Original article

# Incidence of Sacralization of 5th Lumbar and First Coccygeal Vertebrae: An Osteological Study on Dried Sacra of Pakistani Population

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## ABSTRACT

**Background:** Sacralization can occur when the fifth lumbar or the first coccygeal vertebra fuses with the sacrum. Given the increasing incidence of lower back pain and its impact on human health and wellbeing, understanding the etiology of sacralization is important. The study aimed to estimate the incidence of sacralization of the fifth lumbar and first coccygeal vertebrae in the sacrum and to define the types of sacralization observed in the cadaveric sacra.

**Methods:** A descriptive study was done on 285 adult human dry sacra from bone bank of Fatima Jinnah Medical University and Rashid Latif Medical College in Lahore, Pakistan. The study involved examining the number of vertebral segments and sacral foramina and classifying the sacra into different types. We also calculated the sacral index and measured the length and width of these sacra.

**Result:** Out of the sample, 68% of sacra were typical, while sacralization was observed in 32% of cases. Among the sacralized sacra, 70 % were fused with the fifth lumbar vertebra (L5) and 30% were fused with the first coccygeal vertebra. The incidence of sacralization was similar in both genders.

**Conclusion:** Sacralization is common and can be asymptomatic or associated with low back pain, disc degeneration/ herniation, scoliosis, and spondylolisthesis. Surgeons, anesthetists, obstetricians, and physicians can benefit from this knowledge to treat a wide range of patients.

**Keywords:**
Sacrum, Coccyx, Low back pain, Disc Herniation

## INTRODUCTION

Vertebral column typically consists of 33 vertebrae, sacrum is one of them, formed by fusion of five sacral vertebrae1 [1], having four pairs of sacral foramina and articulates with fifth lumbar vertebra above, forming lumbosacral joint, and with first coccygeal vertebrae below constituting sacrococcygeal joint.[2]

Sacralization is the most common anatomical variant in which sacrum has five sacral foramina on each side instead of four and can be either asymptomatic or cause symptoms.[3] It represents a state of transition at lumbosacral region of spine, known as lumbosacral transitional vertebra (LSTV).[3] It affects the lumbosacral angle and increases stress on the L4-L5 motion segment, resulting in degenerative changes in disc and facet joint of vertebrae and degenerative spondylolisthesis.[4] It is of two main types: lumbar and coccygeal. In Lumbar sacralization, fifth lumbar vertebra fuses with the sacrum, whereas in coccygeal sacralization first coccygeal vertebra fuses with the sacrum.[4]

Morphology of sacrum is indispensable to pelvic morphometry, lumbar sacralization effects diameters of pelvic inlet especially in females leading due to obstructed labor at inlet or midplane[1] while in cases of coccygeal sacralization coccyx is fixed, affecting pelvic outlet diameter resulting in prolonged second stage labor, perineal tears, coccygeal pain and affect caudal epidural, block failure and or coccydynia.[4] Sacralization also contributes to Bertolotti syndrome, characterized by lower back pain (LBP) and can lead to pressure on nerve trunks, ligament sprains, compression of soft tissues, bursitis and arthritis.[5]

Defects in segmentation of lumbosacral spine during vertebral development can lead to sacralization and contributes up to 40 percent of spinal anomalies. The sclerotome portion of the somite, derived from the paraxial mesoderm, is responsible for development of the vertebrae under the influence of Hox genes, whereas over expression of Hox 11 is implicated in sacralization.[6] Calcification of the cartilage between

Conflict of interest: The authors declared no conflict of interest exists.
Citation: Munawar S, Zahid A, Athar T, William GP, Ain Q. Incidence of sacralization of 5th lumbar and first coccygeal vertebrae: An osteological study on dried sacra of Pakistani population. J Fatima Jinnah Med Univ. 2024; 18(3): 138-143.

DOI: https://doi.org/10.37018/AGFP1467

the fifth lumbar and first sacral vertebrae can lead to sacralization as well.[7]

Lumbar sacralization has been classified as complete and incomplete but no literature exists for coccygeal sacralization. This study aims to classify both lumbar and coccygeal sacralization based on the Castellvi classification.[8] Previous radiological studies in Pakistani population have shown a high prevalence of sacralization but cadaveric data is lacking.[9] Since the structure and genetic makeup differ distinctly in varied ethnic groups[10], the data for the western world might not be relevant in our context. Therefore, this study is the first-known attempt to highlight the incidence of sacralization in cadaveric sacra in Pakistani population and developed a comprehensive new classification by the authors named as SAT classification, which is modified Castellvi classification. This would be significant for orthopedic surgeons, neurosurgeons, neurologists, rheumatologist, urologists, anesthesiologists, obstetricians, radiologists, forensic doctors, and surgical specialists treating or operating around the vertebral column.

## MATERIALS AND METHODS

This descriptive study was conducted on 285 adult human dry sacra in the department of anatomy and the bones were collected from the bone bank of the osteology museums in the Anatomy departments of Fatima Jinnah Medical University and Rashid Latif Medical College in Lahore, Pakistan. As these were cadaveric sacra so the age and gender of the bones were not known. The length and width of the bones were measured using a measuring tape and later sacral index was calculated as follows:

Sacral Index = Sacral Width × 100/ Sacral Length[11]

Sacral index was used to differentiate between male and female sacra. All the sacra examined to determine their characteristics. The number of vertebral segments and sacral foramina in each sacrum were counted along with the measurement of their length and width using a measuring tape. The sacra with five sacral foramina were separated, as they were sacralized and these specimens were then classified by a new classification developed by the authors and named as SAT classification as follows:

In cases of coccygeal sacralization, the anterior sacrococcygeal length (ASCL) was measured on the anterior surface, commencing from the mid-point of the superior border of the first sacral vertebra to the mid-point of the inferior border of the last coccygeal vertebra. Similarly, in cases of lumbar sacralization, anterior lumbosacral length (ALSL) was measured on the anterior surfaces, commencing from mid-point of the superior border of the L5 vertebra to inferior border of the last sacral vertebra.[3] All the measurements were done by three different observers and then mean was calculated to remove the observer bias. Percentages were calculated for each type of sacralization according to SAT classification. Data was analyzed by SPSS and chi square test was applied to observe if any specific type of sacralization is gender dependent. Mean & standard deviation were calculated and independent t test applied to assess the relationship between genders and various lengths of sacra.

**Table 1:** SAT Classification of sacrum showing lumbar and coccygeal sacralization

| | | |
|---|---|---|
| Lumbar Sacralization | | |
| Type I | L5 fully fuses with S1 vertebra | **IA**–Indicates unilaterally fused transverse processes of L5 &S1<br>**IB**–Indicates bilaterally fused transverse processes of L5 &S1 |
| Type II | L5 fuses with S1 vertebra, except for their bodies | **IIA**–Indicates unilaterally fused transverse process<br>**IIB**–Indicates bilaterally fused transverse processes |
| Coccygeal Sacralization | | |
| Type III | Body, transverse process, and cornua of the coccygeal vertebra fuse with corresponding parts of the fifth sacral vertebra | **IIIA**–Indicates that there's incomplete fusion of either the body, transverse process, cornua, or all 3 elements of the coccygeal vertebra with the corresponding parts of parts of S5<br>**IIIB**–Indicates complete fusion of the body, transverse process, and cornua of the coccygeal vertebra with the corresponding parts of S5 |
| Type IV | The body of the coccygeal vertebra fuses with the apex of the sacrum, and transverse process of the first coccygeal vertebra fuses with the inferior lateral angle of sacrum. This completes the fifth pair of sacral foramina laterally, but it remains open medially because the coccygeal cornua did not fuse with sacral cornua | **IVA**–Indicates unilateral complete fifth sacral foramen laterally<br>**IVB**–Indicates bilateral complete fifth sacral foramen laterally |
| Type V | The coccygeal body fuses with the apex of the sacrum, and cornua of coccygeal vertebra fuse with the sacral cornua. However, the transverse process of the coccygeal vertebra does not fuse with the inferior lateral angle of the sacrum. This fusion completes the fifth pair of sacral foramina medially, but it remains open or incomplete laterally | **VA**–Indicates unilateral complete fifth sacral foramen medially<br>**VB**–Indicates bilateral complete fifth sacral foramen medially |

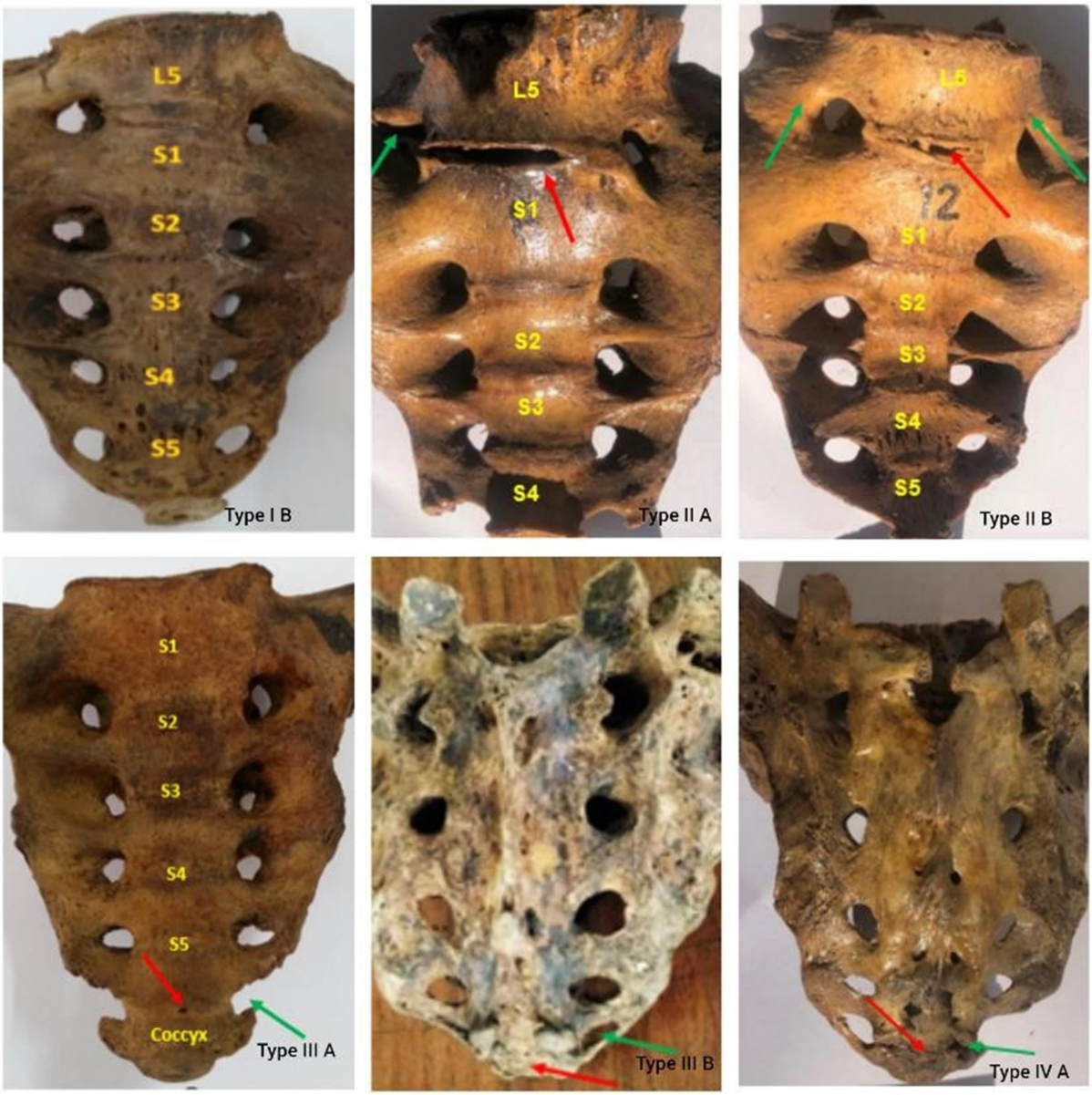


**Figure 2:** The figure shows the various types of sacralization found in our study. IB: Complete fusion of the body of L5, S1, and bilaterally fused transverse processes, IIA: Incomplete fusion of the body of L5, S1(Red Arrow) and unilateral incomplete fusion of transverse process (Green Arrow), IIB: Incomplete body fusion of L5, S1 (Red Arrow) and bilateral complete fusion of transverse process (Green Arrow), IIIA: Incomplete fusion of the body of the coccygeal vertebra with the fifth sacral vertebra (Red Arrow) and incomplete fusion of the transverse process (Green Arrow), IIIB: Dorsal surface of sacrum showing the sacralization of the first coccygeal vertebra with complete fusion of the body (Red Arrow) and transverse process (Green Arrow), IVA: Unilateral complete fifth sacral foramen laterally.

## RESULTS

Of the 285 sacra, the study found that (194) 68 % sacra were normal, while (91) 32 % showed sacralization. Among all the sacralized sacra, 70% exhibited lumbar sacralization and 30% showed coccygeal sacralization. The pie chart in Figure 1 provides a visual representation of the different types of lumbar and coccygeal sacralized sacra. Whereas further type wise classification of various types found in this study are shown in Figure 2 by actual photographs.

Sacra were categorized into male and female on the basis of sacral index. A Chi square test was performed, demonstrating that both lumbar and coccygeal sacralization have a similar incidence in both genders and there is no statistical difference between male and female in relation to this anatomical variant (Table 2a)

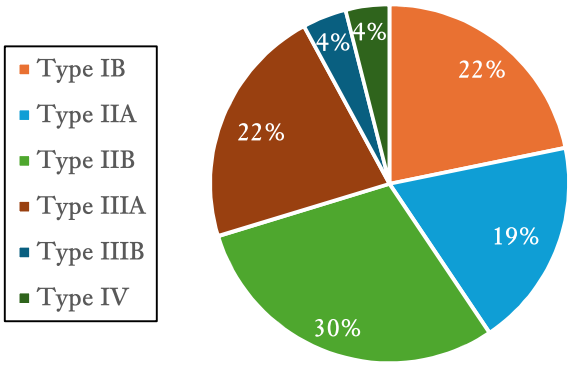


**Figure 1:** Percentages of different types of lumbar and coccygeal sacralized sacra. Among the sacra which had sacralization, 22% belonged to type IB,19% to type IIA, 30% to type IIB, 22% to type III A, whereas type III B and type IV each, were present in 4% sacra.

The results of the Independent t-test presented in Table 2b indicate that male sacra were significantly longer than female sacra. Additionally, the anterior sacrococcygeal length of the sacra with coccygeal sacralization and the anterior lumbosacral length of the sacra with lumbar sacralization were also significantly greater in males compared to females. However, there was no statistically significant difference in width between the genders

**Table 2a:** Chi-Square test showing lumbar and coccygeal sacralization

| Parameter | Female | Male | p-value |
|---|---|---|---|
| Sacralization | 35.7% | 27.9% | |
| Lumbar Sacralization | 57.9% | 42.1% | 0.522 |
| Coccygeal sacralization | 42.9% | 57.1% | 0.522 |

**Table 2b:** Independent t-test showing the mean sacral length, width, ASCL & ALSL of the sacra. ASCL=Anterior sacrococcygeal length, ALSL=Anterior lumbosacral length.

| Parameter | Female | Male | p-value |
|---|---|---|---|
| Mean sacral length ± standard deviation | 8.5 ± 0.78 | 9.9 ± 0.78 | 0.00* |
| Mean sacral width ± standard deviation | 9.9 ± 0.68 | 9.7 ± 0.60 | 0.68 |
| Mean ASCL± standard deviation | 9.78 ±0. 48 | 11.57 ± 0.74 | 0.01* |
| Mean ALSL± standard deviation | 11.03 ± 1.05 | 12.51 ± 1.30 | 0.01* |

*Statistically significant

## DISCUSSION

The current study not only revised and modified the classification of lumbar and coccygeal sacralization, but also estimated the incidence of sacralization in cadaveric sacra at 32%. Of which lumbar sacralization was more common (70%) compared to coccygeal sacralization (30%) yet not significantly different in both genders. In a Turkish study 15.8% asymptomatic individuals had transitional vertebrae, while 35.1% patients with lower backache were found to have transitional vertebrae. This difference was highly significant. Like our study, both males and females were equally affected.[12] The incidence of sacralization varies among different ethnicities and races. It is found in 37 % Nigerians, in 30% people of Finland and 4-35 % Americans had sacralization.[13] Coccygeal sacralization was reported to be 13 % among Bangladeshi population, whereas Indians report their incidence of lumbar sacralization to be 6-18%.[4] Yao and colleagues' study revealed that lumbar sacralization was present in 36% patients with L4 spondylolysis.[14] Lumbosacral transitional vertebrae causing sacralization were more commonly found in patients with disc herniation and hence sacralization predisposes to disc hernia especially in females.[15]

Another study, involving 100 radiographs of patients with lower backache, discovered that the incidence of sacralization (LSTV) in the Pakistani population was 27%. [9] This is close to the current cadaveric study. According to SAT classification type II B was the most common type of sacralization followed by type IIIA.

The lumbosacral length was found more in the male sacra with lumbar sacralization. This could be due to the fact that the male sacra are generally more in length than females and less in width.[11]

Similarly, the anterior sacrococcygeal length was found to be more in male sacra having coccygeal sacralization as compared to females which is consistent with a cadaveric study in Bangladeshi population by Naznin.[4]

In 1917, Bertolotti was the first to report on sacralization, a condition where the transverse process of the fifth lumbar vertebra is enlarged and fused with the sacrum or ilium, or both and was observed in 4% to 30% of the population.[16] Sacralization represents LSTV which could be associated with abnormal articulation, facet joint problems on the opposite side, instability, early degeneration of the level above the transitional vertebrae, and compression of the nerve roots due to hypertrophy of the transverse process. Lower back pain (LBP) resulting from LSTV may manifest above the transitional level.[17]

This anatomical variation can be unilateral or bilateral and takes place when fifth lumbar vertebrae fuses or articulates with 1st sacral vertebra.[18] There are two varieties of LSTV, sacralization and lumbarization, with former more prevalent and clinically significant. LSTV is quite prevalent, and it predisposes the spine and discs to degenerative

changes due to abnormal torque, mechanical stress and mobility Lumbosacral transitional vertebrae runs within the families, suggesting a genetic predisposition of sacralization.[19]

During the embryonic period, transverse clefts form in the paraxial mesoderm leading to formation of vertebrae, hence forming the segments of vertebral column. An anomaly involving segmentation of the vertebral column may lead to numerical irregularities of the various regions of the vertebral column, mostly the caudal area of the lumbosacral region. Hox genes are responsible for the axial pattern and the identity of the vertebrae morphologically. Hox 11 when over expressed would lead to fusion of the first sacral vertebra cranially leading to sacralization.[1]

Patients with lumbar sacralization undergoing microdiscectomy have postoperative pain and recurrence.[20] Decreased mass of paraspinal and trunk musculature is also associated with sacralization. [21] Presence of sacralization increases the risk of treatment failure of low back pain by lumbar transforaminal epidural steroid injection.[8] So the patient should be assessed for sacralization to avoid all these complications in cases with sacralization either lumbar or coccygeal. LBP has a significant impact on quality of life and is a leading cause of disability (Years lived with disability, YLDs) worldwide, surpassing conditions like diabetes and other chronic illnesses.[22]

The present study adds to the database about the presence of sacralization in cadaveric sacra, also elaborating the new SAT classification, including both lumbar and coccygeal sacralization. Therefore, the prevalence of sacralization and its various types should be kept in mind while managing diseases affecting vertebral column and pelvis. Since the cadaveric sacra were studied, no geographical information relating to age, gender, identification, etc., was accessible.

## CONCLUSION

This study provides novel information about how common sacralization is in the Pakistani population. This information is important because it relates to the suggested connection between the lumbosacral transitional vertebra caused by lumbar sacralization and lower back pain. Accurately identifying sacralization of the L5 vertebra and the first coccygeal vertebra can assist different healthcare professionals, including clinical anatomists, obstetricians, orthopedic surgeons, neurosurgeons, radiologists, anesthetists, forensic experts, and physiotherapists, in preventing complications during clinical practice.

**Acknowledgments:** The authors would like to express their gratitude to the staff of the Anatomy departments at Fatima Jinnah Medical University, Lahore, and Rashid Latif Medical College, Lahore (Pakistan) for their assistance in facilitating the current research.

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