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A Study Of Morphology, Prevalence And Clinical Importance Of Lumbosacral Transitional Vertebra In The Population Of Coastal Andhra Pradesh

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Introduction*: Low back ache is a common problem caused by stress and strain on the lumbosacral spine. The lumbosacral region of the spine plays a vital role in supporting body weight and maintaining posture by transferring it to the lower extremities. Lumbosacral transitional vertebrae (LSTV) are prevalent spinal variations. LSTV can occur either when the fifth lumbar vertebra acquires sacral characteristics (sacralisation) or when the first sacral vertebra acquires lumbar characteristics (lumbarisation). These abnormalities have been associated with low back ache and early-onset disc degeneration in younger people.*

Aim*: To estimate the prevalence of LSTV in the population of coastal Andhra Pradesh and investigate the morphological characteristics of these transitional vertebrae, as well as their association with lower back ache.*

Materials and methods: *The present study, performed in the department of Anatomy, KIMS & RF medical college in Andhra Pradesh, India, involved analysing 80 dry human sacra (56 male and 26 female). The researchers examined morphological variations including sacralisation, lumbarisation, vertebral body count, dorsal and ventral sacral foramina count, sacral hiatus, and sacral cornua.*

Results: *The investigation revealed morphological variations in 8 specimens. Six sacra (7.5%) showed signs of fifth lumbar vertebra sacralisation, while two sacra (2.5%) exhibited first sacral vertebra lumbarisation. These findings suggest that the LSTV prevalence in the study population is 10%.*

Conclusion*: Lumbosacral transitional vertebrae (LSTV) are frequent spinal anomalies that require precise identification and numbering of the affected segment. Substantial evidence connects these vertebrae to low back ache. Understanding LSTV is crucial for orthopaedic surgeons, neurosurgeons, anesthesiologists, radiologists, and physicians to ensure accurate diagnosis, appropriate procedural modifications, and prevention of errors during medical interventions.*

Key words*: Disc prolapse, Low back ache, Lumbarisation, Sacralisation, Transitional vertebra,*

Abbreviations: LSTV = lumbosacral transitional vertebra

Introduction:

Low back ache is a widespread problem in contemporary society, affecting approximately 80% of individuals during their lifetime. One common cause of this discomfort is the lumbosacral transitional vertebra, which stems from an abnormality in the lumbosacral spine segmentation.

The sacrum, a wedge-shaped bone resulting from the union of 5 sacral vertebrae, features 4 sacral foramina on the right and left sides. It articulates with both iliac bones and forms the posterior pelvic wall. The cranial base articulates with the L5 vertebra above while its caudal apex joins the coccyx.

LSTV is the frequent developmental defect of the lumbosacral segment of the spine, manifesting as sacralisation of the L5 vertebra and lumbarisation of the S1 vertebra. Sacralisation results from the incorporation of the L5 vertebra with the S1 vertebra, causing the L5 segment to resemble a sacral vertebra. Conversely, lumbarisation occurs when the first sacral vertebra exhibits characteristics of a lumbar vertebra [1].

The degree of sacralisation in the lumbosacral spine can vary. It may be partial or complete, resulting in unilateral or bilateral anomalies [2]. Complete sacralisation involves bony fusion of the atypical transverse process of L5 with the sacrum. In cases of sacralisation, the sacrum presents 6 vertebral segments and 5 sacral foramina on each side.

Morphological variants in LSTV span from elongated, broad transverse processes of the L5 vertebra to complete bony fusion to the sacrum. In lumbarisation, instead of fusing with the sacrum, an anomalous articulation may occur, and the first sacral vertebra may appear squared. A well-formed intervertebral disc can be visualised between S1 and S2 vertebrae.

Sacralisation can be developmental or result from traumatic/age-related changes, impacting spinal stability and biomechanics [3]. L5 sacralisation has been linked to orthopaedic conditions such as intervertebral disc degeneration, prolapse and degenerative spondylolisthesis [4]. LSTV was first observed by Bertolotti who suggested that these anomalous vertebrae could cause low back ache at the site of false articulation due to arthritic changes [5]. LSTV is common anomaly in the community, with the prevalence ranging from 1-20% [6,7].

Understanding the lumbosacral transitional vertebra is crucial for clinicians in diagnosing and treating individuals with low back ache. Accurate identification of the anomaly (LSTV) is essential for patients undergoing surgical or interventional procedures to prevent errors. The present study aims at investigating the prevalence of LSTV in the people of coastal Andhra Pradesh.

Materials and methods

The investigation was conducted at KIMS and RF medical college in Andhra Pradesh. Researchers examined 80 sacral bones (54 male and 26 female) from both articulated and disarticulated skeletons to observe morphological variations. Damaged bones were excluded. The selected sacra were inspected for variations such as sacralisation or lumbarisation, dorsal and ventral sacral foramina count, vertebral body count, sacral hiatus, and sacral cornua.

Castellvi A et al. categorized sacralised or lumbarised vertebrae into four categories depending on S1 and S2 disc morphology and clinical characteristics related to herniated nucleus pulposus (6).

Type 1. Large atypical broad triangle shaped transverse process. (A) Unilateral; (B) bilateral

Type 2. Partial lumbarisation or sacralisation with a large transverse process forming pseudo-articulation with the sacrum. (A) Unilateral; (B) bilateral.

Type 3. Complete lumbarisation or sacralisation with a true bony fusion of the wide transverse process with the sacrum. (A) Unilateral; (B) bilateral.

Type 4. Mixed type with pseudo-articulation (type 2) and bony union (type 3) expressed in same sacrum on either side.

Results:

In the present study of 80 sacra, researchers identified morphological variations in 8 specimens. Of these, 6 sacra (7.5%) exhibited characteristics of sacralisation of the L5 vertebra, whereas 2 sacra (2.5%) displayed features of lumbarisation of the S1 vertebra. These findings indicate the LSTV prevalence to be 10% in the current investigation.

Table: 1 Number of lumbosacral vertebrae observed and their type (Castellvi classification)

Type of LSTV	Type 2 B	Type 3 A	Type 3 B
Sacralisation	1	2	3
Lumbarisation	0	2	0

Among six sacra displaying sacralisation morphology, three exhibited complete bilateral sacralisation (Fig: 1), one showed incomplete bilateral sacralisation (Fig: 2), and two demonstrated complete unilateral sacralisation (Fig: 3). The specimens with complete bilateral sacralisation showed bony a union of the L5 transverse process with the sacrum on both sides, classified as type 3 B. The specimen with incomplete bilateral sacralisation featured a pseudo-articulation between L5 transverse process and the sacrum, categorized as Castellvi type 2 B. Remaining two specimens exhibited complete bony fusion between L5 transverse process and the sacrum on the left side, whereas the right side had an enlarged transverse process without bony attachment or pseudo-articulation to the sacrum. These were categorized as type 3 A lumbosacral transitional vertebrae with unilateral sacralisation.

In sacralised lumbar vertebrae, the auricular articular facet of the sacrum extended to the L5 vertebra when a bony union or pseudo-articulation was present. When a bony union was absent, the auricular articular facet was confined to sacral segments (Fig: 4). All the four bilateral sacralised specimens contained 6 vertebral bodies, 5 dorsal and 5 ventral sacral foramina bilaterally (Fig: 1 and 2). The two unilateral sacralised specimens had 6 vertebral bodies, 5 dorsal and 5 ventral sacral foramina on the left side, but intervertebral foramen between L5-S1 segments was absent on the right side (Fig: 3).

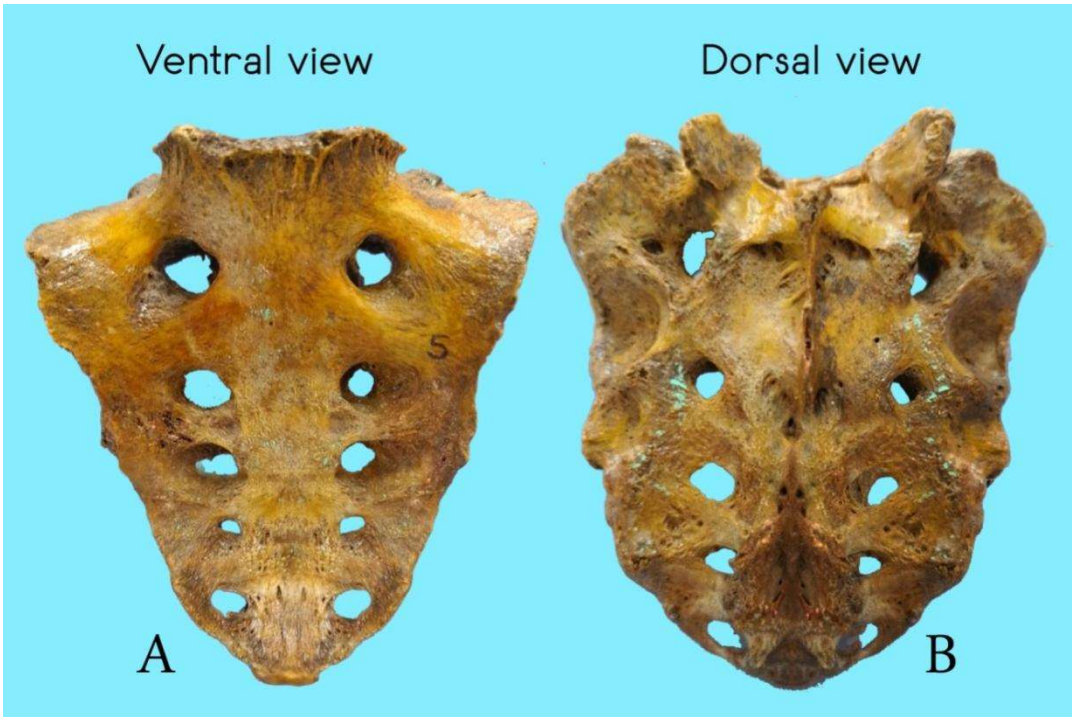

Fig: 1 Complete bilateral sacralisation of fifth lumbar vertebra (Castellvi type III B) showing bilateral bony fusion of transverse process of L5 vertebra with sacrum, six vertebral bodies, five ventral and five dorsal sacral foramina.

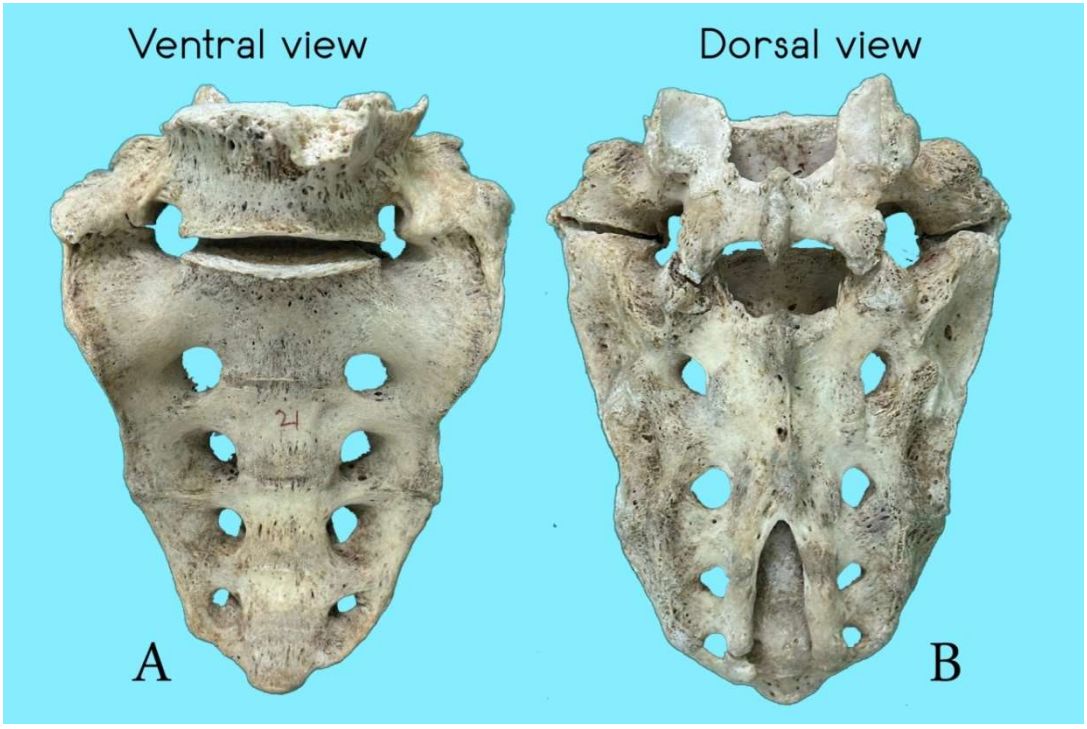

Fig: 2 Incomplete bilateral sacralisation of fifth lumbar vertebra (Castellvi type II B) showing bilateral pseudo-articulation of transverse process of L5 vertebra with sacrum, six vertebral bodies, five ventral and five dorsal sacral foramina.

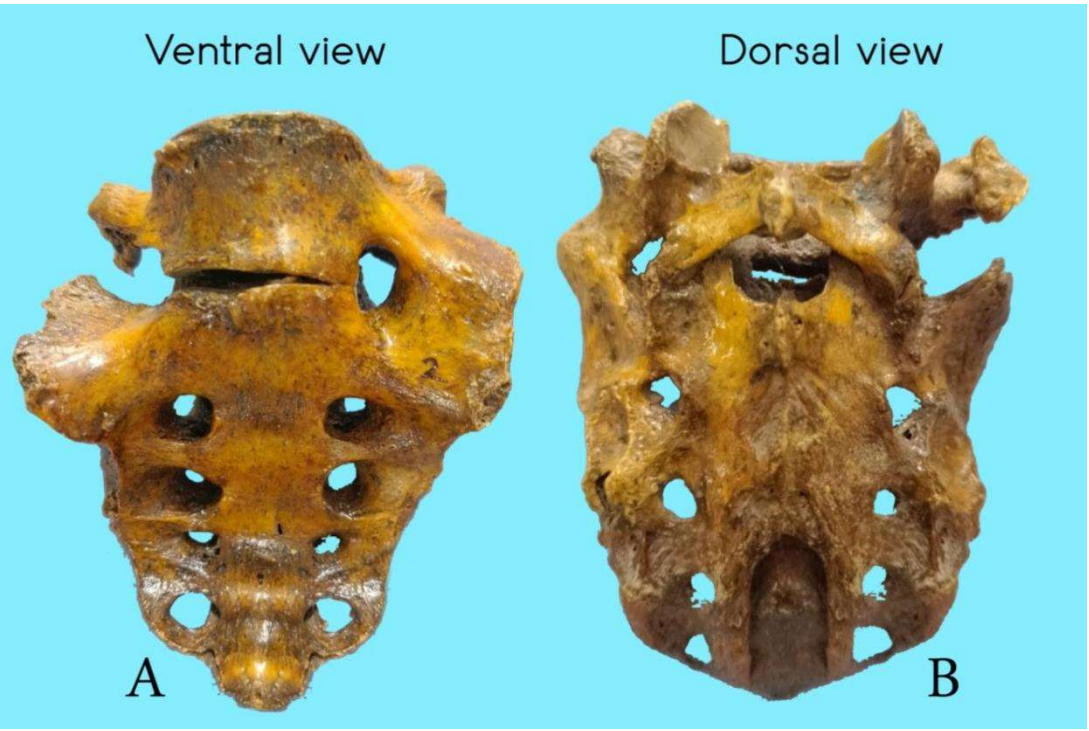

Fig: 3 Complete unilateral sacralisation of fifth lumbar vertebra (Castellvi type III A) showing unilateral bony fusion of transverse process of L5 vertebra with sacrum on left side, six vertebral bodies, five ventral and five dorsal sacral foramina on left side. L5-S1 intervertebral foramina is absent on right side.

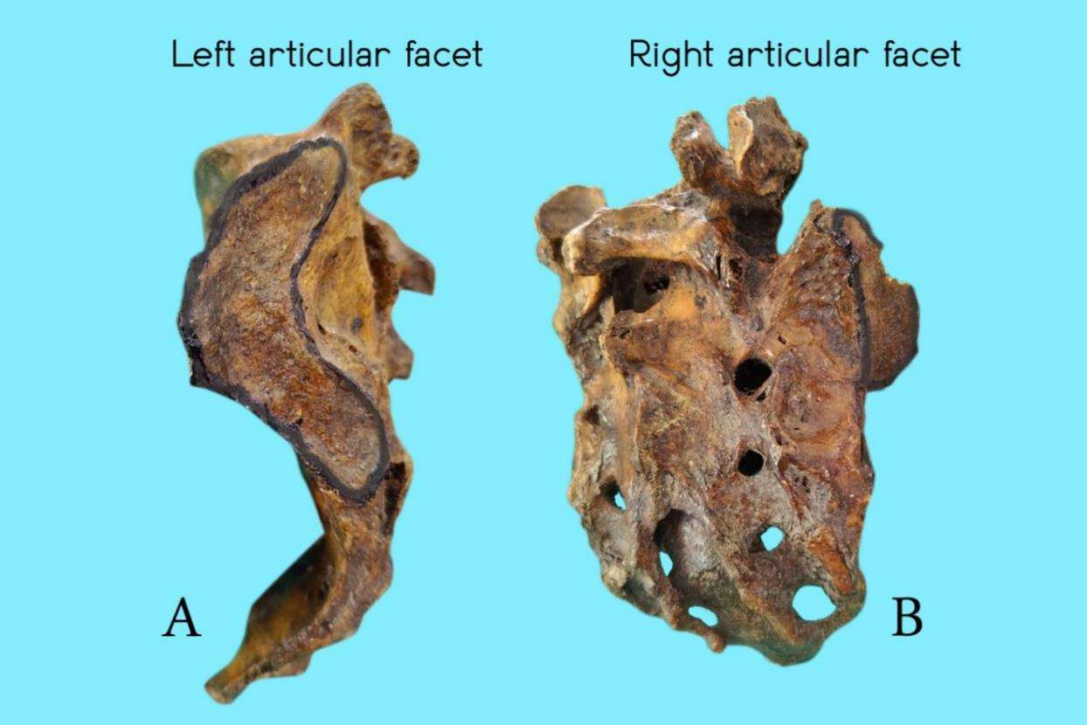

Fig: 4 Complete unilateral sacralisation of fifth lumbar vertebra (Castellvi type III A) showing auricular articular facet extending to L5 vertebra on the side of bony fusion (left). On right side articular facet is confined to sacrum.

Both specimens exhibiting lumbarisation morphology had a square-shaped S1 vertebra body without fusion between S1 and S2 (Fig: 5). A residual space was noted between the bodies of S1 and S2 vertebrae. Complete bony fusion was observed on the right side between the S1 transverse process and the sacrum in both specimens. On the left side, the transverse process became enlarged without attachment to the sacrum. These were classified as type III A lumbosacral transitional vertebrae with unilateral lumbarisation.

Both sacra possessed 5 vertebral bodies, 4 dorsal and 4 ventral sacral foramina on the right side, but the S1 sacral foramen was absent on the left side. In lumbarised sacral vertebrae, the auricular articular facet of the sacrum was deficient opposite the S1 vertebra where the transverse process failed to unite with the sacrum (Fig: 6).

In all 8 transitional vertebrae (LSTV) that were examined in present study, the contour of sacral hiatus and sacral cornua were normal.

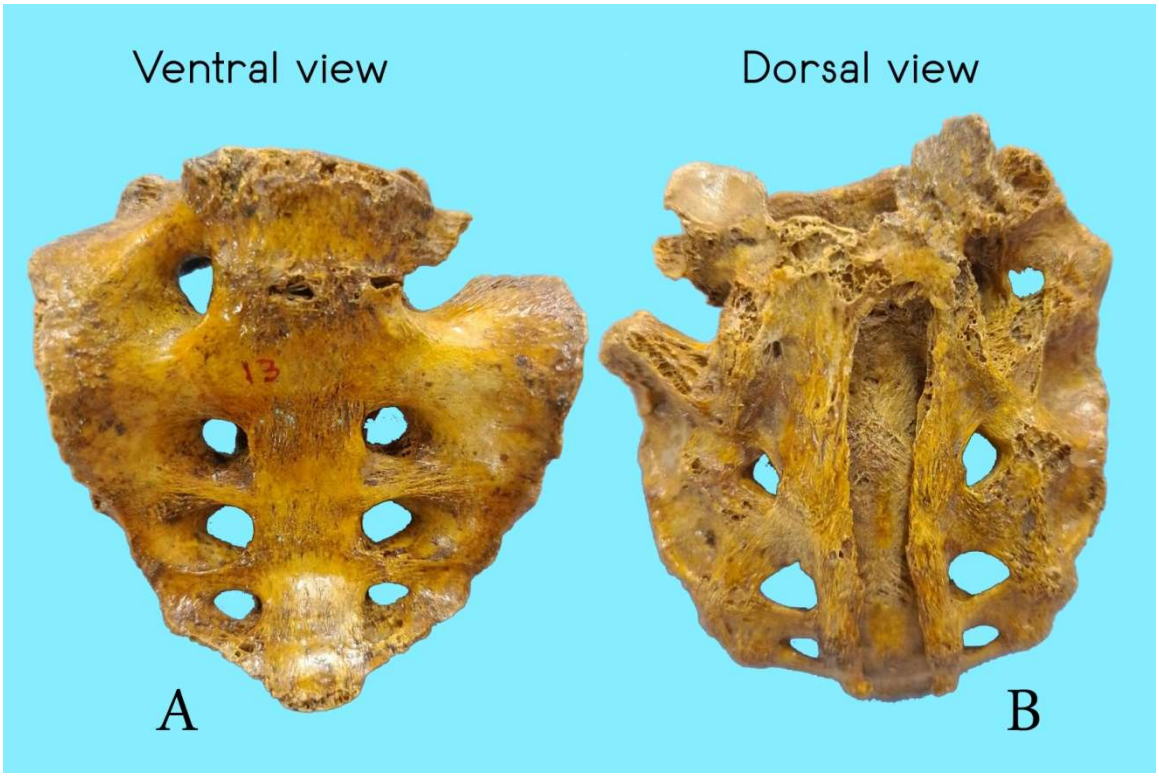

Fig: 5 Complete unilateral lumbarisation of first sacral vertebra (Castellvi type III A) showing unilateral bony fusion of transverse process of S1 vertebra with sacrum on right side, five vertebral bodies, four ventral and four dorsal sacral foramina on right side. S1-S2 sacral foramina is absent on left side. Incidentally sacrum shows incomplete spina bifida anomaly.

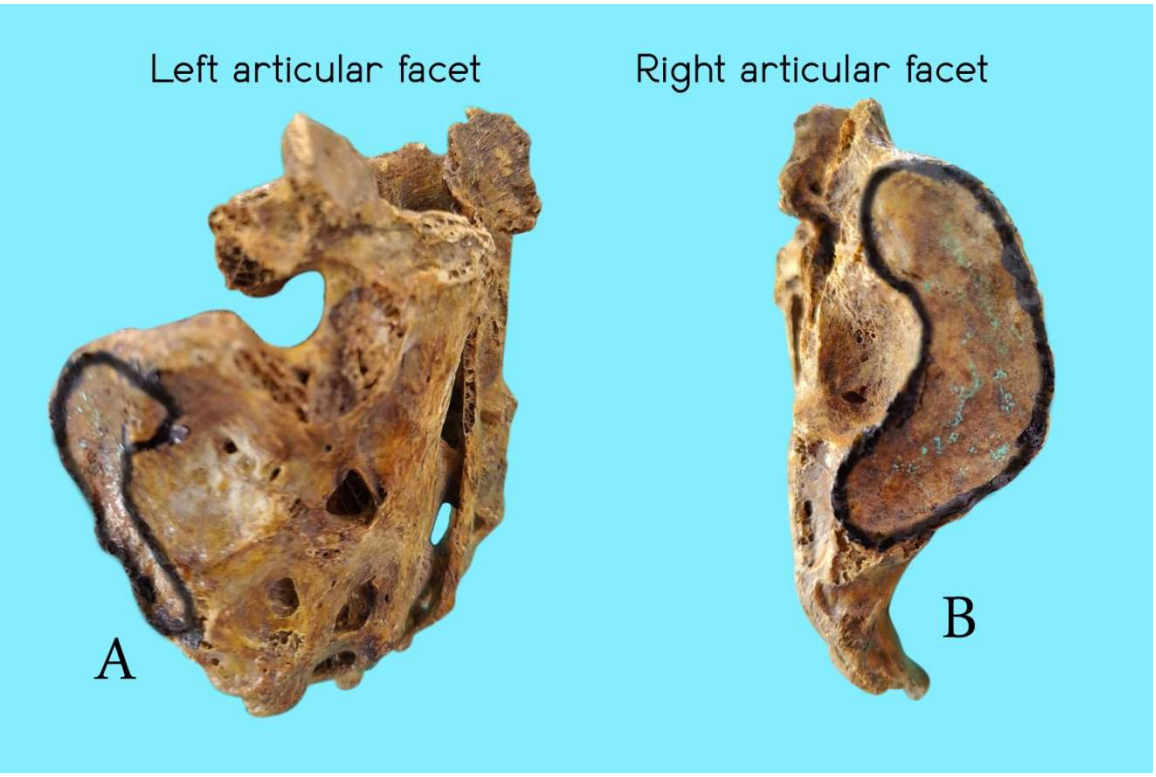

Fig: 6 Complete unilateral lumbarisation of first sacral vertebra (Castellvi type III A) showing normal auricular articular facet opposite to S1-S3 segments on the side of bony fusion (right). On left side articular facet is confined to S2-S3 segments of sacrum.

Discussion:

Numerous investigations have explored the origins, frequency, and manifestations of sacralisation. Our current inspection identified sacralisation in six sacra (7.5%) and lumbarisation in two sacra (2.5%). The total incidence of LSTV is 10% in the present study, all occurring in male sacra, suggesting a higher prevalence among males. Eyo et al. (2001) reported a sacralisation to lumbarisation ratio of 2:1, with a greater occurrence in males [8]. The ratio is found to be 3:1 in our study.

Table: 2 Prevalence of LSTV (%) according to various authors compared to our study.

Authors	Prevalence of LSTV (%)
Magora and Schwartz (1978) [9]	20.8%
Castellvi et al (1984) [6]	1.7%
Peter et al (1999) [10]	6.2%
Chet Savage (2005) [11]	7%
Sharma et al (2011) [12]	14.1%
Kubavat Dharati et al [13]	11.1%
KB Khairnar and MB Rajale [14]	6.6%
Present study	10%

In a comprehensive review, J.L Brow examined related literature from 1986 to 2006, determining the average prevalence of sacralisation to be 12.3%. Otani et al. observed that LSTV were common in individuals with intervertebral disc prolapse (17%) compared to the control group (11%) [15].

To understand the structure of a LSTV, it is crucial to examine the development of lumbar vertebrae. This process begins in the third week of embryonic period. Vertebrae develop from somites which are present on both sides of the notochord along the craniocaudal axis. The somites divide further to form sclerotome and dermomyotome. Vertebra is formed from two adjacent sclerotomes, with contributions from the caudal portion of the upper sclerotome as well as the cranial portion of the lower sclerotome [16].

The sclerotome contains loosely arranged cells in the cranial region and densely packed cells in the caudal region. Some densely packed cells migrate rostrally opposite the centre of the myotome and develop into an intervertebral disc. The remaining densely packed cells combine with loosely packed cells of the immediate caudal sclerotome and form a vertebral body. The neural arch, pedicles, and costal elements are developed from densely packed mesenchymal cells in the caudal half of the sclerotome, encircle the neural tube and unite with the cranial half of the vertebral body.

Consequently, a cranial shift leads to sacralisation of the L5 vertebra, while a caudal shift leads to lumbarisation of the S1 vertebra. Lumbosacral transitional vertebrae are formed due to abnormal differentiation, and union of somites. Cranial shifts occur more frequently than caudal shifts, making sacralisation more common when compared to lumbarisation [12].

Defects in ossification are another important cause of lumbosacral transitional vertebrae development.

Differentiating between ossification and developmental abnormalities is a complex task as they appear morphologically similar [17]. Lumbar vertebrae ossification involves 3 primary and 7 secondary ossification centres that unite by an age of 17 to 25 years. Ossification of sacrum occurs through 21 primary and 14 secondary ossification centres, uniting by 25 years to form a single bone. Abnormalities in these ossification centres can result in morphological variations of LSTV [12].

Genetic factors influence lumbosacral spine segmental development. The Hox 11 genes, also known as Hoxa11 or Tlx-1, are found in mesenchymal cells surrounding the neural tube in lumbar and sacral regions of the developing embryo. These genes play a vital role in embryonic growth and differentiation, particularly in vertebral segmentation and patterning of lumbar and sacral vertebrae. The Hox 11 gene mutations are associated with lumbosacral vertebral anomalies. When the Hox 11 gene function is absent, sacral vertebrae do not develop, and the vertebra resembles a lumbar vertebra [18].

There may be a potential link between lumbosacral spine trauma and the development of lumbosacral transitional vertebra. This association could be due to trauma-induced inflammation and mechanical stress, resulting in abnormal biomechanics that may influence vertebral growth and fusion.

Sacralisation is frequently linked with low back ache which may remain symptom-free for extended periods. It can eventually cause discomfort due to nerve root compression, ligamentous strain and pseudo-arthrosis. Research by Eyo et al. (2001) [8] indicated that in half of the individuals with sacralisation, there is the likelihood of developing low back ache. Based on clinical observations, Bressler and Deltoff proposed that lumbosacral anomalies might lead to atypical sacroiliac mechanisms, resulting in inefficient biomechanical adaptations and symptomatic manifestations [19].

The presence of a sacralised vertebra alters lumbar spine biomechanics. According to Cailliet [20], around 70 to 75% of flexion in the lumbar region takes place at L5-S1, while the remaining 20 to 25% takes place at L4-L5. Approximately 75% range of total flexion-extension movement of the spine (219°) takes place at the lumbosacral joint [21]. Anomalous articulation or bony fusion limits motion between L5 and the sacrum. At the fusion level, a transverse process or abnormal joint effectively absorbs the load, reducing movement and alleviating stress on intervertebral disc. Consequently, the intervertebral disc immediately above the level of sacralisation experiences increased workload, leading to disc changes, spinal cord compression and arthritis. The increased occurrence of degeneration of intervertebral disc one level above the sacralised lumbar vertebra is considered to be due to its relatively increased mobility [22].

Bertolotti's syndrome results from unilateral LSTV. The unilateral contact creates unusual spinal stress, and as a result rotatory movements of lumbosacral spine frequently cause prolapse of the intervertebral disc one level higher than the sacralisation or lumbarisation. The lumbosacral intervertebral disc (L5-S1) narrows, and the immediately higher disc (L4-L5) above the sacralised vertebra (L5) degenerates, leading to intervertebral disc prolapse [17,23]. This prolapse, in turn, causes nerve root compression.

The most significant congenital vertebral anomaly causing low back ache is a change in a number of movable lumbar vertebrae. Lumbarization of the S1 sacral vertebra (effectively creating 6 lumbar vertebrae) increases the lumbar spine's lever arm, causing increased stress on the lumbar spine. Conversely, sacralisation of L5 lumbar vertebra (decreasing number of movable lumbar vertebrae to 4) does not cause any noticeable symptoms as the whole vertebra is fused to the sacrum. In some cases, only transverse process of one side unites with the sacrum which alters biomechanics of the spine and results in severe instability and stress [24].

Conclusion:

Lumbosacral transitional vertebrae are widespread spinal anomalies that require accurate identification and numbering of the affected segment. Substantial evidence links these vertebrae to low back ache. Sacralisation necessitates caution and changes in anaesthetic techniques and surgical procedures. Orthopedic and neurosurgeons operating in this area must be aware of sacralisation or lumbarisation to avoid the error of selecting the incorrect level of the surgical site. This knowledge is also vital for anesthesiologists administering subdural and epidural anaesthesia. Radiologists interpreting computerized tomography, magnetic resonance imaging, and X-rays must consider variations like sacralisation for precise clinical and radiological assessment. Physicians should also take these variations into account when ruling out spinal disorders such as facet arthritis, disc degeneration and herniation.

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