

PEDICLE MORPHOMETRY IN SUBJECTS WITH LUMBOSACRAL TRANSITIONAL VERTEBRA: RELATION TO PEDICLE SCREW FIXATION

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ABSTRACT

Aim of the study: There is a high prevalence of lumbosacral transitional vertebra (LSTV) in the population. This pathology has been reported to be related with increased adjacent level degenerative disease. It is a probability that some cases with this pathology can require posterior spinal instrumentation of these transitional and adjacent degenerated segments. Although knowledge of the pedicle morphology is crucial for the safe application of pedicle screws, there are so few reports investigating the morphological dimensions of the vertebrae in this congenital pathology. The aim of this study is to investigate the morphometric characteristics of lumbosacral vertebra.

Material and Methods:

In this study, the lower lumbar pedicle anatomy including pedicle width, pedicle height, interpedicular distance, transverse and sagittal pedicle angles, and pedicle length at the transitional and two adjacent vertebra levels were investigated with measurements utilizing Computerized Tomography (CT) scans in young or middle-aged, same gender subjects, in whom degenerative changes have not yet become relatively significant. The dimensional differences of the pedicles between the subjects with and without transitional vertebra have also been assessed.

Results: Interpedicular distance was found to be wider and pedicle lengths shorter significantly on the LSTV vertebra level. Pedicle lengths were also found to be significantly shorter on the vertebra adjacent to LSTV. Other morphological measurements revealed no difference.

Conclusion: LSTV anomaly mandates more careful preoperative calculation of the pedicle dimensions using radiological examinations of the patients who are scheduled for posterior spinal instrumentation surgery.

KEYWORDS: Lumbar vertebrae, Transitional, Spiral Computed Tomography, Anatomy

INTRODUCTION

The reported prevalence of the lumbosacral transitional vertebrae (LSTV) in the general population is 3-24% [1,2,3,4,5,6] and vary greatly. There is also a reported increase in degenerative changes including spondylolisthesis, disc protrusion, facet degeneration and nerve root canal stenosis just above the transitional lumbosacral segment [6,7].

Pedicle screw fixation is a popular method of spinal internal fixation [8]. Therefore, it is a probability to operate on patients who have LSTV requiring insertion of pedicle

screws through the pedicles of the segment and adjacent levels. Despite the high occurrence in population and knowledge about the measurements of the pedicles is compulsory for the safe application of pedicle screws. Studies concerning the morphometric values of these spinal segments are rare in the literature. As this congenital anomaly can have some concerns regarding the pathophysiology or biomechanics of the spine [7], it is not known whether the occurrence of this situation affects the pedicle dimensions of the affected and especially the adjacent levels when compared with normal subjects. To our knowledge, this is the first study to measure the pedicle diameters in subjects with LSTV.

Computed tomography (CT) data have been used previously to assess pedicle anatomy in subjects without this anomaly in numerous articles [9,10,11,12].

The aim of this study was to determine indices of the lower lumbar pedicle anatomy at the level of the transitional anomaly and both adjacent levels using CT. This can highlight the structural changes on the adjacent levels that LSTV anomaly can cause. Determination of these data can also have clinical applications in the safe management of patients with LSTV requiring posterior spinal instrumentation for various reasons.

MATERIAL AND METHODS

This study was conducted in a tertiary university teaching hospital between January 2007 and January 2013. CT exams of the patients who were referred for CT examination with clinical indications (low back pain and /or radiculopathy) and who were scanned helically with 2.5 mm slice thickness continuously between L3 and S1 enabling high quality multiplanar reformatting (MPR) were evaluated for the radiological measurements. Only young or middle-aged cases in with degenerative changes not yet relatively significant with LSTV were included into the study. The patients with gross anomaly which can influence the results of the measurements such as high grade spondylolisthesis, fracture, malignancy, facet degeneration or massive disc herniations were excluded from the study. Only female subjects were studied to maintain homogeneity of the sample.

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A total number of 1012 consecutive lumbar spinal multi-detector CT examinations were obtained in the radiology department and evaluated between these dates. A total number of 20 young or middle aged female cases with LSTV anomaly, fulfilling the inclusion criteria were included into the study. Another group of 20 cases with similar demographic properties but without LSTV anomaly were also selected randomly for the comparison between the groups. In the first group of 20 patients with LSTV anomaly, age range was 21-40 (mean age; 29,6). In the second group of 20 patients without LSTV, age range was 19-38 (mean age; 30,4).

The CT examinations of the spine were performed on a Hi-Speed QX/i scanner (General Electric Medical Systems, Tokyo, Japan) with 4 detector rows. All patients were positioned head first and supine in the gantry, with the arms elevated above the head, if possible. Antero-posterior (AP) and lateral digital radiographs were used for localization. Examination was performed from the mid-portion of the first sacral vertebra to the L3.

All examinations were done with a detector configuration of 4x1.25, beam collimation of 5.0mm, pitch of 0.75:1, speed (mm/rot) of 3.75, helical thickness of 2.5mm, 140kV, 230mAs, 16-cm field of view, 0 degree gantry angulation. Data sets were transferred to a workstation (Advantage Windows 4.1; General Electric Medical Systems).

For the MPRs, images with a slice thickness of 2mm and an increment of 2mm were reconstructed using a bone window setting. Slices were taken parallel to the upper margin of each vertebral body. The slice at the middle of the pedicle was selected to measure pedicle width, pedicle length, transverse pedicle angle and interpedicular distance. Sagittal pedicle angle and pedicle height were measured on sagittal reformatted images passing through the midpoint of the pedicle. The LSTV identification and measurements were done by the same radiologist. The measurements were performed three times by the radiologist, and the mean values of these obtained values were calculated for the pedicles and IPD.

The criteria for the identification of LSTV were as follows; fusion or articulation of at least one transverse process with the first contiguous sacral segment and identification of an intervertebral disc space, even vestigial, caudal to the transitional vertebra (Figure 1). The terms 'lumbarization' and 'sacralization' were avoided [20].

The level of the transitional vertebra was accepted as L5. CT measurements were applied on L5, L4 and L3 (lower lumbar vertebra) in the subjects with and without LSTV anomaly

because of the clinical importance of these levels. All measurements were taken directly from the CT video image display, using standard operator-controlled functions.

The following measurements were made:

1. Interpedicular distance (IPD): The distance between the medial borders of the pedicles
2. Pedicle Width (PW): medio-lateral outer cortical diameter of the pedicles
3. Pedicle Height (PH): cranio-caudal outer cortical diameter of the pedicle
4. Transverse Pedicle Angle (TPA): angle between line in CT placed through the center of the pedicle and a line of the vertebral midline in the transverse plane
5. Sagittal Pedicle Angle (SPA): angle between a line in CT from the superior margin of the vertebral body and a line through the pedicle axis in the sagittal plane
6. Pedicle Length (PL): The length of the pedicle measured from the posterior cortex to the midpoint of the anterior vertebral cortex

Data obtained from the individuals with LSTV anomaly were compared with the cases without this anomaly, and measurements of the LSTV level were also compared with the results of the adjacent levels. All data were analyzed using an unpaired Student's t-test by SPSS software (SPSS; Chicago, IL, USA). Statistical significance was attributed to p-values less than 0.05.

RESULTS

Demographic data for patients with and without LSTV were presented in (Table 1). There were no significant differences in mean age, weight or height.

Interpedicular Distance

IPD was widest at the midline of L5 pedicles at both groups (Figure 2). The statistical relation was significant between LSTV and non-LSTV cases at this level. IPD at L5 level was found to be wider significantly on the LSTV vertebra level ($p < 0.001$).

Pedicle Widths

In our study, PWs increased from rostral to caudal at both groups. No significant relation was found between the data on both groups at all levels (Figure 3).

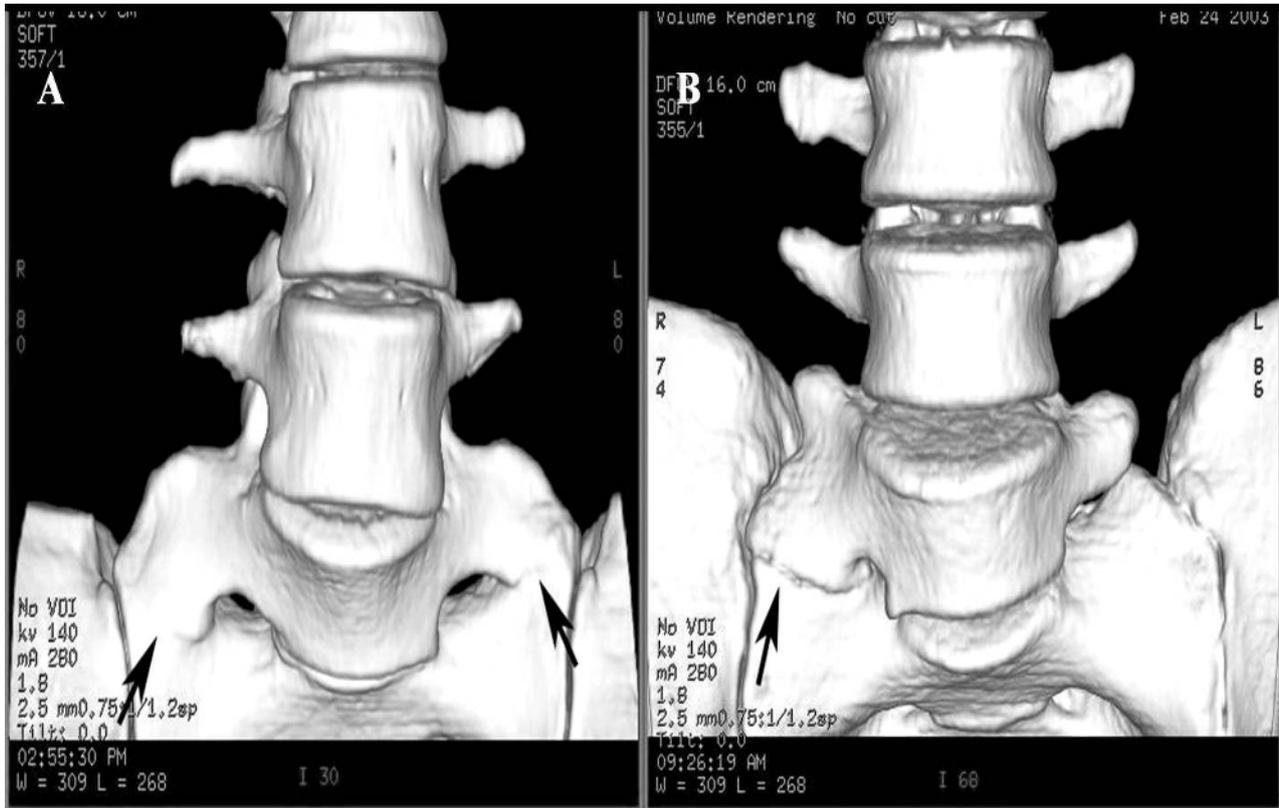


Figure 1. Bilateral (A, arrows) and unilateral (B, arrow) transitional vertebra anomaly observed in 3-D volume rendered CT images in our study group.

Pedicle Heights

Presence of LSTV anomaly has not given rise to any statistical differences on the pedicle heights measurements of both groups at all studied levels (Figure 4).

Transverse and Sagittal Pedicle Angles

TPA findings are shown in (Figure 5) and SPA in (Figure 6). There was a trend of gradual increase of TPAs and SPAs from L3 to L, reaching the highest dimensions at L5 at both groups

at both measurements. The differences were not statistically significant at LSTV and non-LSTV groups.

Pedicle axis lengths

PLs were shorter on LSTV group at L4 and L5 levels. These differences were statistically significant ($p < 0.05$) (Figure 7).

Table 1. Characteristics of all subjects enrolled into the study. (LSTV:Lumbosacral transitional vertebra.)

	Without LSTV	With LSTV	Significance
Age (yrs)	29.55 ± 5.28	31.75 ± 6.34	NS
Weight (kg)	64.85 ± 8.51	65.15 ± 12.91	NS
Height (cm)	161.25 ± 4.20	162.20 ± 5.92	NS

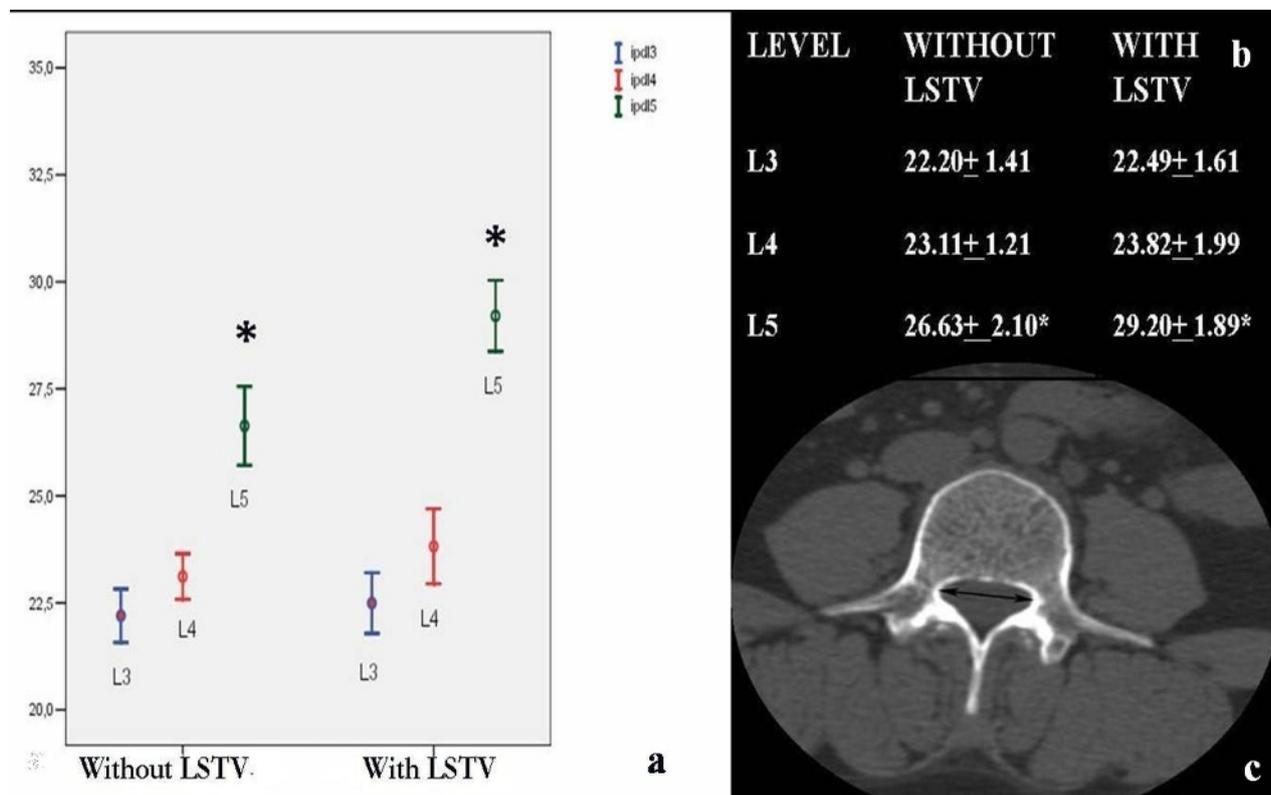


Figure 2. Bar chart representing the 95% confidence interval for IPD means of without -LSTV and with-LSTV groups (a), differences between the groups reached statistical significance at L5 (*p<0.001). Mean IPD (mm) of both groups (b), CT image representing the method of measurement for the IPD (c).

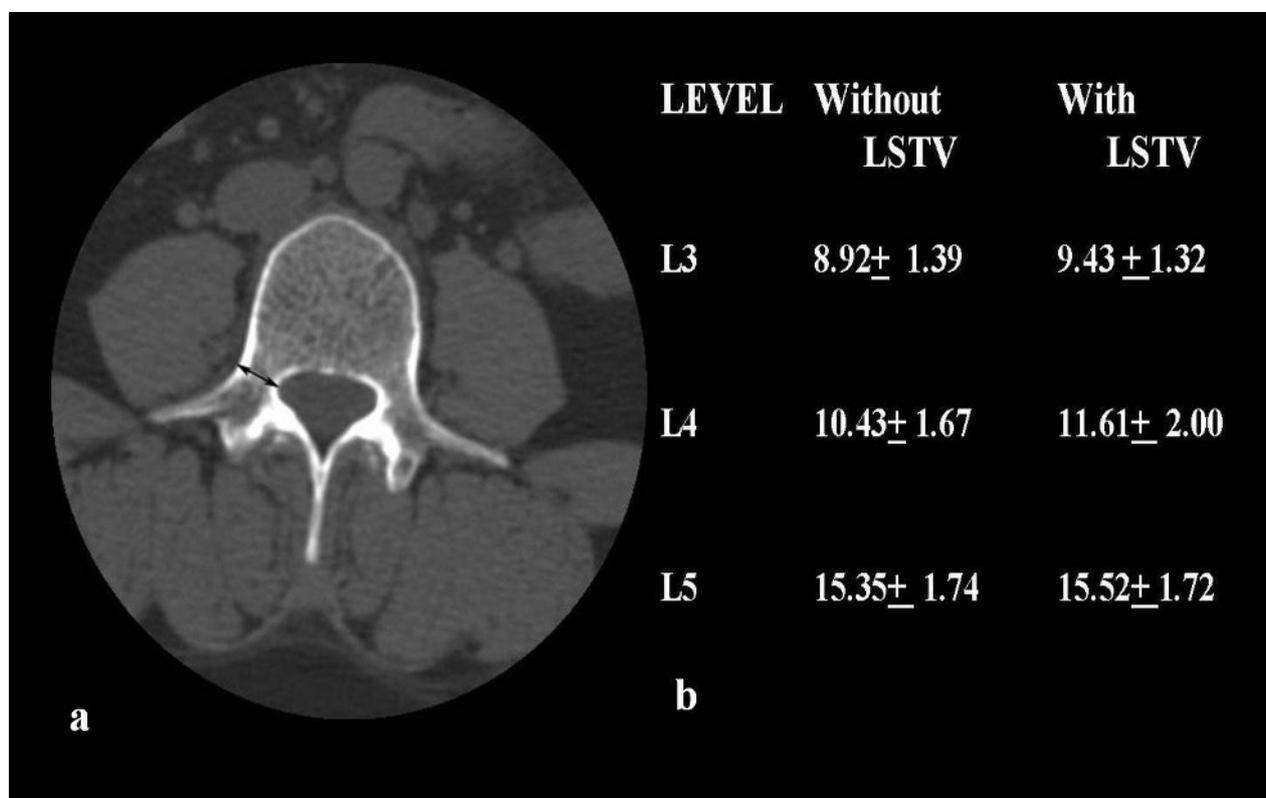


Figure 3. CT image representing the method of measurement for PWs (a), mean PWs (mm) for both groups (b)

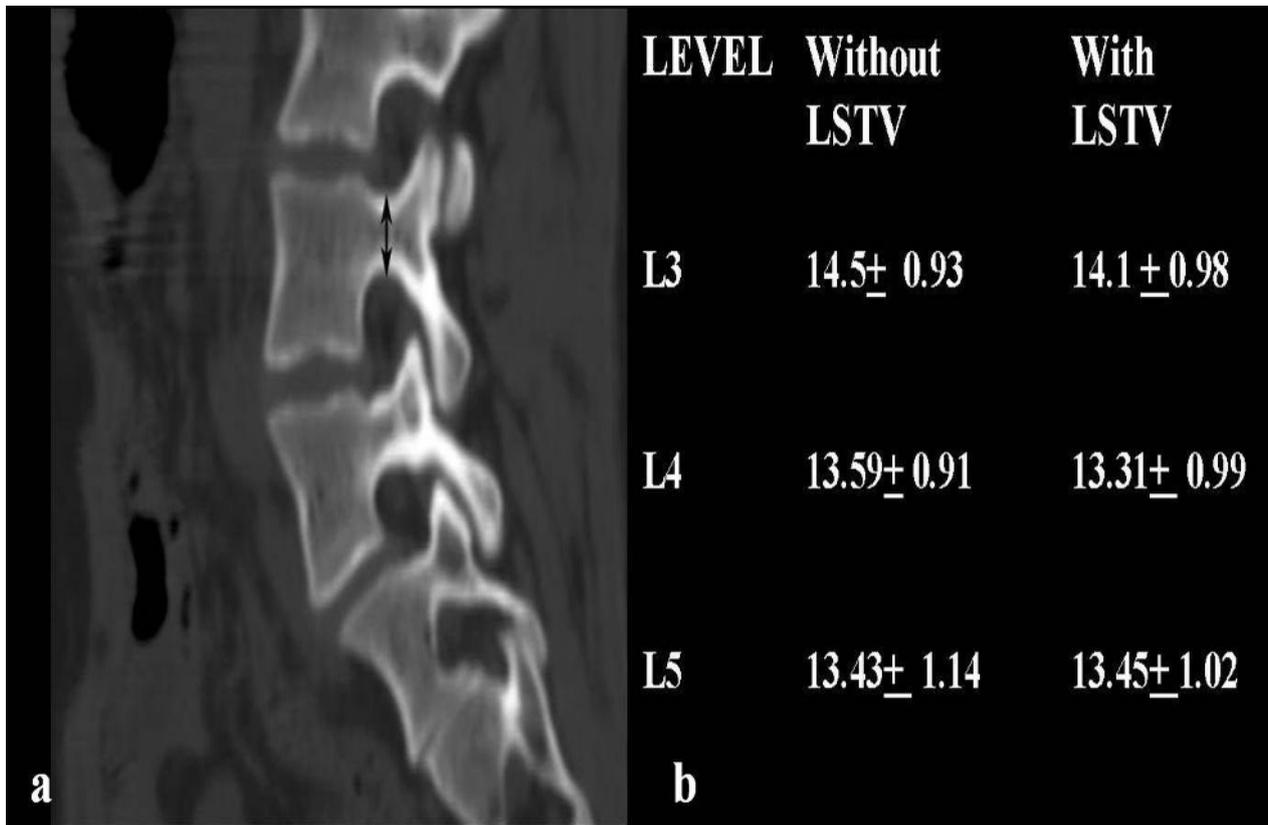


Figure 4. CT image representing the method of measurement for PHs (a), mean PHs (mm) for both groups (b)

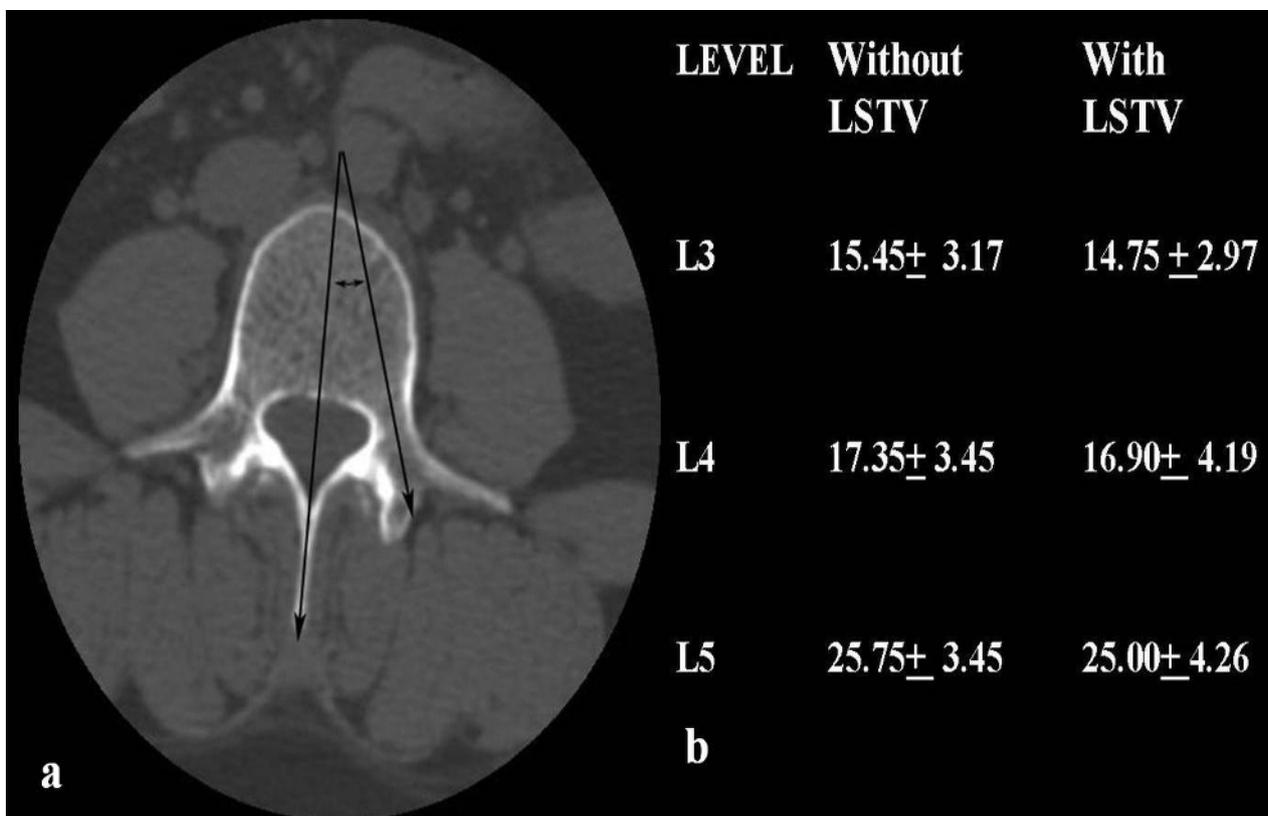


Figure 5 CT image representing the method of measurement for TPAs (a), mean TPAs (mm) for both groups (b)

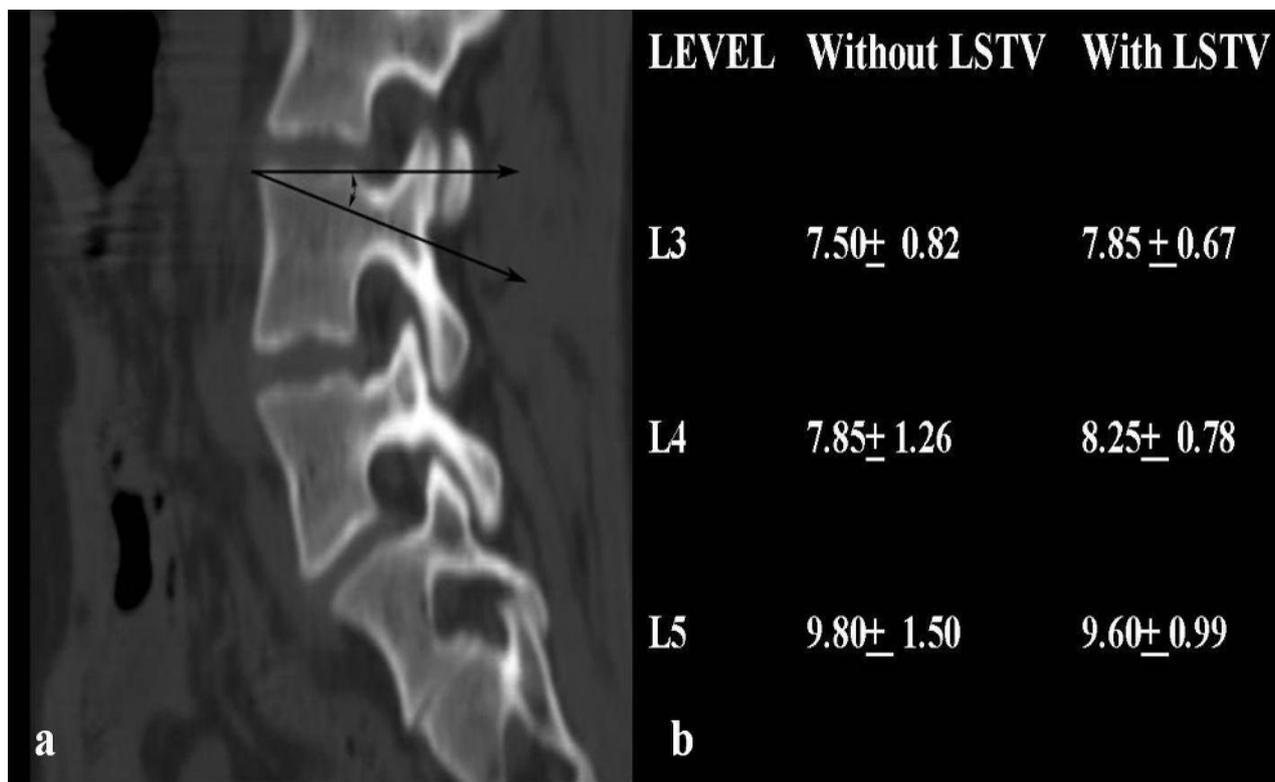


Figure 6. CT image representing the method of measurement for SPAs (a), mean SPAs (mm) for both groups (b)

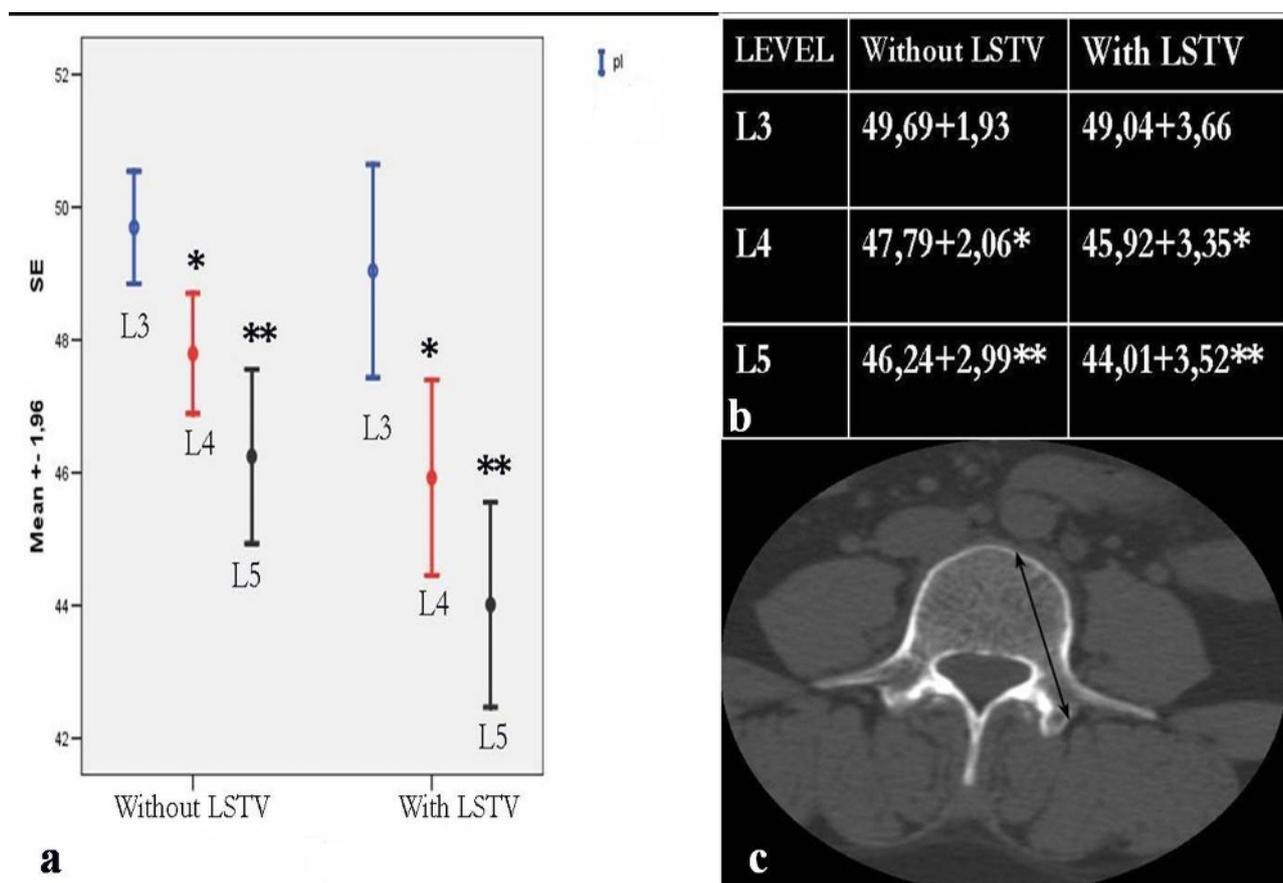


Figure 7. Bar chart representing the 95% confidence interval for PL means of without -LSTV and with-LSTV groups (a), differences between the groups reached statistical significance at L4 (*p<0.05) and at L5 (**p<0.05). Mean PLs (mm) of both groups (b), CT image representing the method of measurement for the PL (c).

DISCUSSION

The main starting point of our study was to investigate any possible effect of the congenital fusion of the transverse processes of the lowest lumbar vertebra with the sacrum on the morphometric measurements of the pedicles of that segment, and the adjacent levels including their width, height, sagittal and transverse angles. PLs and IPDs were also of interest because of the clinical importance of the measurements of these anatomical structures. The hypermobility at the interspace just above LSTV can give rise to some morphological and biomechanical changes and greater incidence of degeneration at this level [6,7]. Therefore we took into account the pedicle dimensions of the adjacent levels to LSTV.

There is a high prevalence of LSTV anomaly in the population [3,4,5,6,13,14]. However, this situation has rarely been taken into account in the studies regarding the morphological measurements of the lower lumbar vertebrae. Oguz; et al. reported an anatomical study regarding the spinal canal diameters in young subjects with LSTV anomaly [5]. In our study, we conducted measurements on the pedicles in cases with LSTV and compared these results with the findings of the cases without this anomaly. We also tried to find out the effect of LSTV on the dimensions of the pedicles of the adjacent vertebrae. As the precise knowledge of the pedicle anatomy is very important for the safe application of the screws, LSTV anomaly should be taken into account in the future morphometric measurement studies.

There are a lot of morphometric studies about the lumbar pedicles in the literature. Some of the researches used CT data [9,12,15,16,17,18] and others utilized calipers and goniometers to directly measure the dimensions on the vertebrae of the cadavers [19,20,21,22] without significant difference between the osteological and the CT scan measurement. It can be very difficult and unreliable to clearly define the transitional vertebra on dried specimens and also very hard to supply unembalmed or embalmed cadavers with detected LSTV anomaly. Therefore, CT measurements can be an appropriate method of obtaining data about vertebral morphology especially when LSTV is taken into account.

Cases with LSTV can also be identified at lumbar CT examinations of the patients who have been referred to the radiology department with a clinical indication. As the routinely scanned levels are between L3-S1, the measurements related with the pedicle dimensions were taken only in the lower lumbar vertebrae in the present study (L3, L4, L5). Degenerative changes including spondylolisthesis, facet degeneration or disc protrusion were reported to be higher in the adjacent levels to LSTV [6,7]. Application of pedicle screws to these levels can be encountered frequently in the clinical practice. Therefore our findings can be of clinical importance even though data related with L1 and L2 in LSTV cases are lacking. Anatomical measurement studies including the upper levels can be the aim of further studies which can only be conducted in volunteers of both genders because of the additional radiation exposure. Magnetic Resonance measurements can also be another possibility.

Pedicle dimensions rather than the pedicle lengths of the LSTV and the adjacent level were consistent with those of previously reported studies in this study [8,9,20,22,23]. IPD was found to be wider at the LSTV level. This finding was not compatible with the results of Oguz et al. [5]. They reported that there was no significant difference in the measured values of IPD between the normal and subjects with LSTV. Our cases were consisted of symptomatic subjects who were referred to radiology department for lumbar CT examination.

The measurements on the above mentioned study were done on asymptomatic volunteered university students (mean age 18.43 years old). Our study groups were also chosen among relatively young cases (20-40 years old) but the mean age of our LSTV cases were 29.6. The measurement method of Oguz et al. were obtained from axial sections taken parallel to disc interspaces [5] which was different from our method. We obtained axial sections parallel to the upper margin of the vertebral body. These all can give rise to subtle measurement changes and inconsistency between these both studies. Morphometric measurements conducted on subjects with signs and symptoms of low back pain and/or radiculopathy can be more clinically relevant. There can be the cases who will require posterior spinal stabilization and/or decompressive surgery, and this morphometric data can be very useful during the surgery.

More studies with a larger number of subjects utilizing the same measurement methodology can be helpful to better understand whether are not there are differences between IPDs of LSTV subjects and normal subjects. According to the results of this study, IPD was wider therefore the screw trajectory should be more convergent in patients with transitional anomaly.

The bone architecture as regarding the screw fixation which can also be studied by the utilization of computed tomography techniques and the angle for directing the screws and the screw pullout strength are all very important topics in LSTV cases. These can both be the topics of future studies about pedicle screw fixation in patients with LSTV.

The terms like lumbarization or sacralization can be confusing in the spinal literature in order to address the transitional segmental anomalies [6]. Therefore, we avoided these terms and instead accepted the last lumbar vertebra with fusion of the one or both transverse processes with the contiguous sacral segment and an intervertebral disc space even fastigial caudally as the L5 vertebra on the LSTV group of the study. Oguz et al also applied this protocol in the material and methods section of their study [5]. Addressing the LSTV level as L5 and avoiding obsolete spinal terms in the future studies can be useful to supply compatibility and reproductibility of the anatomical measurements.

Our findings revealed shorter pedicles on the LSTV and adjacent level as compared to normal subjects. Therefore, shorter pedicle screws can be utilized at above mentioned levels. Preoperative calculation of the pedicle dimensions especially pedicle lengths is a common procedure in the subjects undergoing posterior spinal instrumentation. This

procedure can be more important in order to find out the appropriate pedicle screw length in these cases.

The junction between the transverse process and the lateral facet is the entrance point of the screw and visualization of this point requires lateral dissection of the muscles during the operation (24,25). The results of this preliminary study also revealed wider spinal canal transverse diameters (IPD) indicating more lateral settlement of the facets requiring wider exposure of the operative area and extensive muscle dissections in order to find out the correct entrance point of the instruments while operating on patients with LSTV.

A concern about this study can be that the study group who underwent CT examination all had symptoms e.g., back pain, radiculopathy. Our results are then skewed in part as the selection criterion is biased. Therefore, patients without symptoms and with transitional vertebrae would not have the same increases in vertebral dimensions; but, as we worked on the cases needing spinal surgery and pedicle screw application, we believe that our results have clinical importance. Morphometric measurements about this topic can also be conducted on asymptomatic, volunteered subjects in the future studies.

CONCLUSION

Presence of LSTV anomaly can have some effects on the PLs and IPD dimensions on symptomatic patients. As LSTV is a commonly encountered congenital pathology in the population, precise preoperative preparation and measurement of the pedicle dimensions on radiological examinations of the surgical candidates with LSTV are compulsory for the avoidance of complications related with pedicle screw insertion. LSTV anomaly should also be taken into account in the future morphometric studies related with pedicle dimensions of different populations.

SUMMARY BOX

- There is a high prevalence of lumbosacral transitional vertebra (LSTV) in the population
- LSTV anomaly mandates more careful preoperative calculation of the pedicle dimensions of the patients who are scheduled for posterior spinal instrumentation surgery
- There are so few reports investigating the morphological dimensions of the vertebrae in this congenital pathology
- Interpedicular distance was found to be wider and pedicle lengths shorter significantly on the LSTV vertebra level.
- Pedicle lengths were also found to be significantly shorter on the vertebra adjacent to LSTV.
- Shorter pedicle screws applied at a more convergent manner can prevent some of the complications at cases with LSTV.

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Conflict of Interest

All authors have no actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations

Contribution for authorship

- ¹ conception and design
- ² analysis and interpretation of the data
- ³ drafting of the article
- ⁴ conception and design
- ⁵ drafting of the article