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Original Research Article

LUMBOSACRAL TRANSITIONAL VERTEBRAE- AN OSTEOLOGICAL STUDY IN DRY HUMAN SACRA OF NORTH INDIAN ORIGIN WITH ITS CLINICAL AND FORENSIC IMPLICATIONS

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ABSTRACT

Context: Lumbosacral transitional vertebrae (LSTV) are congenital anomalies that occur due to defect in normal segmentation of the lumbosacral spine during development. This may be either in the form of assimilation of fifth lumbar vertebra with the sacrum (sacralisation), or transition of the first piece of sacral vertebra into the lumbar configuration (lumbarisation).

Aims and Objectives: Although presence of LSTV is common in general population but knowledge about its exact clinical implications is still lacking. The primary aim of the present study was to determine the rate of incidence of transitional vertebra and their sex difference (if present) in dried human sacra. Secondary aim was to study these transitional vertebra in detail and correlate these findings clinically.

Materials and Methods: A total of fifty unbroken adult sacra were examined (male to female ratio of 3:2). The presence or absence of a lumbar transitional vertebra was noted and classified as incomplete or complete. The sacral indices (SI) of all sacra were measured and values compared between typical and atypical sacra with LSTV as well as between male and female sacra.

Results: Out of fifty sacra, six sacra (12%) showed presence of LSTV. Among them, four (8%) showed sacralisation of the fifth lumbar vertebra and two (4%) showed lumbarisation of first sacral vertebra. Among the four sacra showing sacralisation, two showed incomplete fusion and two showed complete fusion of fifth lumber vertebra with sacrum. LSTV was found to be more common in male than female. Sacralisation was seen only in male sacra while lumbarisation only in female sacra. The difference in the mean SI of typical sacra (97.76±4.08) and sacra with LSTV (83.69±2.38 and 98.11±1.52 for sacralised and lumbarised sacra respectively) was found to be statistically significant ($p<0.05$) and that between the male (94.55±5.70) and female (100.14±3.42) sacra was found to be highly significant ($p<0.01$).

Conclusion: Presence of LSTV has many clinical and forensic implications and its knowledge is important for orthopaedic surgeons, neurosurgeons, forensic experts and also to radiologists.

KEY WORDS: lumbarisation, sacralisation, congenital anomaly, low back pain, Sacral index.

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INTRODUCTION

Lumbosacral transitional vertebrae (LSTV) are common congenital anomalies of the lumbosacral spine [1] in which either the fifth lumbar vertebra may show assimilation to the sacrum (sacralisation), or the first sacral vertebra may show transition to a lumbar configuration (lumbarisation) [2]. Although the condition has an incidence of over 12%, with prevalence ranging from less than 1% to more than 20% [3], knowledge regarding its clinical and forensic implications is still lacking. Bertolotti et al [4] first described an association between LSTV and low back pain, almost a century ago. However, this association has remained a matter of debate. Furthermore, several conflicting studies have been published regarding the association of LSTV with other spinal pathologies. There seems to be a relation with early disc degeneration above the LSTV in young patients. However with age, these differences fade as they are masked by other degenerative changes of the spine. Complete transition results in numerical abnormalities of the lumbar and sacral segments. From a practical view-point, failure to recognise and to number LSTV during spinal surgery may have serious consequences [2].

The identification of physical identity from skeletal remains is one of the main problems faced by forensic experts. Congenital and acquired malformations of skeletal system can prove to be an important tool in order to establish such identity, provided antemortem records are available. LSTV is one such congenital anomaly that has clinical and medicolegal implications [5]. Forensic anthropologists may come across such congenital abnormalities during the examination of skeletal remains. These observations may then be matched with the antemortem hospital records that these individuals are likely to have for treatment of the underlying condition [6].

Though this skeletal variation is well known in general population, there is paucity of its reports in anatomical literature and those available are from orthopaedic literature. Hence this osteological study was done to determine the occurrence of transitional vertebra in dried adult human sacra of north Indian origin with detailed discussion on its clinical and forensic implications.

MATERIALS AND METHODS

In the present study, fifty sacra, collected from the bone room of the anatomy department, were examined. Only unbroken adult sacra (approximately 40-65 years old) of both the sex were included. All the sacra were sexed subjectively using morphological features given in standard text books of anatomy, anthropometry and forensic science [7, 8, 9], thirty sacra probably belonged to males and twenty belonged to females. Presence of transitional vertebra was noted by naked eye examination. The sacra consisting of six pieces of vertebra (incorporation of the fifth lumbar) and sacra consisting of four pieces of vertebra (deletion of first lumbar) were selected while those with fusion of the first coccygeal vertebra were excluded from the study.

Castellvi's classification [10]: was used to classify the sacra with presence of LSTV

Type I: Dysplastic transverse process - unilateral or bilateral large triangular transverse process.

Type II: Incomplete lumbarisation / sacralisation - enlarged transverse process with unilateral or bilateral pseudoarthroses with the adjacent sacral ala.

Type III: Complete lumbarisation / sacralisation - enlarged transverse process, with unilateral or bilateral complete fusion with the adjacent sacral ala.

Type IV: Mixed - Type II on one side and type III on the other.

In this study, the sacra were divided into two groups according to the number of pieces of vertebra

Group A: Typical sacra with five pieces of vertebrae

Group B: Atypical sacra with presence of LSTV. It can be further divided into two subgroups:

Subgroup B1- Atypical sacra with six pieces of vertebra (sacralisation).

Subgroup B2- Atypical sacra with four pieces of vertebra (lumbarisation).

Calculation of SI: The maximum straight length and maximum breadth of all sacra were measured with the help of digital vernier callipers (with least count of 0.01mm) [Fig 1a, 1b]

Maximum straight length (SL) of sacrum: It measures the straight distance from sacral promontory in the mid sagittal plane to the corresponding lowest point on anterior margin of sacrum.

Maximum breadth (width) of sacrum: It measures the straight distance between the two lateral end points of the ala of sacrum.

The sacral indices (SI) of all sacra were then derived.

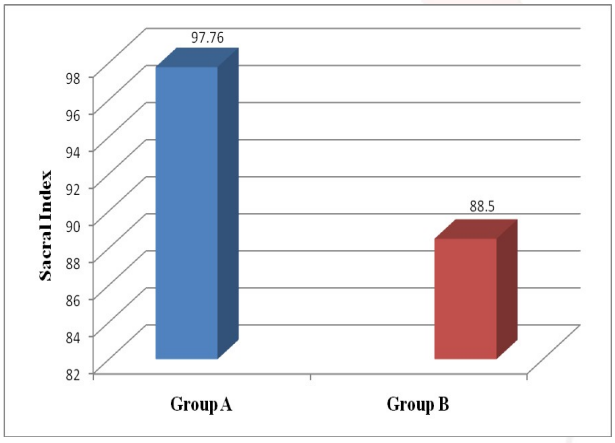
The formula for SI is: $\frac{\text{Maximum width}}{\text{Maximum straight length}} \times 100$

The data was tabulated and compared between typical and atypical sacra as well as between male and female sacra. The prevalence of LSTV, sacralisation and lumbarisation was reported separately.

Statistical analysis: Statistical analysis was performed using Statistical Program for Social Sciences (SPSS) software version 15.0 Chicago, Illinois, USA. The comparison of SI between the typical and atypical sacra and also between male and female sacra was done by using unpaired 't' test. The p-value of < 0.05 was considered as statistically significant and p < 0.01 as highly statistically significant.

RESULTS

Chart 1: Comparison of sacral index between Group A and Group B:



In our study, forty four sacra (88%) were found to be typical (Group A) while six sacra (12%) were atypical sacra with presence of LSTV (Group B). Out of the six sacra of group B, four had six vertebrae (subgroup B1) and two had four vertebrae (subgroup B2). The mean SI of Group A was 97.76 ± 4.09 and Group B was 88.5 ± 7.70 (Mean SI of Subgroup B1 was 83.69 and Subgroup B2 98.11). [Table 1]

Mean SI of Group A and Group B were compared using unpaired t-test. The difference between the two means was statistically significant (p = 0.031). [Chart 1]

Group B sacra were further studied in detail and classified according to Castellvi's classification [Table 2]. Accordingly, two sacralised sacra were Castellvi's Type IV [Fig-2a, 2b], two sacralised sacra were Castellvi's type III [Fig-3a, 3b] and two lumbarised sacra were Castellvi's type III [Fig4a, 4b].

The mean length of male and female sacra was 119.08 mm and 109.83mm respectively and the mean breadth was 112.10 mm and 110.00 mm respectively. The mean SI for male and female sacra were calculated as 94.55±5.70 and 100.14±3.42 respectively. Within group comparison of SI was done by unpaired t-test. These results were seen to be highly statistically significant (p <0.000136). [Chart 2]

Chart 2: Comparison of sacral index between males and females.

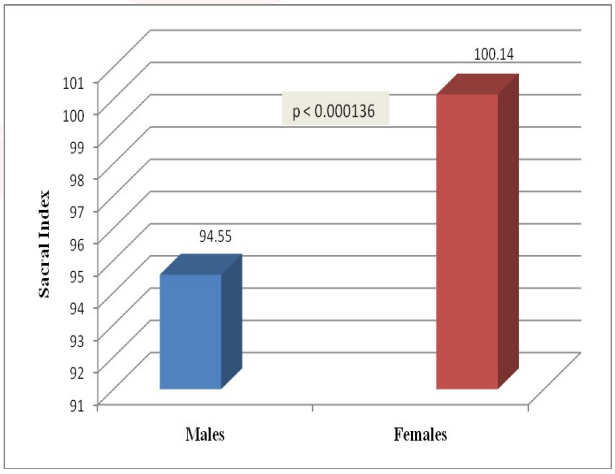


Fig. 1a: Measurement of max. breadth of sacrum
Fig. 1b: Measurement of max. straight length.

Fig. 2a: Anter view: complete sacralisation on right side incomplete on left.
Fig. 2b: Posterior view: failure of union of spinous processes of S1.


Fig. 3a: Anterior view: complete sacralisation.
Fig. 3b: Posterior view: completely roofed spinal canal.


Fig. 4a: Anterior view: complete lumbarisation with pseudoarthroses.
Fig. 4b: Posterior view: open spinal canal due to failure of union of spinous processes of S3-S5.


Table 1: Morphometric data of sacra under study.

Parameter	Group A		Group B			
			B1		B2	
	Mean	Range	Mean	Range	Mean	Range
Max. SL (mm)	112.66	108.60-118.64	147.27	122.74-151.00	115.37	114.12-116.62
Max. Breadth (mm)	110.08	102.32-116.25	123.22	120.32-126.52	113.21	110.75-115.68
SI (SI)	97.76	88.54-105.17	83.69	81.28-86.84	98.11	97.04-99.19

Table 2: Morphological features and Castellvi's typing of Group B sacra.

Specimen no	Anterior view	Posterior view	Pseudoarthroses	Castellvi's type	SI
1	Complete sacralisation on right, incomplete on left side	Failure of union of spinous processes of S1	Present between bodies of L5—S1.	Type IV (mixed)	82.62
2	Complete sacralisation on left, incomplete on right side	Complete fusion of the spinous processes	Absent	Type IV (mixed)	81.28
3	Complete sacralisation on both right and left sides	Complete fusion of the spinous processes	Absent	Type III	86.84
4	Complete sacralisation on both right and left sides	Complete fusion of the spinous processes	Absent	Type III	84.04
5	Complete lumbarisation with three pairs of sacral foramina	Incomplete union of spinous processes and open spinal canal	Present between bodies of S2-S5.	Type III	97.04
6	Complete lumbarisation with three pairs of sacral foramina	Incomplete union of spinous processes and open spinal canal	Absent	Type III	99.19

DISCUSSION

LSTV and its implications: In the present study, out of 50 dry sacra, only six (12%) showed presence of LSTV. Among these six, two cases (one with sacralisation and lumbarisation each) showed the presence of pseudoarthroses. [Table 2] On reviewing the results of similar studies by various authors, the incidence of LSTV is seen to vary widely ranging from 4% to 35.9%. [Table 3] This can be due to the differences in individual diagnostic and classification criteria, imaging techniques, observer error, and confounding factors of the population or ethnic group under study [2].

Clinical Implications: LSTV in patients with disc herniation or lumbar canal stenosis without spondylolisthesis may be a risk factor for the development of nerve root symptoms [15]. Louma et al. [16] suggested that the LSTV decreases the risk of annulus fibrosis degeneration of the disc below and also protects the L5-S1 disc from traumatic injuries because of the restriction of rotational and bending movements by the pseudoarthroses. Aihara et al. [17] claimed that LSTV may cause disc degeneration to occur more frequently at higher vertebral levels than at L5-S1 level as the iliolumbar ligament at the level immediately above the LSTV is very thin and weak. According to Singh et al [18]The exact diagnosis of low back pain may be challenging at times, and in cases with anatomical variations, the diagnostic and therapeutic difficulties can increase tremendously.

Forensic implications: Kanchan et al. [5] reported that some congenital abnormalities are of vital importance in physical identification during medicolegal investigations, especially when ante mortem records are available. Since individuals with symptomatic LSTV are more likely to seek frequent medical advice, they have more availability of ante mortem medical records which can prove very useful in confirming physical identity of an individual when skeletal remnants of spine and sacrum are available for medicolegal investigation.

Sacralisation and its implications: In the present study, out of the fifty sacra, only four (8%) showed sacralisation. Of these two showed complete and incomplete sacralisation each. On reviewing the results of similar studies by various authors across different ethnicities, the incidence of sacralisation is seen to vary between 3% to 20.8%. [Table 4]

The result of present study is similar to the findings by Brailsford et al [20]. Similar studies in Indian sub-continent have reported variable incidence of sacralisation with a study by Shewale et al. [24] reporting lesser incidence (3%) while that by Kubavat et al. [14] reporting higher incidence (11.1%).

In the present study, comparison of data between male and female sacra revealed that sacralisation were seen only in male sacra and mean length of the male sacra (119.08mm) was higher than that of the female sacra (109.83mm). This is in accordance with studies conducted by Mishra et al. [27], Davivongs et al. [28] and Sachdeva et al [29]. Also, increased incidence of sacralisation in males is proposed to be the cause for the increased length [28].

Association between sacralisation and low back pain remains a matter of debate. Unilateral or incomplete sacralisation frequently increases local stress potentially resulting in joint pain [5]. Whereas bilateral or complete sacralisation results in altered morphology at the L5-S1 joint and thus altered biomechanics of body weight transmission along the joint [30], it also limits the motion of this joint [15]. Both conditions thus have differing implications with unilateral sacralisation leading to pain and bilateral sacralisation leading to increased risk of disc degeneration at the level of transition (L5-S1) or above.

Lumbarisation and its implications: In the present study, only two (4%) out of total fifty sacra showed lumbarisation. Also the reported incidence of lumbarisation in the literature varies ranging from 1.7 to 6.2%. [Table 5]

The findings of our study are similar to those of Mahato et al. [30]. Individually lumbarisation is found to be less common than sacralisation in our study which is consistent with findings of Ucer et al. [25]. However, Leboeuf et al. [34], Kim et al. [35], Peh et al. [36] and Nakajima et al. [26] have reported opposite results.

Individuals with lumbarisation may present clinically with pain in lower part of the back and

legs [37]. Also, fourth sacral nerve roots may possibly be seen exiting through the sacral hiatus along with the fifth sacral, coccygeal roots and the filum terminale in sacra with lumbarisation. Any sacrococcygeal tumor, if occurs in individuals with lumbarised sacra, may compress upon fourth sacral roots simultaneously and present with unusual clinical findings due to neurological involvement of the bladder and rectum also [38].

Table 3: Incidence of LSTV as reported by various authors.

Author (year)	Population under study	Number of specimen		Incidence (%)
		Radiographs	Dry bone	
Hseish et al. (2000)[11]	Chinese	1668	-	4
Erken et al. (2002) [12]	Turkish	1053	-	35.9
Apazidis et al. (2011) [13]	American	211	-	35.6
Kubavat et al. (2012) [14]	Indian	-	189	12.7
Present study (2015)	Indian	-	50	12

Table 4: Incidence of sacralisation as reported by various authors.

Author (year)	Population under study	Number of specimens studied		Incidence (%)
		Radiographs	Dry bone	
Moore and Illinois (1925) [19]	Americans	-	-	3.6
Brailsford (1928) [20]	British natives	3000	-	8.1
Magora et al., (1978) [21]	-	312	-	20.8
Bustami et al., (1989) [22]	Arabs	-	-	10
Chang et al., (2004) [23]	Chinese		62	16
Kubavat et al., (2012) [14]	Indian	-	189	11.1
Shewale et al., (2013) [24]	Indian	-	167	3
Ucar et al., (2013) [25]	Turkish	3607	-	17.2
Nakajima et al., (2013) [26]	Japanese	226	-	2.7
Present study (2015)	Indian		50	8

Table 5: Incidence of lumbarisation as reported by various authors.

Author (year)	Population under study	Number of specimens studied		Incidence (%)
		Radiographs	Dry bone	
Kumar et al., (1992) [31]	Indian	-	159	1.9
Mahato et al., (2010) [30]	Indian	-	320	3.9
Sharma et al., (2011) [32]	Indian	-	206	4.3
Nakajima et al., (2013) [26]	Japanese	226	-	6.2
Ucar et al., (2013) [25]	Turkish	3607	-	1.7
French et al., (2014) [33]	Australian	5941	-	4.1
Present study (2015)	Indian	-	50	4

Variations in SI of sacra with LSTV and its implications: Our study showed that SI of typical sacra (97.76) was lesser than that of lumbarised sacra (98.11) by a marginal difference but significantly higher than that of sacralised sacra (83.69). This may be due to the fact that in sacralisation the breadth of sacra is infact breadth of fifth lumber vertebra which has been assimilated into sacrum but not as developed as first sacral vertebra. Whereas in lumbarisation the second sacral piece takes place of the first which has the capacity of developing into alae.

Also, human sacral bone is one of the important bones used for identification of gender. Various parameters of the sacrum including its length, breadth and indices like SI, curvature index, alar index, corporo basal index are used to identify the sex [39]. SI can be used with 95% accuracy in identification of sex [40]. While using SI in sex determination, due consideration should be given to the fact that SI varies among different populations due to difference in length and breadth of the sacra and LSTV may be one of the common contributing factors to this variation.

CONCLUSION

The incidence of LSTV in North Indian population was significantly high (above 10%) with that of sacralisation being double the incidence of lumbarisation. Sacralisation was exclusively associated with male sacra while lumbarisation with female sacra. The knowledge of LSTV is important for orthopaedic surgeons, neuro-surgeons, forensic experts and also to radiologists while reporting X-Rays, CT, MRI of the lumbosacral region for proper clinical and radiological assessment of such clinical presentations as low back pain. Inclusion of more number of samples and undertaking radiographic studies in live adults may substantiate the documented evidence.

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Conflicts of Interests: None

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