

Pars Inter-Articularis and Lamina Morphology of the Terminal Lumbar Vertebra in Lumbosacral Transitional Variations

Niladri Kumar Mahato

Department of Anatomy, SRM Medical College and Research Centre, Kattankulathur, Kanchipuram, Tamil Nadu, India

Abstract

Background: Lumbo-sacral transitional variations are common in the general population. Structural inadequacies of the terminal lumbar vertebral pars interarticularis (PI) and lamina have often been implicated as important factors for lumbo-sacral instability. **Aims:** Quantifying dimensions of PI and laminae in terminal lumbar vertebrae associated with lumbosacral transitions and compare them with their normal counterparts. **Materials and Methods:** Fourth lumbar vertebrae in spines involved with complete sacralization of the fifth lumbar (L5) vertebrae and L5 vertebrae associated with lumbosacral accessory articulation were measured for the height, width and thickness of the PI and the laminae on both sides and compared to normal vertebrae. **Results:** Dimensions in sacralization associated terminal vertebrae were smaller than the normal. The height of the PI and the widths of laminae were observed to be significantly smaller in terminal lumbar segment in sacralized specimen. Lumbo-sacral accessory articulations demonstrated smaller overall dimensions of several parameters. Laminae in the last lumbar segment associated with lumbo-sacral transitions demonstrate smaller dimensions compared to the normal ones. Sacralization results in maximum diminution of these parameters. **Conclusions:** Smaller PI may predispose spondylolysis and spondylolisthesis at lumbo-sacral junctions associated with transitional variations, and warrant special attention to avoid iatrogenic injuries.

Keywords: Low back pain, Lumbarization, Sacral, Sacralization, Spondylolisthesis

Address for correspondence: Dr. Niladri Kumar Mahato, Department of Anatomy, SRM Medical College and Research Centre, Kattankulathur - 603 203, Kanchipuram, Tamil Nadu, India. E-mail: mahatonk@yahoo.co.in

Introduction

Transitional variations at the lumbo-sacral junction are common anomalies associated with the lower spine.^[1] These anomalies are often accompanied by alterations of the facet joint structure and their orientation.^[2-6] Despite the morphological discrepancies observed in the facets associated with lumbo-sacral transitional variations, the facet joints remain highly loaded structures.^[7-10] The facet or zygapophyseal joints serve as an important component in a vertebral motion unit and regulates the range of movements at the motion segment^[9,11-14] and

are also subjected to different load patterns in different attitudes of the spine.^[13,14]

Spondylolisthesis or the pathological displacement of the fifth lumbar (L5) vertebra on the sacrum is usually directed anteriorly.^[15] This displacement at the L5-first sacral segment (S1) junction has been classified according to anatomical features of the neural arch elements of the L5 vertebra.^[6] The L5 vertebra is prevented from slipping forward by the facet joint between the inferior articulating facet of the last lumbar vertebra and the superior articulating facets of the sacrum. Poorly developed (hypoplastic) or defectively oriented (more coronally disposed) facet joints are compromised in preventing the forward displacement of the L5.^[10] Elongation of the pars interarticularis (PI), the bridge of bone extending vertically between the upper and lower articulating facets, may also result in spondylolisthesis.^[6] Actual disruption at the PI (spondylolysis) leading to a L5-S1 slippage may be sudden or develop over a period of time.^[10,15] Spondylolisthesis

Access this article online

Quick Response Code:



Website:
www.najms.org

DOI:
10.4103/1947-2714.114167

may be associated with generalized pathological disease of the bone or may be iatrogenic.^[16-18] Epidemiology of spondylolysis, interestingly, also demonstrates sexual and racial variations.^[19,20] Despite the etiological and demographic variations, spondylolysis and to a great extent spondylolisthesis involve the basic structural integrity at the PI.^[18,19] Immobilization of spinal motion segments with the help of facet joint fixation have been tried since long. King first reported trans-laminar screw fixation through the facet articulating surfaces to achieve high rates of lumbar fusion.^[21] This technique was later adapted, modified and popularized by workers who improvised the insertion of the screw with penetration of the screw-tip into the ipsilateral vertebral pedicle for better anchorage.^[22,23] The trans-laminar screw fixation of vertebral motion segments has become an important tool for eliminating vertebral movements in almost all planes, and is used to augment anterior fusions to achieve solid bony union.^[24-26] The screw fixation can also be used to obtain spinal stability after segmental decompression or dysfunctional pain. The trans-laminar screw fixation is applied to achieve stability at the lumbar spine, the technique probably being as efficient as the pedicular screw fixation.^[27,28]

The aim of this study was to quantify the dimensions of the PI and the laminae in the last lumbar vertebrae (L4 in case of complete sacralization of the L5 vertebra with the sacrum; L5 in case of L5-S1 accessory articulations) associated with L5-S1 transitional states and to compare them with dimensions observed in corresponding vertebrae in the normal spines.

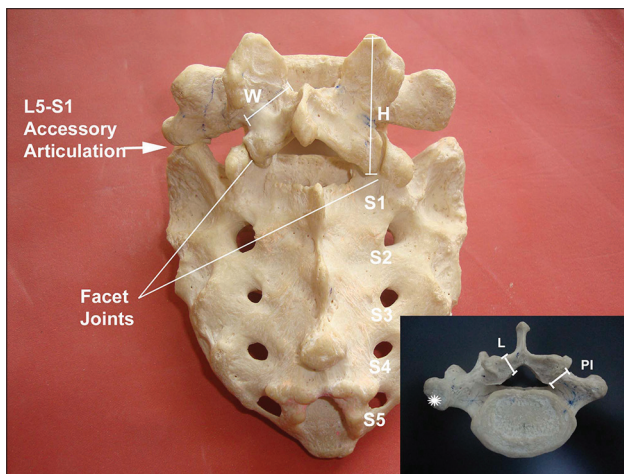


Figure 1: Fifth lumbar-first sacral segment (L5-S1) junction with left sided unilateral accessory articulation (arrow). Note the smaller facet joints on the affected side. The pars interarticularis parameters are shown as height and width. Inset shows the inferior surface of one L5 vertebra with left sided accessory articulation (asterisk), and the thickness of the lamina and PI as observed in the study. Transverse elements of individual sacral segments have been numerically represented as S1 through S5

Materials and Methods

L5 vertebrae ($n = 20$) belonging to lumbar spines with L5-S1 accessory articulations were measured for the height, width and thickness at the PI of both sides [Figure 1]. Similar dimensions were observed in the L4 vertebrae ($n = 15$) where the last lumbar vertebra was completely fused to the sacrum (sacralization). The dimensions recorded in these two varieties of transitional variations were compared with those observed in normal L5 samples ($n = 50$). In case of unilateral L5-S1 accessory articulation, PI and lamina data was compared from both sides. The lumbar vertebrae were also measured for the dimensions of their laminae as height, width and thickness [Figure 2]. Data on the sex of the samples were available for about seventy percent of the samples from catalogue records. Gender-wise comparison of the pars and the lamina parameters failed to yield significant differences. Therefore, male and female data for parameters were pooled in the two variants of lumbo-sacral transitional vertebrae included in the study. Mean values and standard deviations of all parameters in lumbosacral transitional vertebrae (LSTV) related PI and the lamina were calculated and data were compared with that observed from normal vertebrae at the corresponding regions. Dimensions obtained from unilateral L5-S1 accessory articulated L5 vertebrae were categorized as ones on the sides with the articulation, and ones on the sides without such accessory articulation [Tables 1 and 2]. Bones with gross deformities resulting from osteophytes were excluded from the study. Ethical information/Informed Consent were not required for this study as all samples used in

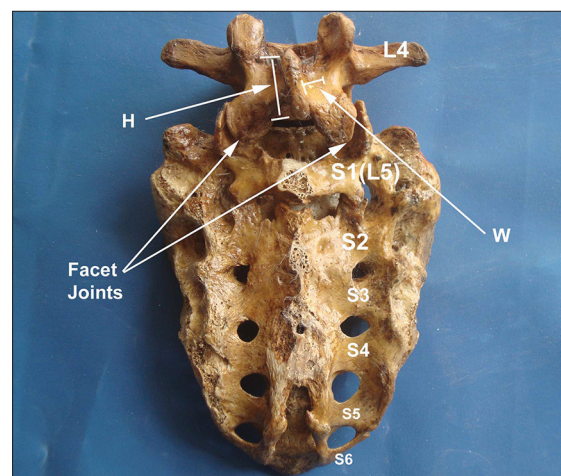


Figure 2: Specimen showing complete sacralization of the fifth lumbar vertebra that now represents the first sacral segment (S1) in a six segmented sacrum. The vertebra on top is the fourth lumbar vertebra. The parameters shown are the height and width of the lamina as measured in the study. Transverse elements of individual sacral segments have been numerically represented as S1 through S6

Table 1: Mean values of parameters measured at the PI in normal L5 vertebra, L4 vertebra in L5-S1 sacralized situations, and in L5 vertebrae with uni- or bi-lateral L5-S1 accessory articulation. All dimensions are given in millimeters with the standard deviations in parenthesis ($\pm 2SD$)

	PI (left)			PI (right)		
	Height (mm)	Width (mm)	Thickness (mm)	Height (mm)	Width (mm)	Thickness (mm)
L5 values in normal junction; <i>n</i> =50	17.24 (2.66)	13.93 (2.71)	6.33 (1.02)	17.92 (1.89)	12.78 (1.67)	6.12 (1.32)
L4 values in sacralization; <i>n</i> =15	16.10 (2.66)	12.03 (2.46)	6.00 (1.34)	16.25 (2.93)	12.11 (1.77)	6.03 (1.98)
Test statistic	1.546*	0.969	0.921	0.557	0.381	0.063
	On the sides with accessory articulation (in unilateral and bi-lateral L5-S1 transition)			On the normal side (in unilateral L5-S1 accessory articulation)		
L5 values in accessory L5-S1 articulation; <i>n</i> =20	16.96 (2.34)	13.21 (2.23)	5.98 (1.24)	17.80 (2.30)	12.56 (1.61)	6.08 (1.45)
Test statistic	0.872	0.235	0.914	0.001	0.044	0.152

*Significant at $P \leq 0.05$, 2-tailed; $\alpha = 0.05$; PI: Pars interarticularis; L5: Fifth lumbar; L4: Fourth lumbar; S1: First sacral segment

Table 2: The mean values of parameters measured at the lamina in normal L5 vertebra, L4 vertebra in L5-S1 sacralized situations, and in L5 vertebrae with uni- or bi-lateral L5-S1 accessory articulation. All dimensions are given in millimeters with the standard deviations in parenthesis ($\pm 2SD$)

	Vertebral lamina (left)			Vertebral lamina (right)		
	Height (mm)	Width (mm)	Thickness (mm)	Height (mm)	Width (mm)	Thickness (mm)
L5 values in normal junction; <i>n</i> =50	9.02 (1.63)	14.00 (1.33)	9.54 (1.79)	9.16 (2.02)	14.48 (2.13)	9.14 (1.26)
L4 values in sacralization; <i>n</i> =15	8.98 (2.18)	11.80 (1.94)	8.16 (2.42)	8.83 (2.43)	12.60 (2.02)	8.94 (2.62)
Test statistic	0.691	1.086*	0.744	0.885	0.003	0.657
	On the sides with accessory articulation (in unilateral and bi-lateral L5-S1 transition)			On the normal side (in unilateral L5-S1 accessory articulation)		
L5 values in accessory L5-S1 articulation; <i>n</i> =20	8.64 (1.58)	13.87 (1.40)	9.20 (2.03)	9.14 (1.96)	13.88 (2.13)	8.88 (1.56)
Test statistic	0.922	0.064	0.538	0.004	0.365	0.751

*Significant at $P \leq 0.05$; 2-tailed; $\alpha = 0.05$; L5: Fifth lumbar; L4: Fourth lumbar; S1: First sacral segment

this study were obtained from bone collections from medical teaching institutes, and no patients or living subjects were included as samples for data collection. Samples used in this study belonged to adults from both sexes and were obtained from repositories belonging to medical institutes across the central, western and southern provinces in India. Transitional variations observed in this study were detected after screening more than three hundred sacra and the corresponding vertebrae from assorted specimen collections in these institutes.

Statistical analysis

All dimensions were measured with a digital vernier caliper (sensitivity = 0.01 mm) by two independent observers twice. Average measures were entered for each parameter in case of an inter-observer difference of 0.5 mm. Student's *t*-test was used to detect the significance of difference of means between the values of dimensions in the normal vertebrae and those obtained

from transition associated vertebrae separately for the two types of transitional variations.

Results

The results obtained from the study indicates that (a) the overall dimensions of the PI as well as the laminae in the vertebrae L4 associated with the sacralization of the L5 are smaller than the normal (L5) counterparts that constitute the normal (L5-S1) lumbo-sacral junctions. The heights of the L4 pars in sacralized specimens are significantly smaller than the normal ones [Table 1]. The widths of the laminae in these vertebrae (L4) have been detected to be smaller than the other corresponding vertebrae [Table 2]. Other dimensions measured in these samples were comparable to the normal as well as those observed in the L5-S1 accessory articulated L5 vertebrae. All parameters pertaining to the PI and the laminae associated with the L5 related to accessory L5-S1 articulation demonstrated smaller dimensions

in comparison to the normal ones. These L5 vertebrae, however, possessed larger dimensions for all parameters used in this study when compared to the L4 vertebrae involved with a sacralized transitional state. The samples with unilateral L5-S1 accessory articulation demonstrated smaller dimensions of PI and lamina parameters on the affected sides as compared to the normal side in the same vertebra.

Discussion

Epidemiology of spondylolisthesis suggests that apart from traumatic causes of the displacement, majority of the cases present a prior susceptibility of the PI that eventually culminates in this condition.^[29] Facet dimensions at the upper end of the S1 in lumbo-sacral transitions may be quite small, rudimentary or dysmorphic; often measuring less than 1 cm² at the articular surface area or one of the facets in the pair measuring less than 45% surface area in contrast to the normal facet on the contra-lateral facet.^[3]

This study reports that the dimensions of the L5 PI as measured on the side of the accessory L5-S1 articulations and identical parameters observed in the L4 PI (in sacralized samples) are smaller in comparison to the normal controls selected from the same population samples. The L5 PI on the sides without L5-S1 accessory articulations demonstrates near normal values for all the three parameters such as the height, width and thickness of the structure.

There are several discrete indications for surgical interventions directed towards achieving repair for spondylolysis and listhesis. Repair for PI fractures have often been approached directly with repairing the pars defect.^[30,31] The results of direct repairs of the PI are often encouraging, especially when performed in cases without associated lumbar disc degeneration.^[32] Nevertheless, careful evaluation of the relevant anatomy at the disc, pedicles and the facets is essential prior to a direct instrumentation at the L5 PI.^[33-35] The study documents that the dimensions of the PI involved with accessory L5-S1 articulations should be evaluated carefully. The L4 PI are naturally found to be smaller (in sacralized L5-S1 states) than their counterparts (L5 PI) in the normal contexts.

The presence of smaller dimensions of the neural arch elements at the L5 vertebrae with L5-S1 transitions and reduced L4 PI and lamina elements in sacralized spines should be investigated prior to exploring the instrumentation modalities at transitional lumbo-sacral regions. In situations where a reduction is decided over fusion, it is best to be seen whether persistent short pars gives way to spinal root compressions at the L5-S1

inter-vertebral foramen. Transitional vertebrae have been documented to be definitive in determining the degree of aggressiveness in treatment strategies in spondylolysis and spondylolytic spondylolisthesis, in only a few studies that are available in the primary literature.^[36] A trans-lamina screw fixation is initiated near the cranial border of the lamina belonging to the upper vertebra of the segment to be fused. The screw is inserted close to the spinous process of the upper vertebra and extended obliquely to pass through the contra-lateral facet joint of the concerned motion segment. This technique can be implemented bilaterally and at different spinal segments to achieve desired fixation of the motion segment. The success rate of trans-lamina fusion is reported to vary according to application of the technique to achieve single-level, bi-level or a multi-level vertebral fusion.^[26,27,35]

Lumbar spine fixation through the PI or the laminae should be carefully planned in L5-S1 transitional situations according to the available bony dimensions at the PI and laminae of any adjoining transition-affected vertebra. In light of the trans-lamina screw fixation technique and its application in context of fusion or segmental immobilization requirements in LSTV (accessory L5-S1 articulations/L5 sacralization), the present study analyses the dimensional morphology of laminae in the fourth (in sacralization of the L5) and the L5 vertebrae (in accessory L5-S1 articulation) associated with L5-S1 transitional vertebrae. According to the PI and lamina dimensional alterations reported in the context of transitional L5-S1 variations in this study, trans-lamina screw placement in these circumstances needs careful evaluation of the dimensions of the L4/L5 vertebral laminae in achieving spinal immobilization, especially when applied to obtain reduction and fixation in spondylolisthesis. Laminectomies done to achieve a posterior decompression also need evaluation of the lamina dimensions at appropriate levels in these transitional L5-S1 states.^[24,35]

Conclusions

Since structural and biomechanical alterations occur at lumbo-sacral junctions due to LSTV variations, investigations trying to probe links between LSTV and spondylolysis or spondylolisthesis may find dimensional data useful in defining the role of pars and lamina morphology in lumbo-sacral stability issues in LSTV or their utility as surgical anchors in lumbo-sacral slippage corrections.

References

1. Bron JL, van Royen BJ, Wuisman PI. The clinical significance of lumbosacral transitional anomalies. *Acta Orthop Belg* 2007;73:687-95.

2. Mahato NK. Complete sacralization of L5 vertebrae: Traits, dimensions, and load bearing in the involved sacra. *Spine J* 2010;10:610-5.
3. Mahato NK. Association of rudimentary sacral zygapophyseal facets and accessory and ligamentous articulations: Implications for load transmission at the L5-S1 junction. *Clin Anat* 2010;23:707-11.
4. Mahato NK. Facet dimensions, orientation, and symmetry at L5-S1 junction in lumbosacral transitional States. *Spine (Phila Pa 1976)* 2011;36:E569-73.
5. Mahato NK. Morphological traits in sacra associated with complete and partial lumbarization of first sacral segment. *Spine J* 2010;10:910-5.
6. Mahato NK. Morphometric analysis and identification of characteristic features in sacra bearing accessory articulations with L5 vertebrae. *Spine J* 2010;10:616-21.
7. Tulsi RS, Hermanis GM. A study of the angle of inclination and facet curvature of superior lumbar zygapophyseal facets. *Spine (Phila Pa 1976)* 1993;18:1311-7.
8. Pal GP. Weight transmission through the sacrum in man. *J Anat* 1989;162:9-17.
9. Farfan HE. Biomechanics of the lumbar spine. In: Kirkaldy-Willis WH, editor. *Managing Low Back Pain*. New York: Churchill Livingstone; 1983. p. 9-21.
10. Wiltse LL, Rothman LG. Spondylolisthesis: Classification, diagnosis and natural history. *Semin Spine Surg* 1989;1:78-94.
11. Abumi K, Panjabi MM, Kramer KM, Duranceau J, Oxland T, Crisco JJ. Biomechanical evaluation of lumbar spinal stability after graded facetectomies. *Spine (Phila Pa 1976)* 1990;15:1142-7.
12. Haheer TR, O'Brien M, Dryer JW, Nucci R, Zipnick R, Leone DJ. The role of the lumbar facet joints in spinal stability. Identification of alternative paths of loading. *Spine (Phila Pa 1976)* 1994;19:2667-70.
13. Kong MH, He W, Tsai YD, Chen NF, Keorochana G, Do DH, *et al*. Relationship of facet tropism with degeneration and stability of functional spinal unit. *Yonsei Med J* 2009;50:624-9.
14. Grob D. Translaminar screw fixation. In: Herkowitz HN, Dvorak J, Gordon RB, Nordin M, Grob D, editors. *The lumbar spine*. Philadelphia: LWW; 2004. p. 292-6.
15. Rowe GG, Roche MB. The etiology of separate neural arch. *J Bone Joint Surg Am* 1953;35-A: 102-10.
16. Fredrickson BE, Baker D, McHolick WJ, Yuan HA, Lubicky JP. The natural history of spondylolysis and spondylolisthesis. *J Bone Joint Surg Am* 1984;66:699-707.
17. Wiltse LL, Widell EH Jr, Jackson DW. Fatigue fracture: The basic lesion is isthmic spondylolisthesis. *J Bone Joint Surg Am* 1975;57:17-22.
18. Sagi HC, Jarvis JG, Uththoff HK. Histomorphologic analysis of the development of the pars interarticularis and its association with isthmic spondylolysis. *Spine (Phila Pa 1976)* 1998;23:1635-9.
19. Albanese M, Pizzutillo PD. Family study of spondylolysis and spondylolisthesis. *J Pediatr Orthop* 1982;2:496-9.
20. King D. Internal fixation for lumbo-sacral fusion. *Am J Surg* 1944;66:357-68.
21. Boucher HH. A method of spinal fusion. *J Bone Joint Surg Br* 1959;41-B: 248-59.
22. Magerl FP. Stabilization of the lower thoracic and lumbar spine with external skeletal fixation. *Clin Orthop Relat Res* 1984;189:125-41.
23. Heggeness MH, Esses SI. Translaminar facet joint screw fixation for lumbar and lumbosacral fusion. A clinical and biomechanical study. *Spine (Phila Pa 1976)* 1991;16:S266-9.
24. Kornblatt MD, Casey MP, Jacobs RR. Internal fixation in lumbosacral spine fusion. A biomechanical and clinical study. *Clin Orthop Relat Res* 1986;203:141-50.
25. Hopp E, Tsou PM. Postdecompression lumbar instability. *Clin Orthop Relat Res* 1988;227:143-51.
26. Katz JN, Lipson SJ, Larson MG, McInnes JM, Fossel AH, Liang MH. The outcome of decompressive laminectomy for degenerative lumbar stenosis. *J Bone Joint Surg Am* 1991;73:809-16.
27. Deguchi M, Cheng BC, Sato K, Matsuyama Y, Zdeblick TA. Biomechanical evaluation of translaminar facet joint fixation. A comparative study of poly-L-lactide pins, screws, and pedicle fixation. *Spine (Phila Pa 1976)* 1998;23:1307-12.
28. Rainville J. Nondegenerative spondylolisthesis. In: Herkowitz HN, Dvorak J, Gordon RB, Nordin M, Grob D, editors. *The lumbar spine*. Philadelphia: LWW; 2004. p. 556-64.
29. Bonnici AV, Koka SR, Richards DJ. Results of buck screw fusion in grade I spondylolisthesis. *J R Soc Med* 1991;84:270-3.
30. Buck JE. Direct repair of the defect in spondylolisthesis. Preliminary report. *J Bone Joint Surg Br* 1970;52:432-7.
31. Seitsalo S, Schlenzka D, Poussa M, Osterman K. Disc degeneration in young patients with isthmic spondylolisthesis treated operatively or conservatively: A long-term follow-up. *Eur Spine J* 1997;6:393-7.
32. Floman Y. Progression of lumbosacral isthmic spondylolisthesis in adults. *Spine (Phila Pa 1976)* 2000;25:342-7.
33. Salib RM, Pettine KA. Modified repair of a defect in spondylolysis or minimal spondylolisthesis by pedicle screw, segmental wire fixation, and bone grafting. *Spine (Phila Pa 1976)* 1993;18:440-3.
34. Grob D, Humke T. Translaminar screw fixation in the lumbar spine: Technique, indications, results. *Eur Spine J* 1998;7:178-86.
35. Weinstein J, Rydevic B. The pain of spondylolisthesis. *Semin Sin Surg* 1989;2:100-5.
36. Kim NH, Suk KS. The role of transitional vertebrae in spondylolysis and spondylolytic spondylolisthesis. *Bull Hosp Jt Dis* 1997;56:161-6.

How to cite this article: Mahato NK. Pars inter-articularis and lamina morphology of the terminal lumbar vertebra in lumbosacral transitional variations. *North Am J Med Sci* 2013;5:357-61.

Source of Support: Nil. **Conflict of Interest:** None declared.