Original Article

Morphological And Morphometric Study of The Sacrum In The Pakistani Population

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Abstract

Objective: This study aimed to assess the morphological and morphometric variations in the dry human sacrum, considering the clinical importance of sacral variations in different interventions.

Methods: Thirty-nine dry human sacra were inspected in the Department of Anatomy, King Edward Medical University, Lahore, from April to June 2024. Specimens with any abnormalities or fractures were not included. All measurements, including the width and height of the sacral canal and hiatus, were taken using a digital Vernier caliper. All data were assessed using SPSS version 26.

Results: The most prevalent shape of the sacral hiatus was an inverted V, accounting for 35.9%. Moreover, the most common shape of the sacral canal was a V shape, with 51.3%. The mean sacral height and width were 109.45 ± 14.75 mm and 105.21 ± 13.56 mm, respectively. The right and left oblique distances showed no significant difference.

Conclusion: The Pakistani population showed substantial variation in the morphology of the sacrum. The prevalence of inverted V and V morphometry of the sacral hiatus and canal signifies specific population patterns. Various clinical procedures, such as ilio-sacral fixation, sacral nerve stimulation, and caudal epidural anaesthesia, require precise anatomical knowledge to ensure safety and accuracy.

Keywords: Sacrum, Spinal canal, Epidural Anesthesia, Pakistan

Introduction

The sacrum is a triangular bone located at the base of the vertebral column between the two hip bones.[1] It is formed by the fusion of five sacral vertebrae.[2] The sacrum is one of the most important bones that transmits weight from the axial skeleton to the lower limbs.[2] It forms the posterior wall of the pelvic girdle and articulates with the hip bone to form the sacroiliac joints.[3] The sacrum is convex posteriorly and concave anteriorly. Internally, the sacral canal represents a continuation of the vertebral canal and transmits the sacral nerves.[4] Laterally, the dorsal surface contains four pairs of dorsal sacral foramina, which allow the passage of the posterior rami of the sacral spinal nerves.[5] Inferiorly, it connects to the tailbone.[6] All these features provide support to the pelvis.

In the fields of neurology, anaesthesia, and obstetrics, anatomical data of the sacrum are of immense importance.[8] During prenatal observations, assessing the foetal development measurement of sacral height is crucial.[9] Percutaneous electrodes are inserted through the dorsal sacral foramina in sacral nerve stimulation to evaluate sacral nerve activity for managing pelvic floor dysfunctions.[10] Furthermore, caudal epidural block is a commonly utilised technique for both intraoperative anaesthesia and chronic pain management, especially in conditions such as lumbosacral disorders and persistent lower back pain.[11] This procedure involves the administration of anaesthetic or analgesic agents into the epidural space through the sacral hiatus.[12] Anatomical variations in the shape and dimensions of the sacral hiatus and cornua can contribute to procedural difficulties.[13] Stabilisation procedures involving the sacrum are frequently required in response to sacral fractures or disruptions of the sacroiliac joint.[14] Iliosacral screw fixation is a common technique in which screws are directed through the S1 pedicle into the sacral body to achieve rigid stabilisation.[15] However, sacral pedicle screws are associated with a higher incidence of implant failure than those placed in lumbar vertebrae due to anatomical variability and the complex morphology of the sacrum. Detailed knowledge of the pedicles, neural foramina, and sacral canal in relation to the surrounding ligaments and neural elements is indispensable for safe and effective anatomical interventions.

The present study was designed to perform a detailed morphometric analysis of the anatomical structures located on the pelvic and dorsal aspects of the sacrum.

Materials And Methods

This was a descriptive cross-sectional study. A total of 39 dry human sacra of undermined age and sex were analyzed morphologically and morphometrically from April 2024 to June 2024 in the Department of Anatomy, King Edward Medical University, Lahore, from April to June 2024. Sacral specimens were limited by the exclusion of sacra with fractures, deformities, or missing segments to ensure measurement accuracy. Only anatomically intact specimens were considered to maintain the reliability of the research, which resulted in a smaller but methodologically significant sample size. All measurements were obtained using a digital vernier caliper and recorded in millimetres.

Contributions:
IA MH - Conception, Design
IA MT SSR WI RT - Acquisition, Analysis, Interpretation
IA MT - Drafting
MH SSR WI RT - Critical Review

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The following parameters were evaluated on the pelvic and dorsal surfaces of each sacrum, as shown in Figure 1.[1,7,14,18]

1. Length of the sacral hiatus (SH), measured from the superior margin of the hiatus to the tip of the sacral cornua
2. Vertical distance from the sacral apex to the highest point of the sacral hiatus
3. Transverse diameter between the lateral tips of the sacral cornua
4. Distance from the dorsal sacral foramina at the S2 level to the superior margin of the sacral hiatus
5. Vertical distance from the superior border of the S1 vertebra to the superior margin of the sacral hiatus
6. Distance from the S2 dorsal sacral foramina to the sacral apex
7. Oblique distance from the highest point of the sacral hiatus to the most prominent point of the right lateral sacral crest (D1)
8. Oblique distance from the highest point of the sacral hiatus to the most prominent point of the left lateral sacral crest (D2)
9. Total height of the sacrum measured from the sacral promontory to the apex along the midline on the dorsal surface
10. Sacral height measured from the sacral promontory to the apex along the midline from the pelvic surface
11. The maximum sacral width recorded the greatest transverse distance between the most lateral points of the ala.
12. Mid-vertical height of the S1 vertebral body measured from the superior to the inferior margins of the S1 body
13. Anteroposterior median diameter of the S1 vertebral body
14. Maximum transverse diameter of the S1 vertebral body
15. Maximum transverse diameter of the sacral canal
16. Anteroposterior median diameter of the sacral canal

The morphological characteristics of the sacrum, including the shape of the sacral hiatus and sacral canal opening at its superior entrance, were also examined. All data were tabulated for statistical analysis.[19,20]

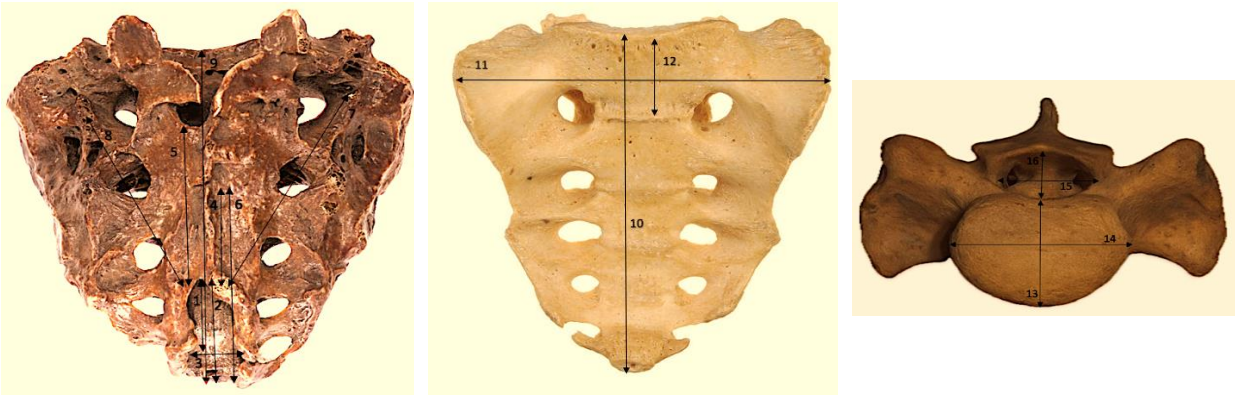

Figure 1: Sacral morphometric parameters

Results

The quantitative data obtained were analysed using SPSS (version 26), and the mean values of all parameters and the standard deviation of the mean are presented in Table 1. As shown in Table 2, the inverted V-shaped sacral hiatus predominated among the observed specimens, whereas the V-shaped sacral canal represented the most frequent canal morphology.

Table 1: The morphometric parameters of the sacrum

Parameter	Range	Minimum	Maximum	Mean	Std. Deviation
1.	35.80	9.50	45.30	26.19	10.01
2.	51.20	11.40	62.60	42.22	13.26
3.	11.50	5.40	16.90	10.66	3.23
4.	45.50	22.40	67.90	44.09	10.91
5.	40.00	50.30	90.30	71.76	11.58
6.	44.10	43.40	87.50	66.23	12.69
7.	49.00	44.50	93.50	74.27	12.81
8.	35.60	56.80	92.40	74.96	10.35
9.	40.00	87.40	127.40	105.41	11.65
10.	55.00	82.40	137.40	109.45	14.75
11.	45.40	82.40	127.80	105.21	13.56
12.	19.70	20.30	40.00	30.77	6.57
13.	18.90	20.50	39.40	28.64	5.99
14.	32.30	34.60	66.90	51.10	8.14
15.	17.40	20.80	38.20	31.51	4.17
16.	11.60	8.20	19.80	14.38	3.28

Table 2: Shapes of Sacral Hiatus and Canal

Shape of Sacral Hiatus	Frequency (n)	Percentage (%)
Inverted U	13	33.33
Inverted V	14	35.90
Bifid	2	5.13
Irregular	8	20.51
M	1	2.56
Dumbbell	1	2.56
Shape of Sacral Canal	**Frequency (n)**	**Percentage (%)**
Deep V	6	15.38
V	20	51.28
U	13	33.33

To assess the lateral symmetry of the sacral hiatus, we compared the mean values of D1 (oblique distance from the highest point of the sacral hiatus to the most prominent point of the right lateral sacral crest) and D2 (oblique distance from the highest point of the sacral hiatus to the most prominent point of the left lateral sacral crest). No statistically significant difference was found between D1 (74.27 ± 12.81 mm) and D2 (74.96 ± 10.35 mm), indicating that the sacral hiatus was positioned approximately at the midline. The agreement between D1 and D2 was further evaluated using Bland–Altman analysis. The mean difference between D1 and D2 was approximately *0.69* mm, with 95% limits of agreement ranging from the *lower* to the *upper limit.* Figure 2 demonstrates that most data points lie within these limits, suggesting good bilateral symmetry. It shows minimal systematic deviation of the sacral hiatus toward either side.

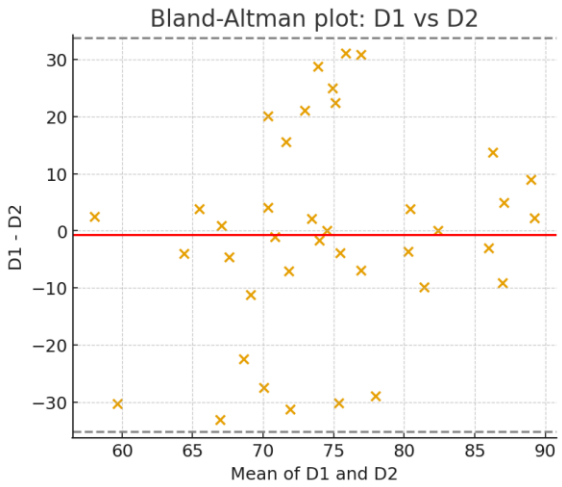

Figure 2: Measurements of the sacral hiatus between right (D1) and left (D2) using–Altman plot

Discussion

This study represents the morphological and morphometric characteristics of the sacrum in Pakistan.
Marked variability was noted in the dimensions and shape of the sacral hiatus and canal. These are consistent with earlier reports from regional and international populations. These variations are vital for clinical fields of anesthesia, gynecology, orthopedics, and radiology.
In the current study, an inverted V-shaped sacral hiatus was the most frequently observed configuration, followed by an inverted U shape, aligning closely with the observations of Anusha et al.[5] and Sugawara et al,[9] who reported that inverted V and U morphologies predominated in their respective populations. Similar trends have been noted by Abera et al.[12] in Ethiopian dry bones and Polat et al ([10] in Turkish samples, suggesting that these shapes represent a common morphological pattern across diverse ethnic groups. Conversely, rare forms, such as M-shaped and dumbbell-shaped hiatuses, were less prevalent, which coincides with the findings of Rathod et al,[14] and Khokhar et al,[7] who also reported these variants as uncommon anatomical occurrences.
The mean length of the sacral hiatus and the transverse distance between the sacral cornua in the present study were within the range reported by Kumar et al, [2] and Jakka et al, [3.] Minor differences in mean values may be attributed to population-based genetic diversity, sample size, and methodological differences in measurement. These parameters are of significant practical importance in caudal epidural anaesthesia, where accurate localisation of the sacral hiatus influences both the success rate and patient safety. As Sugawara et al,[19] and Khokhar et al,[13] emphasised, reduced hiatus dimensions or irregular morphology may complicate needle placement and increase the risk of dural puncture or injection failure.
Symmetry assessment of the sacral hiatus evaluated by comparing D1 and D2 measurements revealed no significant lateral deviation. It means that the hiatus is almost present in the middle of the sacrum. This finding agrees with the morphometric results of Erbek et al,[18] and Pandey,[6] who found bilateral symmetry in the majority of specimens.
Banik et al, [16] and Erbek et al,[18] observed similar maximum height and width of the sacrum. These parameters are necessary in orthopaedic and spinal surgeries. For iliosacral screw fixation, accurate sacral dimensions minimise the risk of iatrogenic nerve injury. Polat et al,[10] and Nastoulis et al,[11] further emphasised that the anatomical variability of the sacral canal and foramina influences the stability and placement of spinal implants in the S1 and S2 regions.
The morphological variations of the sacral canal observed in the current analysis showed a predominance of the V-shaped canal, followed by the U and deep V types. Similar findings were reported by Elvan et al,[9] and Özcan et al.[1] This implies that during sacral development, the shape of the sacral canal correlates with the pattern of dorsal wall fusion. Developmental anomalies, such as incomplete fusion of laminae with irregular canal shapes, can affect caudal block procedures and radiological interpretation.
Differences were observed between different populations as reported in Ethiopian Abera et al.[12], Indian Kumari et al,[4.] Turkish Polat et al.,[10.] and Pakistani Khokhar et al.,[13.] and Billah et al.[20.] This shows the importance of different genetic and nutritional factors on the morphology of the sacrum. Accurate knowledge of sacral anatomy is mandatory for safer interventions in various clinical procedures.
However, more advanced research is needed for further refinement of the data.

Conclusions

This study highlights the important morphological and morphometric differences in the sacrum in the Pakistani population. Inverted V shapes were the most common form of the sacral hiatus, whereas V shapes were the most common for the sacral canal. Differences in sacral height and width compared with those in other populations were also noted, which could be due to environmental or genetic factors. However, further research is needed in different regions to compare more populations. The study was limited by a small sample size, and the sacra were obtained

only from King Edward Medical University. We should obtain more data regarding variations in the morphological characteristics of the sacrum with larger and regionally diverse samples to strengthen the findings.

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