

Original Research Article

Morphological Variations of Sacrum in Adult Indian Population

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ABSTRACT

Introduction: The sacrum is considered as a highly variable bone. Several morphological variations have been documented which exhibit differences in the frequency of occurrence and morphological characteristics in various study populations. Variant anatomy of the sacrum may be associated with backache, enuresis, neurological anomalies of the lower limb and functional disorders of lower urinary tract.

Purpose: The purpose of this study was to identify and describe morphological variations of sacrum in Indian population and enable comparison with different populations.

Materials and Methods: The study was conducted on 108 dry adult human sacra and morphological characteristics and variations were noted.

Results: Sacral skewness was observed in 7.4% sacra with right sided skewness being predominant. The presence of accessory auricular surface (AAS) was noted in 13% sacra which was at the level of S3 vertebra in most sacra. Spina bifida (SB) was observed in 11.1% sacra and it was most commonly located at S1 vertebral level. Furthermore, the lumbo-sacral transitional vertebra (TV) was documented in 10.2% sacra.

Conclusions: Sacrum displays numerous variations in Indian population such as skewness, AAS, SB and TV. Thorough knowledge of morphological characteristics and variations of sacrum is vital and should be contemplated during diagnosis and treatment of sacrum-related diseases.

KEY WORDS: Accessory auricular surface, Spina bifida, Transitional vertebra, Sacral skewness, Variations.

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INTRODUCTION

The sacrum is formed by union of five progressively smaller sacral vertebrae and their costal elements, sustaining the integrity of the

spinal column. The bony framework of the true pelvic cavity is constituted postero-superiorly by the pelvic surface of the sacrum and coccyx. Its base forms the lumbo-sacral angle

by articulating with the fifth lumbar vertebra, and the apex articulates with the coccyx [1]. In the anatomical position, superior surface of the base inclines downwards and forwards at 30° or more [2]. The anteriorly projecting upper margin of the first sacral vertebra is the sacral promontory which constitutes an important obstetric landmark during clinical and radiological pelvimetry [3]. Lateral to the bodies of sacral vertebrae, is the wing like ala of sacrum on each side, comprising of fused costal elements and transverse processes. It has an auricular surface on its lateral side for articulation with the ilium, thereby completing the pelvic ring [2]. The sacrum contributes to the stability of the pelvic ring by its situation, being wedged between the two hip bones and also endures weight transmission. The transmission of weight to the sacrum is initially from its body and two articular facets and then through its two auricular surfaces to the hip bone [4].

The sacrum is recognized as a highly variable bone and numerous morphological variations have been reported [5]. Position and extent of the sacral auricular surfaces show variations which are normal, high up or low down, these may produce vertical shift in weight-bearing patterns between L5 and S1 segments, changing weight distribution at the lumbo-sacral and sacroiliac regions. This positional change of auricular surface can explain low back pain conditions [6]. In addition to the sacral auricular surface (AS), accessory auricular surfaces (AAS) are encountered, that may vary in measurement, location and laterality in each sacrum [7]. These usually result from stress of weight-bearing and could be frequently mistaken for an abnormal osseous projection (exostosis), especially when there is associated osteoarthritis or ankylosis [8].

Various developmental defects also plague the sacrum, most known being spina bifida (SB), a condition in which there is incomplete fusion of the vertebral neural arch. It is usually seen at lumbo-sacral region at the level of the fifth lumbar or upper one or two sacral vertebrae and occasionally may affect all the components of dorsal sacral arch [9]. SB may not present any external manifestations or its location may

be marked by a dimple, hairy patch, haemangioma or pigmented area. Its clinical significance ranges from anatomical variants of little importance to strong association with clinical conditions such as posterior disc herniation, backache, enuresis, neurological abnormalities of the lower limb and functional disorders of lower urinary tract [10]. Presence of SB may enhance the chances of injury to the sacral nerves and cause hindrance in internal fixation of screws [11]. Knowledge of sacral SB assumes significant clinical importance during caudal epidural block (CEB) to avoid complications [10].

The lumbo-sacral spine plays an important role in posture and supports the weight of the body [12]. Lumbo-sacral transitional vertebrae (TV) are common congenital anomalies of the lumbo-sacral spine [13]. The sacrum may contain six vertebrae, by development of an additional sacral element or by incorporation of the fifth lumbar or first coccygeal vertebra. Complete or partial fusion of fifth lumbar vertebra with sacrum (sacralization) is seen in over 6% of normal population. It is usually incomplete and limited to one side and one or both transverse processes of L5 may be enlarged with reduced L5-S1 disc space [1]. Less frequently an extra lumbar vertebra due to lumbarization of S1 is also seen. The existence of transitional vertebrae may result in a vertebral level being wrongly identified unless detected preoperatively [14]. Lumbo-sacral transitional vertebrae (TV) are frequently named the culprit in the etiology of low back pain as they increase the risk for development of nerve-root symptoms [15, 16]. Patients with lumbo-sacral TV have been reported with increased risk for advanced disc degeneration or disc herniation above the TV and facet joint arthrosis which can lead to stenosis of spinal canal and neural foramina [17].

Differences exist in the morphological characteristics of sacrum in various study populations. So far, out of the studies available, few determine the morphological variations of sacrum, especially in the Indian population. The present study is an attempt to describe morphological variations of the Indian sacra which are implicated in several

clinical conditions.

MATERIALS AND METHODS

A cross-sectional observation study was done on 108 dry adult human sacra in Department of Anatomy. Sacra displaying damage or bony outgrowth were excluded from the study.

The following characteristics were observed:

- 1. Sacral skewness-** An asymmetry of sacrum in which the middle sagittal line of pelvic surface skews to right or left, was noted.
- 2. Auricular surface (A.S.)-** Surface and location of auricular surface was observed.
- 3. Accessory auricular surface (A.A.S.)-** Shape, surface, location and unilateral or bilateral presence of accessory auricular surface were noted.
- 3. Sacral spina bifida:** The number and vertebral level was documented for sacral spina bifida.
- 4. Lumbo-sacral transitional vertebra -** Presence of lumbo-sacral transitional vertebra was observed.

RESULTS

A total of 108 dry adult human sacra were obtained to study the following morphological characteristics and variations.

Sacral Skewness: Sacral skewness was found in 8 sacra (7.4%), with skewness being right sided in 5 (4.6 %) and left sided in 3 (2.8 %) sacra (Fig. 1, Table 1).

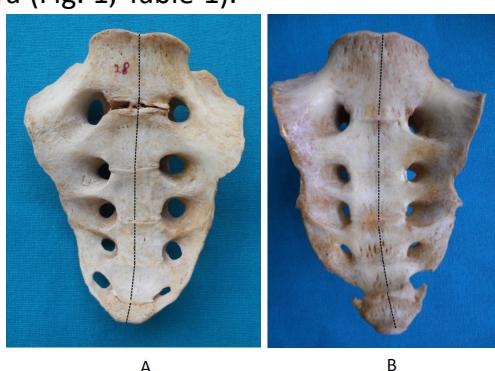


Fig. 1: Anterior surface of sacrum showing- A Right sided sacral skewness, B Left sided sacral skewness

Sacral Skewness	Total (n=108)	Percent
Absent	100	92.6
Right	5	4.6
Present	Left	2.8
Total	8	7.4

Table 1: Incidence and laterality of sacral skewness.

Auricular Surface: On the right side, the AS was flat in 13 and slightly concave in 95 sacra; while on the left side it was flat in 14 and slightly concave in 94 sacra (Fig. 2, Table 2).

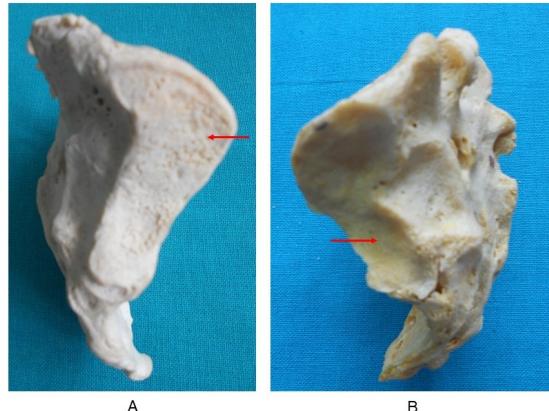


Fig. 2: Lateral aspect of the sacrum showing - A Flat auricular Surface B Slightly concave auricular Surface

Table 2: Morphological characteristics of auricular surface (AS).

AS	Right AS (n=108)	Percent	Left AS (n=108)	Percent
Flat	13	12	14	13
Slightly concave	95	88	94	87
Location				
S1-S2	4	3.7	4	3.7
S1-S3	103	95.4	103	95.4
S1-S4	1	0.9	1	0.9

The most common location of AS was at the level of S1-S3 vertebrae, found in 103 (95.4%) sacra. The AS was located at the S1-S2 vertebral level in 4 (3.7%) sacra and at the level of S1-S4 in one sacrum (0.9%).

Accessory Auricular Surface: The presence of AAS was noted in 14 sacra (13%). The AAS was found to be bilateral in 9 and was unilateral in 5 sacra (Table 3).

Table 3: Incidence and laterality of accessory auricular surface (AAS).

AAS	Total (n=108)	Percent
Absent	94	87
Present	14	13
Bilateral	9	8.4
Unilateral	5	4.6

AAS were observed to be of two shapes- crescent and oval. The crescent variety was found in 8 sacra on right side and in 5 sacra on left side. Oval articular surface was found in 6 sacra on right side and in 4 sacra on left side (Fig. 3, Table 4).

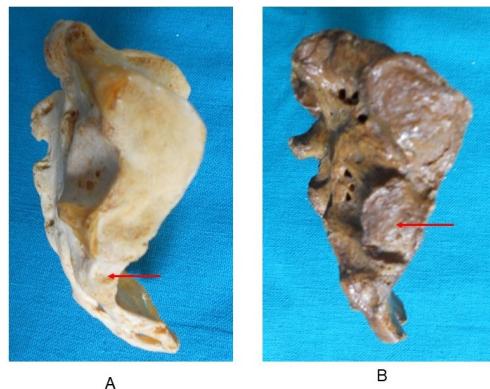


Fig. 3: Lateral aspect of the sacrum showing-
A Crescent shaped accessory auricular surface
B Oval accessory auricular surface

Table 4: Morphological characteristics of accessory auricular surface.

AAS	Right AAS (n= 14)	Percent	Left AAS (n=9)	Percent
Shape				
Crescent	8	57.1	5	55.6
Oval	6	42.9	4	44.4
Surface				
Flat	2	14.3	0	0
Slightly concave	12	85.7	9	100
Location				
S2	1	7.1	0	0
S3	12	85.7	9	100
S3-S4	1	7.1	0	0

The AAS on the right side was flat in 2 and slightly concave in 12 sacra; while on the left side it was slightly concave in 9 sacra.

The location of AAS was seen at the level of S2 vertebra on the right side in 1 sacrum. AAS was at the level of S3 vertebra in 12 sacra on the right side and in 9 sacra on left side. It was found at the level of S3-S4 in only one sacrum. Sacra with bilateral accessory auricular surface were located at the level of S3 in all 9 sacra.

Spina Bifida: SB was observed in 12 sacra (11.1%). It was most commonly located at S1 level (8.3%). Only one sacrum (0.9%) showed the non-closure at S1 and S2 and 2 sacra (1.8%) showed non closure of S1 to S5 (Fig. 4, Table 5).

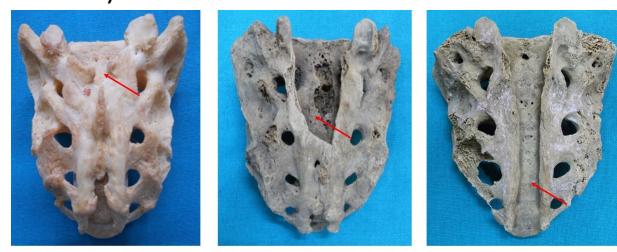


Fig. 4: Posterior surface of sacrum showing-
A Spina Bifida at S1 vertebral Level
B Spina Bifida at S1, S2 vertebral Level
C Spina Bifida at S1, S2, S3, S4, S5 vertebral Level

Table 5: Incidence and vertebral level of spina bifida (SB).

SB	Total (n=108)	Percent
Absent	96	88.9
Present	12	11.1
S1	9	8.3
S12	1	0.9
S12345	2	1.8

Transitional Vertebra (Lumbar-Sacralization):

Lumbo-sacral TV was seen in 11 sacra (10.2%) (Fig. 5, Table 6).



Fig. 5: Anterior surface of sacrum showing- Lumbar-sacralization

Table 6: Incidence of lumbo-sacral transitional vertebrae (TV).

TV	Total (n=108)	Percent
Absent	97	89.8
Present	11	10.2

DISCUSSION

The sacrum is an integral part of the spinal column and forms the posterosuperior wall of the pelvic cavity. Transmission of body weight from the vertebral column to the sacroiliac joints is made possible by the wedge-shaped interlocking mechanism of the articular surfaces of the sacroiliac joints. The sacrum is the target of various pathologies, fractures and instrumentation done for various spinal disorders.

The morphological variations of the sacrum assume clinical importance as the pelvic ring stability depends posteriorly on the sacroiliac joints. Skewness of sacrum can result in asymmetry of sacroiliac joint, which is likely to be misdiagnosed as sacroiliac joint

subluxation [7].

Further the existence of transitional vertebrae increases the risk for development of nerve-root symptoms and may result in a vertebral level being wrongly identified unless preoperatively detected [14].

In the light of these facts, knowledge of morphological characteristics of the sacrum and its anatomical variations are clinically extremely important. The present study attempts to elucidate the morphological variations of dry adult human sacra in Indian population.

Skewness is a developmental asymmetry of the sacrum with the middle sagittal line of pelvic face of sacrum skewing to right or left. Presence of skewness results in asymmetry of sacroiliac joint. With increasing use of sacrum in various orthopaedic procedures for lumbosacral fixation, the recognition of sacral skewness poses significant importance.

In the present study, skewness was observed in 7.4% sacra in comparison to the finding of Wu LP (23.6%). Sacral skewness was noted to be mostly right sided (4.6%) which was similar to the finding of Wu LP in Chinese population. Higher incidence of right sided skewness may be postural due to more weight bearing on right lower limb during prolonged standing.

The most common extent of AS was from S1-S3 vertebrae, found in 95.4% sacra. The auricular surface was present at the S1-S2 vertebral level in 3.7% sacra. It was at the level of S1-S4 vertebrae in 0.9% sacrum. Different levels of AS may cause change in weight distribution pattern and elucidate many low back pain conditions [6]. The knowledge of extent of AS can be vital during sacroiliac joint instrumentation.

In present study, it was observed that AAS was present in 13% sacra. AAS was unilateral in 4.6% sacra; and bilateral in 8.4% sacra. The incidence and laterality were almost similar to study conducted by Wu LP et al.

The crescent-shaped AAS was most common and present in 57.1% sacra; while the oval surface, found in 42.9% sacra. The most of the AAS had slightly concave surfaces. Many researchers have encountered facets

for accessory sacroiliac articulations in roentgenographic examinations of patients, pelvic CT scans or in dried skeletons and did not investigate the qualitative morphological features [7, 8, 18-22] (Table 7).

In present study, the most common position of AAS was observed in 85.7% sacra at S3 level. Many researchers found the most common location of AAS at the level of the 2nd dorsal sacral foramina [8, 18, 19]. Valojerdy MR et al. found the AAS at the level of 1st dorsal sacral foramina [20] (Table 7). The AAS take part in weight transmission proportionate to their size and can be a cause of low back pain due to change in line of weight transmission. Furthermore, the acquaintance of morphological characteristics of AAS can be crucial during sacroiliac joint instrumentation.

Many authors have reported varying data on the incidence of SB in different populations with most common occurrence at S1 level [7, 16]. In the present study, SB was found to be present in 11.1% sacra which was comparable to the finding of Ali S et al in Pakistani population [23]. The frequency of occurrence of spina bifida varies widely ranging from 4.5% in British Population to 61.5% in Chinese population (Table 8) [24-30]. The most common vertebral level of SB was found to be at S1 (75% of SB cases) in our study which is similar to other investigators [9, 16]. Present study on dry adult sacra seems to have greater accuracy as direct visual observation of the sacrum is more objective than inspection of radiographs and CT scans. Variations in the frequency of spina bifida may be due to different methods of acquiring data and classifying the condition and also it may be related to genetic endowment and environmental conditions of different population which can alter the occurrence of anatomical variations [31].

The incidence of transitional vertebrae has been reported to be variable in different populations, with fewer incidence of lumbarization being documented. Although reduction of the sacral constituents is less common, lumbarization of 1st sacral vertebra does happen which may be totally or partially separate [1].

Table 7: Comparison of AAS between previous and present studies.

Researcher	Population	No. of sacra	Frequency	Laterality	Location	Data source
Trotter M [18] [1940]	American	958	36%	U/L: 50% B/L:50%	S2 PSF	Dry adult sacra
Hadley LA [19] [1952]	American	185 200	18% 33.50%	U/L: 58% B/L:42%	S2 PSF	Dry adult sacra Radiographs
Ehara S et al. [1988]	American	100 56	13% 16%	U/L: 5(55.6%) B/L:3(33.3%)	S2 PSF	CT scan Dried skeletons
Valojerdy MR et al. [20] [1990]	British	153	18%	U/L:65% B/L: 35%	S1 PSF	Dry adult sacra
Prassopoulos PK et al. [21] [1999]	Greek	534	19.10%	--	--	CT scan-Pelvis
Demir M et al. [22] [2007]	Turkish	400	17.50%	U/L:46(65.7%) B/L:24(34.3%)	-	CT scan- Pelvis
Wu LP et al. [2009]	Chinese	203	12.30%	U/L:9(36%) B/L:16(64%)	Postero-inferior	Dry adult sacra
Present study	Indian	108	12.90%	U/L:5(35.7%) B/L:9(64.3%)	S3	Dry adult sacra

Table 8: Comparison between previous and present studies on SB.

Researcher	Population	No. of dry sacra/Radiograph/CT	Frequency	Data Source
Lorber J et al. [24] [1967]	British	200	4.50%	Radiographs
Vannier JP et al. [25] [1981]	French	299	8.40%	Radiographs
Boone D et al. [26] [1985]	British	653	17.30%	Radiographs
Fidas A et al. [27] [1987]	British	2707	23%	Radiographs
Saluja PG [1988]	British	140	15.70%	Radiographs
Avrahami E et al. [28] [1994]	Israeli	1200	17%	Radiographs & CT
Thorpe AC et al. [29] [1994]	British	Control:48 Cases:52	22.90% 32.60%	Radiographs
Taskaynatan MA et al. [2005]	Turkish	881	4.30%	Radiographs
Secer M et al. [2009]	Turkish	401	8.50%	Radiographs
Wu LP et al. [2009]	Chinese	203	28.10%	Dry sacra
Ali S et al. [2014]	Pakistani	200	10.50%	Dry sacra
Li W et al. [30] [2021]	Chinese	148	61.50%	Radiographs
Present study	Indian	108	11.10%	Dry adult sacra

Table 9: Comparison between previous and present studies on TV.

Researcher	Population	No. of dry sacra/Radiograph/CT	Frequency	Data Source
Moore BH [31] [1925]	American	87 1104	3.40% 3.35%	Skeletons Radiographs
O'Driscoll CM et al. [32] [1996]	British	100	15%	Radiographs
Vergauwen S et al. [1997]	Belgian	350	15%	CT scans
Olofin MU et al. [2001]	Nigerian	300	37%	Radiographs
Otani K et al. [33] [2001]	Japanese	501 508	13% case 11% control	Radiographs
Taskaynatan MA et al. [2005]	Turkish	881	5.40%	Radiographs
Hughes RJ et al. [34] [2006]	British	500	13.40%	MRI
Lee CH et al. [35] [2007]	Korean	534	13.90%	MRI
Secer M et al. [2009]	Turkish	401	4.50%	Radiographs
Wu LP et al. [2009]	Chinese	293	16.70%	Dry adult sacra
French HD et al. [36] [2014]	Australian	5941	4.10%	Radiographs
Bhattarai M [37] [2018]	Nepalese	947	11.90%	Radiographs
Present study	Indian	108	10.20%	Dry adult sacra

The present study showed transitional vertebra in 10.2% sacra. Moore BH in American population, Taskaynatan MA et al. and Secer M et al. in Turkish Population and French HD et al. in Australian population reported lower incidence of TV while other researchers

observed higher incidence of TV in comparison to Indian population (Table 9) [31-37]. Olofin MU et al. observed the highest incidence of TV (37%) in Nigerian population [12]. The knowledge of occurrence of TV is of utmost importance for clinicians as it may be

associated with increased risk of disc degeneration, disc herniation and stenosis of spinal canal and neural foramina [17].

CONCLUSION

Sacrum is highly variable bone exhibiting variations such as skewness, AAS, SB and TV. Frequency of occurrence of such variations also differs in various populations which may be related to genetic endowment and different environmental conditions. Variations of the sacrum may be involved in many clinical conditions such as stenosis of spinal canal and neural foramina, nerve-root compression, disc degeneration, posterior disc herniation, backache, enuresis, neurological abnormalities of the lower limb and functional disorders of lower urinary tract. Ultimately, the thorough knowledge of sacral variations is crucial for surgeons performing lumbosacral and sacroiliac instrumentation and the present study might be useful for them.

ABBREVIATIONS

AS: Auricular surface

AAS: Accessory auricular surface

SB: Spina Bifida

TV: Transitional vertebra

Authors' contribution

Sandeep Saluja- Acquisition of data and its analysis

Sneh Agarwal- Conception & design of manuscript

Anita Tuli- Analysis and interpretation of data

Shashi Raheja- Final approval of the version to be published

Sarika Rachel Tigga- Drafting of manuscript and its revision

Conflicts of Interests: None

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