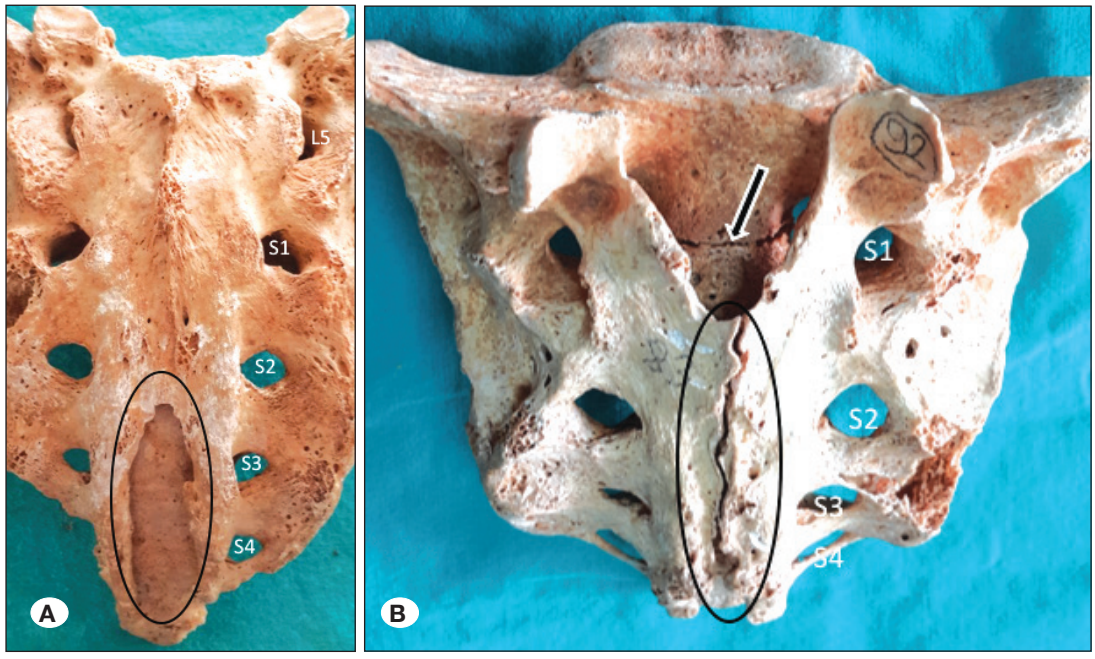


**Figure 4:** Sacrums representing spina bifida with sacralization or lumbalization. **A)** Sacralization, **B)** Lumbalization.

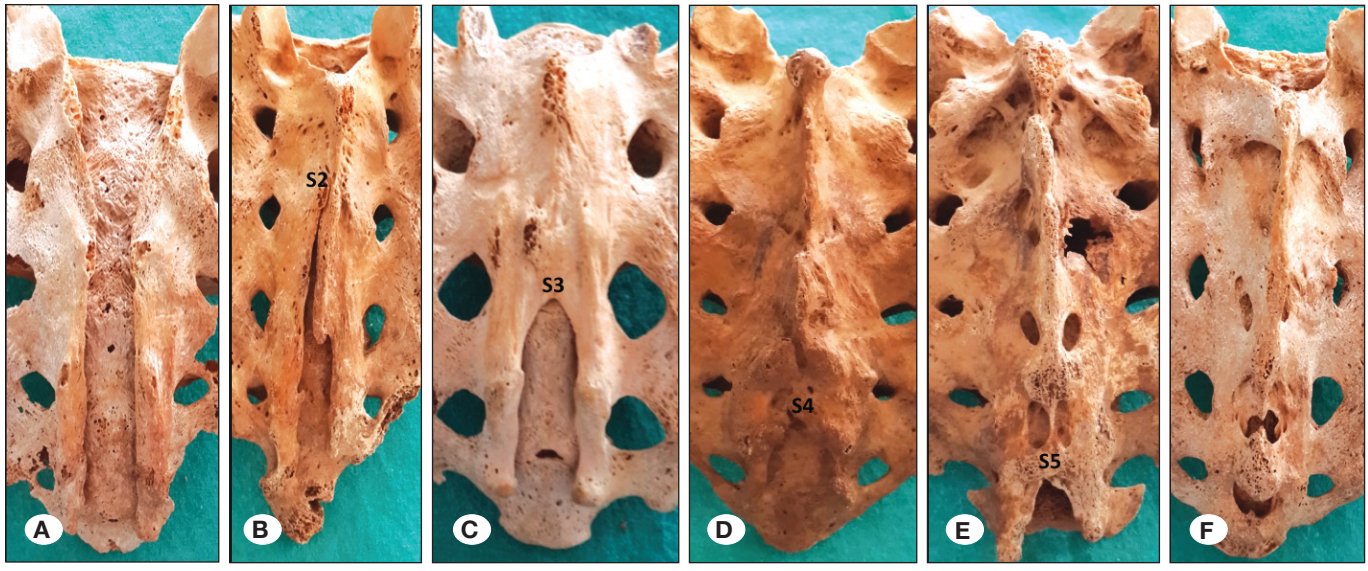


**Figure 5:** Determined the level of the apex of the sacral hiatus. **A)** Completed Open Posterior Wall, **B)** S2 vertebra level, **C)** S3 vertebra level, **D)** S4 vertebra level, **E)** S5 vertebra level, **F)** Completed Close Sacral Hiatus.

All sacrums were photographed, and measurements were obtained using a Mitotoyo digital calliper sensitive to 0.01 mm.

## RESULTS

We determined that 22 of the 110 sacrums (20%) demonstrated complete (4 of 22 [18.18%]) or incomplete (18 of 22 [81.82%]) spina bifida (Table II). We also observed the coexistence of spina bifida with sacralisation (6 of 22 [27.27%]) and lumbalisation (5 of 22 [22.73%]) (Figure 4A, B). The types of the defects were grouped as 'V' (Type 1), inverse 'V' (Type 2), window (Type 3), foramen (hole) (Type 4), sand watch (Type 5), narrow linear (Type 6), wide linear (Type 7), and bridged (Type 8) (Table II, Figure 2). Types 1, 2, and 3 were the most frequently observed defects in the dorsal wall of the sacrums (4 of 22 [18.18%] for each type). There were 2 cases with a Type 4 (2 of 22 [9.09%]) defect, and 1 case each involving Type 6 (1 of 22 [4.54%]), Type 7 (1 of 22 [4.54%]), and Type 8 (1 of 22 [4.54%]) defects. We observed that Type 5 is not a stand-alone defect, and it was found in 2 cases combined with Type 3 (1 of 22 [4.54%]) and Type 6 (1 of 22 [4.54%]) defects. Additionally, there were 3 other cases with combined defects: Types 1 and 4 (1 of 22 [4.54%]), Types 3 and 6 (1 of 22 [4.54%]), and Types 1, 2, 3, and 6 (1 of 22 [4.54%]) (Table II). There were only 4 sacrums with a completely open posterior sacral wall (Table II). The evaluated parameters were as follows: horizontal (A) and anteroposterior (B) diameter of the sacral canal superiorly, posterior height of the sacrum (C), distance between the median sacral crest and the upper margin of the sacrum (D), length of the median sacral crest (E), height of apex of the sacral hiatus (F), distance between the sacral corns at the sacral hiatus (G), and anteroposterior distance at the apex of the sacral hiatus (H) (Table I, Figure 1A-C). The shape of the upper surfaces of the sacrums (superior surface of the corpus of the S1 vertebrae) with spina bifida were evaluated and grouped as: cavity (20 of 22 [90.9%]), hump (1 of 22 [4.5%]), or flat (1 of 22 [4.5%]) (Figure 3A-C).

We also determined, in descending order, the location of the apex of the sacral hiatus: S4 level (7 of 22 [31.82%]), S3 level (7 of 22 [31.82%]), S2 level (1 of 22 [4.54%]), and S5 level (1 of 22 [4.54%]). There were 4 cases with a completely open sacral canal, and 2 cases with a completely closed sacral hiatus (Table III, Figure 5A-F).

We observed 6 cases (27.27%) with sacralisation and 5 cases (22.72%) with lumbalisation among the 22 sacrums with closure defects in the dorsal wall (Figure 4A, B).

The location of the different types of dorsal closure defects among the 22 sacrums were determined, in descending order, as follows: S4 level (22 of 22), S5 level (20 of 22), S3 level (14 of 22), S1 level (13 of 22), and S2 level (12 of 22) (Table IV).

## DISCUSSION

Spina bifida, is a group of developmental anomalies which occur as a result of defects in neural tube closure (76). With an occurrence rate of 1 per every 1000 pregnancies preceding folic acid fortification, neural tube defects are the second most prevalent malformation after congenital heart defects (11). De Bakker et al. declared that the human neural tube unites at a single site and that neural tube defects are not limited to a specific location (13).

Spinal dysraphism (Greek: bad suture) defines all types of congenital spinal disorders that involve abnormal differentiation or incomplete closure defect at the midline of the mesenchymal, osseous, and neural tissue (45,68). The severity of the condition is directly influenced by whether the nervous tissue or meninges are protected by skin or whether they are exposed to the environment (36).

The spina bifida cyctica refers to a neural tube defect, whereas SBO refers to a small defect brought about by the nonclosure of the posterior vertebral neural arches (36). Paleopathologists have mostly accepted and reported that SSBO was a congenital anomaly (e.g. 15,17,53,71). However, there is no consensus on the level of closure defects that should be considered as SSBO. Under normal conditions, the neural arches of the last 2 sacral segments remain underdeveloped, thus forming the sacral hiatus (6,12).

There are variations at the level of nonclosure of the lamina of the sacral bodies (56). Normal variations of the sacral hiatus are observed at the S4–S5 vertebrae levels with high frequency and at the S3 level with intermediate frequency. Therefore, SSBO that is determined at the S3, S4, or S5 level is accepted as being within the normal variation (e.g.1,19,26,43,53). Bagheri and Govsa examined 87 dry adult human sacrums and determined the rate spina bifida rate to be 19% at the S1–S5 level (5). In addition to the above-mentioned studies, we determined this rate as 20% (22 of 110). In the present study, the SSBO were observed at the S1 level in 13 sacrums (11.82%) (Table IV).

We also grouped the sacrums with SSBO according to the shape of the closure defects: 'V', inverse 'V', window, foramen (hole), sand watch, narrow linear, wide linear, bridged (Table II, Figure 2). The most frequently observed shapes were 'V' (4 of 22 [18.18%]), inverse 'V' (4 of 22 [18.18%]), and window (4 of 22 [18.18%]). Singh and Mahajan examined 159 dry human sacrums and also grouped the shapes of the sacral hiatus using the following terms: inverted 'U' (42.95%), inverted 'V' (27.51%), irregular (16.10%), dumbbell (11.40%), and bifid (2.01%) (63). Similar to Singh and Mahajan (63), Bagheri and Govsa (5) examined 87 adult dry sacrums according to the shape of the sacral hiatus and grouped them as: inverted 'U' (33.33%), inverted 'V' (19.45%), irregular (19.45%), dumbbell (6.90%), bifid (3.45%), and 'M' shaped (10.34%). In these studies, the types of closure defects were described and grouped differently and, therefore, the rates of the each type of closure defect have been observed differently.

Tardieu et al. reported that Muscatello investigated patients with SBO and found that it was most commonly observed in the caudal part of the spine (66). French reported the incidence of SBO in adult cases as approximately 10% and, similar to Muscatello's findings, commonly encountered in the lumbosacral region (21). In the present study, the incidence of spina bifida (complete and incomplete) was observed as 20% (22 of 110). SSBO in adults may not cause any symptoms for many years and may, therefore, be diagnosed coincidentally. This may be the reason why the incidence is twice as common in the present study than what has been reported in the normal population.

Eubanks and Cheruvu studied 3100 dry sacrums and reported that the defect extended from S1 to S5 in only 12.4% of SSBO cases, meaning that total SSBO was found in only 1.2% of the population studied (16). Kumar et al. studied dry bone sacrums in India and observed the deficient dorsal wall of the sacrum as 2.7% and 12.5% in males and females, respectively (38). In the present study, we determined that 22 of the 110 sacrums (20%) had spina bifida, 4 (18.18%) with complete and 18 (81.82%) with incomplete spina bifida (Table II). Eubanks and Cheruvu examined a large collection of sacrums from both white and black races and found the incidence of spina bifida to be 1.2% (16). This difference may be the result of geographic conditions, racial differences or number of bones evaluated in the studies.

Seçer et al. evaluated 401 patients with low back pain (LBP) lasting longer than 2 weeks by using standard lumbosacral x-rays. They found that 34 (8.5%) patients had spina bifida, which was most commonly observed at the level of the S1 vertebra (30 patients [7.48%]) (60). In this study, 52 (12.1%) of the 401 patients with LBP were reported to have congenital vertebral abnormalities. Of the congenital vertebral abnormalities, 34 (8.5%) were spina bifida and 18 (4.5%) were transitional vertebra (60). In the current study, we determined the number of sacrums with spina bifida as 22 of the 110 (20%) examined. Of these, 11 (50%) had transitional vertebra. Six cases (27.27%) had sacralisation and 5 cases (22.72%) had lumbalisation defects (Figure 4A, B). The rate of spina bifida was higher in our study than the rates reported previously. This difference may be due to the differences in the studied material and population. Seçer et al. performed their study using lumbosacral x-rays of patients with LBP and we evaluated the human dry sacrums (60).

We measured the posterior length of the sacrums as 113.0 ± 11.21 mm. Maddikunta and Ravinder studied 60 adult sacrums (27 male, 33 female) and measured the posterior length of sacrums as 113.9 ± 11.53 mm in males and 90.0 ± 9.13 mm in females (41). Ravichandran et al. studied 123 sacrums (63 males, 60 females) and measured the mean posterior length as 97.8 mm in males and 90.96 mm in females (54). Both of these studies were performed in India, but in different geographic regions. The length of the sacrums in males was longer in Ravichandran et al.'s (54) study compared with that of Maddikunta and Ravinder (41). This difference may be due to the differences in sample size. Furthermore, regional differences may account for the differences in length. The results of male sacrum examinations in Maddikunta and Ravinder's (41) study were almost the same as the results of the present study, but we do not have any knowledge regarding the sex of the bones.

Developmental errors of vertebrae are highly variable, ranging from 1 level to multiple defects throughout the spine, and may affect any part of the vertebrae (neural arch defects, segmental defects of vertebral bodies, anterior vertebral body defects, and minor fusion anomalies) (74). The vertebral defects that cause congenital scoliosis may be caused by failure of formation, failure of segmentation or a combination of both (3,25,27,29,72). Cowell and Cowell studied the coexistence of SBO and idiopathic scoliosis in 100 patients and observed the incidence as 34% (3 at L5, 31 at S1) (12). In a recent study, Passias et al. reported clinical data for the coexistence of spinal anomalies, such as spina bifida and scoliosis. They reported that 11.4% of patients with spinal anomalies had scoliosis (50). Marchetti and Bartolozzi categorised spondylolisthesis as developmental

spondylolisthesis and acquired spondylolisthesis (42). According to the severity of the bony dysplastic changes, developmental spondylolisthesis was further divided into 2 groups: low dysplastic and high dysplastic. High dysplastic spondylolisthesis has a congenital nature and is found in one-third of the patients with SBO of either L5, the sacrum or both (4,75). High grade L5–S1 spondylolisthesis is associated with a variable degree of bony dysplasia, including rounding of the upper sacral endplate (sacral doming), an abnormal superior sacral facet, malformations such as hypoplasia of the upper surface of the body of the first sacral vertebra, hypoplasia or aplasia of the facets, and other dysplastic changes (70). The coexistence of these malformations with spina bifida reduces the efficiency of the stabilising system represented by the posterior articular complex (40). Therefore, the definition of the upper sacral endplate is of importance. In the present study, we evaluated the upper sacral surfaces of sacrums with spina bifida. We did not observe any dome-shaped upper surfaces. Furthermore, we noted the shape of the upper surfaces as 20 (90.9%) cavity, 1 (4.5%) hump, and 1 (4.5%) flat (Figure 3A-C).

Bony defects of the sacrum may be accompanied by fibrous bands, fatty or other tumours occupying the area on the laminal defect. This can cause compression of the nerves of the cauda equina, resulting in interference in nerve conduction in the sacral reflex arcs (32,39,65).

Depending on the level and nature of the lesions that affect the spinal cord in spina bifida patients with myelomeningocele, serious motor, sensory and autonomic disorders can occur in the lower limbs, bladder, and bowels (7). Therefore, faecal incontinence, constipation, and urinary incontinence and retention are major problems profoundly affecting the life quality and social integration of spina bifida patients (67). Galloway and Tainsh reported an increased prevalence of SBO among adults with lower urinary tract problems (22). The incidence of SBO was determined to be 35% to 60% among enuretic children (34,37,55,57). However, the rate was also as high as 17% in normal children (8). Kumar et al. reported the outcome of enuresis treatment in children with SBO to be relatively the same as that for normal children (37). Pippi Salle et al. found SBO in 70% of children with voiding dysfunction (52).

The abnormality presents clinical importance with respect to caudal epidural block (CEB), which is used in the diagnosis and treatment of lumbar spine disorders (61). The anatomical variations may lead to the failure of the CEB or transpedicular and lateral mass screw placement (61,64). Spina bifida may lead to a possible increased risk of damage to the sacral nerves and present difficulty in internal fixation by screws (64). Knowledge about the anatomic distance between the sacral hiatus and dural sac is important in CEB with respect to the risk of dural puncture. The causes of failure of CEB are bony septum in the sacral hiatus, hiatal agenesis, or complete agenesis (spina bifida) in 7% of cases. Additionally, in 1% of cases, total spina bifida and detection of the dura mater just beneath the hiatus were reported (61,62). Park et al. applied caudal epidural steroid injection to patients in Korea using ultrasound guidance and measured the intercornual distance between the apex of both cornua as 16.9 ± 2.7 mm (49). In the present study, we measured the mean distance between the bilateral cornua and found similar results (16.47 ± 2.90 mm). Bagheri and Govsa examined 87 dry adult human sacral bones and measured the length of sacral hiatus as 28.07 ± 7.1 mm (5). Singh and Mahajan measured the mean length of sacral hiatus as 22.69 mm in India, whereas we measured the length of sacral hiatus as 24.51 ± 11.30 mm (63). This difference may be because of the cases with spina bifida included in our study. We determined mostly the location of the apex of the sacral hiatus at S4 and S3 level (14 of 22 [63,64%]). Similarly, Kumar et al. found the location of the apex at S4 in 76.23% of cases (38). At the level of apex, Pal et al. measured the mean anteroposterior diameter of sacral canal as 5.34 mm, whereas we measured it as 5.63 ± 2.51 mm (47).

## CONCLUSION

It is essential to precisely define the anatomical variations of sacrums for surgeons, particularly when they are operating using endoscopic techniques, and for anaesthesiologists applying CEB. We assume that the present study may guide medical doctors and surgeons during diagnostic and surgical procedures related to the sacrum.

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