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Original Article

Evaluation of spinopelvic parameters in patients with lumbosacral transitional vertebra: a cross sectional and comparative study

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Abstract: Introduction: Lumbosacral transitional vertebra (LSTV) is the most common congenital anomaly of the lumbosacral junction and is a frequent cause of back pain in young patients with a prevalence of 4.6% to 36% in different regions. Objective: The objective of this study was to evaluate spinopelvic parameters in patients with lumbosacral transitional vertebra and to compare them with the same parameters of low back ache patients without lumbosacral transitional vertebra. Methods: This was a cross-sectional and comparative study conducted among low back ache patients presenting to our tertiary care center. Low back ache patients presenting to the outpatient department of AIIMS Jodhpur were screened for LSTV using radiographs. The spinopelvic parameters of those with LSTV were measured using Surgimap software and compared with the parameters of low back ache patients without LSTV. An Independent sample t-test was done and *p*-values were calculated. Results: The spinopelvic parameters, pelvic incidence, pelvic tilt and lumbar lordosis differed significantly in the patients with LSTV. Pelvic incidence was higher in the group with LSTV (58.5+9.3) when compared to the group without LSTV (50+8.8) with a *p*-value (<0.001). Pelvic tilt was higher in the group with LSTV (19.4+8.8) when compared to the group without LSTV (13.6+7.8) with a *p*-value (0.001). Lumbar lordosis was significantly higher in the group with LSTV (57.6+13.2) when compared to the group without LSTV (50.7+12.2) with a *p*-value (0.007). No significant differences were obtained in sacral slope and Pelvic-incidence and lumbar lordosis mismatch. Conclusion: LSTV alters the spinopelvic parameters. Altered spinopelvic parameters predispose to spondylolisthesis, degenerative disc disease, and facet joint arthritis and are important in preoperative planning in spine and pelvic surgeries.

Keywords: Lumbosacral spine, transitional vertebra, spinopelvic parameters

Introduction

Lower back discomfort is frequently caused by Bertolotti's syndrome or lumbosacral transitional vertebra (LSTV) syndrome, especially in younger people. It has been a subject of discussion regarding its correlation with low back pain and subsequent therapy ever since Bertolotti first identified it in 1917. Its prevalence varies from 4.6% to 37% in different regions.

The typical biomechanics of the lumbar spine are impacted by transitional vertebrae. An LSTV may cause low back pain because of arthritic changes that take place at the site of pseudoarthrosis. Facet joint arthrosis, disc herniation or degeneration, as well as spinal canal or foraminal stenosis, can all cause pain in the presence of an LSTV.

LSTV can be identified by multiple imaging techniques. The best method for identifying lumbar vertebrae is the anteroposterior radiograph with 30° cranial tilt (Ferguson view) and the lateral view. For numbering the vertebrae, according to the literature, the best technique is whole-spine imaging [1]. The identification and linkage of intraoperative and preoperative imaging become of utmost importance because there are essentially no failsafe means for precisely identifying a transitional segment without high-quality imaging of the complete spine.

There are various benefits to using lateral lumbar radiography. First off, radiographs are simple to obtain and don't need special film or chassis. Second, there is less radiation exposure. When compared to lateral whole-spine radiographs, Chung et al. found that the PI and PT readings on lateral pelvic radiographs were more reliable [2].

Berthonnaud et al. [3] reported linear correlations that were stronger at the pelvic and lumbar levels and between the thoracolumbar levels between shape and orientation factors. In order to maintain a stable posture with the least amount of energy expenditure, they thought of the sagittal plane between the pelvis and spine as a linear chain connecting the head to the pelvis and the neighboring segment.

Several treatment approaches have been recommended, despite the lack of agreement about the clinical importance of LSTVs. These include radio-frequency ablation and surgical management with partial transverse process resection and/or posterior spinal fusion, as well as conservative nonsurgical management with local injections of anesthetic and corticosteroids within the pseudo articulation or contralateral facet joint.

In patients with Bertolotti syndrome for whom surgery is being considered, it is advised that local anesthetic injection be included in the diagnostic workup [4]. Direct local anesthetic and steroid injection, surgical removal of the aberrant or contralateral facet joint, and other methods have successfully reduced pain while also providing useful diagnostic data.

In certain cases, surgical intervention is advised. For those who exhibit discomfort that is actually coming from a transitional joint and are unsuccessful with conservative therapy, resection of the transverse process may be useful. An alternative to posterior fusion is if the discomfort originates from a deteriorated disc that is above a level of transition [4]. In a case study, Brault et al. [5] documented how resecting the ipsilateral aberrant articulation effectively treated contralateral facetogenic pain. Following surgical removal of a unilateral LSTV pseudoarticulation, it was observed to provide pain alleviation in 9 of 11 patients. In a case report by Almeida et al. [6], radio-frequency denervation, another potential therapeutic approach, temporarily relieved discomfort brought on by an abnormal articulation.

The slightest alterations in the shape or orientation of a spinal segment at one level will directly affect the segment next to it, causing spinal instability.

In a study by Jeyaraman et al. [7], it was discovered that patients with chronic low back pain and aberrant LS spine architecture had substantial changes in the spinopelvic parameters. The development of spinal degenerative disease is influenced by the spino-pelvic factors and pelvic shape.

According to Mac-Thiong et al. [8], PI and LL have the most characteristic clinical association, which should be taken into account when planning spinal surgical operations before surgery.

Since the pelvic and lumbar regions bear a significant portion of the body weight and abnormal orientation of these spinal segments could result in excessive energy expenditure to maintain a balanced posture, it was discovered that maintaining PT and LL within a strict range would be particularly important.

Marty et al. [9] postulated that an increased pelvic incidence could predispose to spondylolisthesis, as it is specific and remains constant for each individual after childhood.

Spinopelvic parameters such as sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL) have all been reported to be affected by this anatomical variant in LSTV populations [10].

This study was conducted with the hypothesis that the spinopelvic parameters differed in patients with lumbosacral transitional vertebra. The aim was to confirm the hypothesis in our set of patients.

Materials and methods

Study design

This was a cross sectional and comparative study conducted in the department of Orthopedics, AIIMS Jodhpur.

Table 1. The definition of the parameters taken

Pelvic Incidence (PI)	The angle formed between a line from the center of the femoral head to the midpoint of the sacral end plate and a line orthogonal to the sacral end plate.
Pelvic Tilt (PT)	The angle formed by a vertical line through the center of the femoral heads and the line from the center of the femoral axis and the midpoint of the sacral end plate.
Lumbar Lordosis (LL)	The sagittal Cobb angle measurement from the superior end plate of L1 to the sacral end plate.
Sacral Slope (SS)	The angle formed between the horizontal and the sacral end plate.
PI-LL mismatch	The difference between PI and LL.

Study population

We compared the lateral radiographs of the lumbosacral spine of two groups to identify the difference in spinopelvic parameters between them. This included 51 low back ache patients with LSTV (cases) and 51 low back ache patients without transitional vertebra (controls) who were selected from among a screening population which included low back pain patients that presented to the Orthopedics Outpatient Department of AIIMS Jodhpur from August 2020 to March 2022 and fulfilled the inclusion criteria.

The inclusion criteria were: 1. Patient age >18 years and 2. Patient suffering from chronic low back ache (for more than 3 months). All patients with spine fractures, high grade spondylolisthesis (grade 2 and above), spine tumors, who have undergone spine or hip surgery, those with hip disorders, febrile patients and those with infectious and inflammatory spondylitis were excluded from the study. Additionally excluded were those who did not give consent.

The case group had 26 males and 25 females with a mean age of 37.5 years. The control group had 31 males and 20 females with a mean age of 40 years.

Radiographic protocol

The radiographs of the subjects were obtained and this included: 1. Antero-posterior radiographs of the whole spine (stitch views). 2. Antero-posterior (Ferguson view) of the lumbar spine and 3. Lateral view of the lumbosacral spine with both femoral heads in erect standing position.

This was obtained using GE TEJAS 6000-XR on 14×17 inch cassette with 85-95 kV range and 50-65 mAs depending on the patient were taken for the patients.

Measurements

Identification and classification was done using the antero-posterior and lateral views. Numbering was done using the whole spine radiographs.

Radiograph based measurements of the spinopelvic parameters were taken according to the standard criteria (as given in **Table 1**) for all patients meeting inclusion criteria using SURGIMAP software (v 2.3.2.1). The same observer took all of the measurements. The measurements included pelvic parameters (pelvic incidence, pelvic tilt and sacral slope) and spinal parameters (lumbar lordosis and PI-LL mismatch) as given in **Table 1**. The pelvic positional and morphological parameters were defined as given by Duval-Beaupere (**Figure 1**).

The following parameters were measured in the radiographs.

Statistical analysis

The data obtained were documented in the form of a master chart.

Statistical Software SPSS (v 28.0.1.1) IBM Inc. was used to analyze the difference between the spinopelvic parameters of the two groups. Data analysis was done with independent sample t-test. The mean and standard deviation for each of the parameters of the 2 groups were calculated.

Percentages of the numerical values of the nominal variables were calculated. The results from the analysis of the data obtained were reproduced graphically with bar graphs, pie charts and error bars. A p value less than 0.05 was considered to be significant.

Results

Among the 51 low back ache patients with lumbosacral transitional vertebrae, 42 (82.3%) had

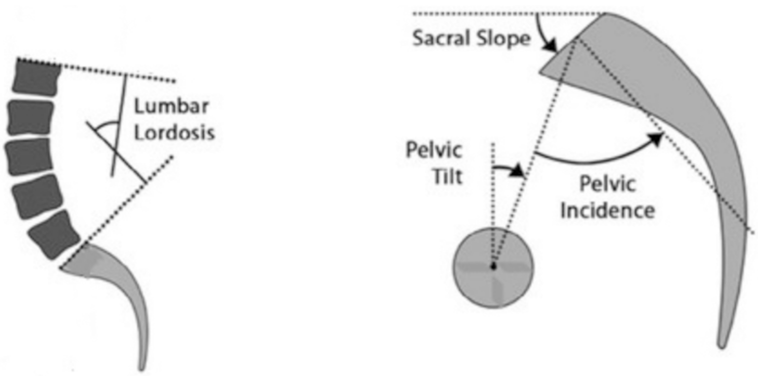

Figure 1. Measurement of spinopelvic parameters.

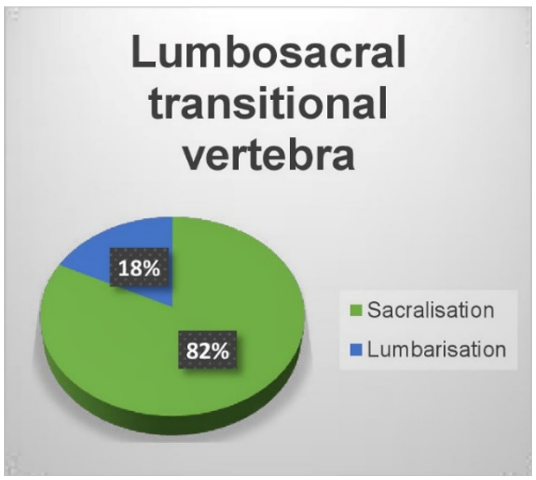

Figure 2. Percentage of lumbarization and sacralization in the subjects.

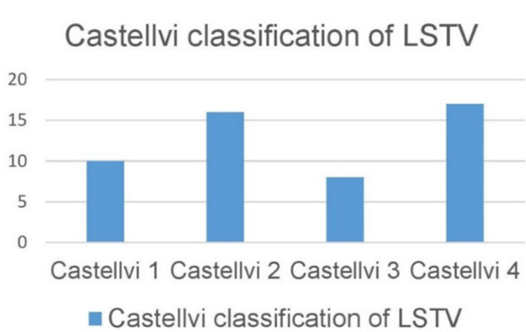

Figure 3. Number of subjects belonging to each class.

sacralization of the L5 vertebra and 9 (17.6%) were found to have lumbarization of the 1st sacral vertebra (**Figure 2**).

Castellvi classification

In the study, the radiographs of 51 low back ache patients evaluated were classified as per the Castellvi classification (**Figure 3**).

● 10 patients were found to have type 1 transitional vertebra (a large transverse process).

● 16 patients belonged to the type 2 category where there is incomplete lumbarization/sacralization, a large transverse process that follows the contour and articulates with the sacrum but is not fused, creating a diarthrodidal joint between the final lumbar vertebra and the first sacral segment.

● Castellvi type 3 had 8 patients among the total 51 where there is complete lumbarization/sacralization - a large transverse process with bony fusion to the sacrum.

● 17 patients belonged to the type 4 category where there is lumbarization/sacralization, incomplete (type II) on one side and complete (type III) on the contralateral side.

From earlier studies, it has been shown that sum of the positional parameters Pelvic tilt (PT) and sacral slope (SS) is roughly equal to pelvic incidence (PI) {PI=PT+SS}. The values in this study satisfy the above equation. To assess the validity of the data obtained, the 2 sets of parameters were compared using independent t-test. **Table 2** shows the parameters measured.

The results showed that: 1. Pelvic incidence (**Figure 4**) was significantly higher in the group with LSTV (58.5+9.3) when compared to the group without LSTV (50+8.8) with a *p*-value (<0.001). The results are displayed with the help of an error bar diagram. 2. Pelvic tilt (**Figure 5**) was significantly higher in the group with LSTV (19.4+8.8) when compared to the group without LSTV (13.6+7.8) with a *p*-value (0.001). 3. Lumbar lordosis (**Figure 6**) was significantly higher in the group with LSTV (57.6+13.2) when compared to the group without LSTV (50.7+12.2) with a *p*-value (0.007). 4. Sacral slope (**Figure 7**) was (39.2+8.6) in the group with LSTV when compared to the group without LSTV (36.9+7.7) with a *p*-value (0.166). 5. PI-LL mismatch (**Figure 8**) was (10.2+7.4) in the group with LSTV when compared to the group without

Table 2. Mean and standard deviations of age and spinopelvic parameters of the two groups of patients in the study

	Lumbosacral Transitional Vertebra Absent		Lumbosacral Transitional Vertebra Present		*P*-value
	Mean	SD	Mean	SD	
Age	38.2	15.0	36.3	14.2	0.516
Pelvic Incidence	50.0	8.8	58.5	9.3	<0.001
Pelvic tilt	13.6	7.8	19.4	8.8	0.001
Sacral Slope	36.9	7.7	39.2	8.6	0.166
Lumbar Lordosis	50.7	12.2	57.6	13.2	0.007
PI-LL	12.2	8.8	10.2	7.4	0.221

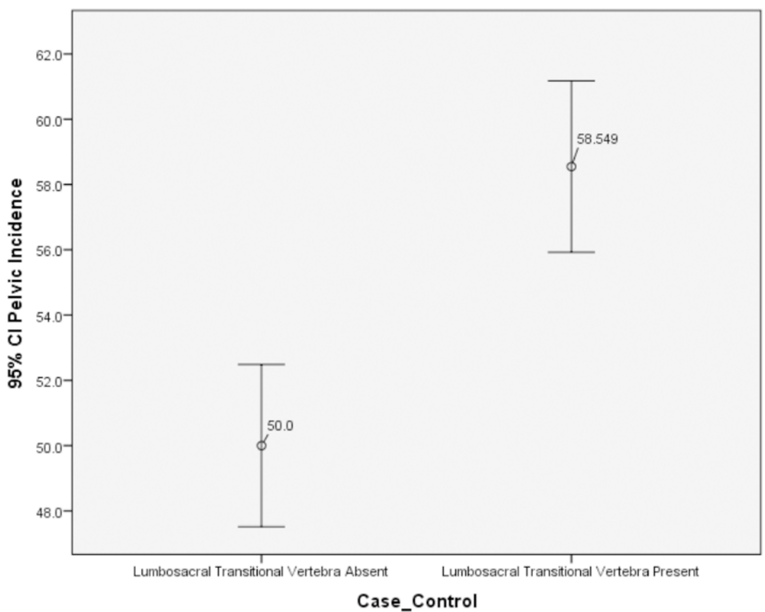

Figure 4. Error bar for pelvic incidence in the two groups of patients. Pelvic incidence was significantly higher in the group with LSTV.

LSTV (12.2+8.8) with a *p*-value (0.221). Both sacral slope and PI-LL mismatch did not show a statistically significant difference between the two groups.

Discussion

The primary change in human evolution may be seen in the acquisition of a vertical posture. The evolution of vertical posture and bipedalism was significantly influenced by the spine and spinopelvic complex.

It is well recognized that spinal sagittal balance and functional spinopelvic parameters are decisive elements in describing spinal alignment [11]. According to Glassman et al. [12], determining the parameters of sagittal balance is crucial for both the evaluation of patients who complain of backache and the success of surgical therapy.

Spinopelvic characteristics offer insight into the pathophysiological underpinnings of lumbar spinal illnesses by assisting in the understanding of the transmission of biomechanical stress across the lumbosacral junction.

This study was conducted in a limited population that presented to the Hospital OPD to identify and compare the spinopelvic parameters in patients with lumbosacral transitional vertebra with patients without a transitional vertebra.

Our study found a higher prevalence of lumbarized sacral segments (82%) than sacralized lumbar segments (18%), consistent with other studies as in one by Zhou et al. [13].

The significance of these parameters stems from the fact that spinal surgery aims to restore sagittal alignment by taking into account the pelvic morphology and sagittal spinal profile [14-16]. Following spine surgery for various disease conditions, the improvement of pain and function is directly correlated with the restoration of the sagittal profile [17].

However, it has been noted that the spinal profile, and therefore the functional spinopelvic characteristics, are very changeable and subject to both short-term changes brought on by

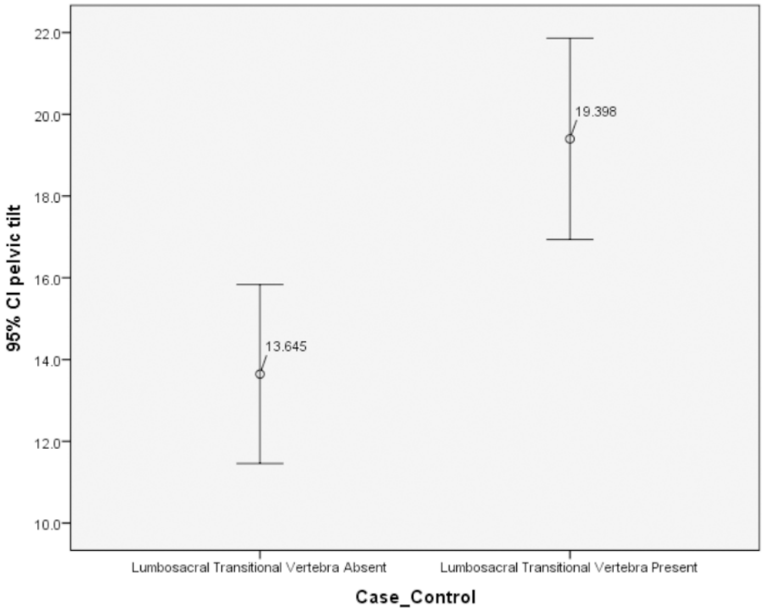

Figure 5. Error bar for pelvic tilt in the two groups of patients. Pelvic tilt was significantly higher in the group with LSTV.

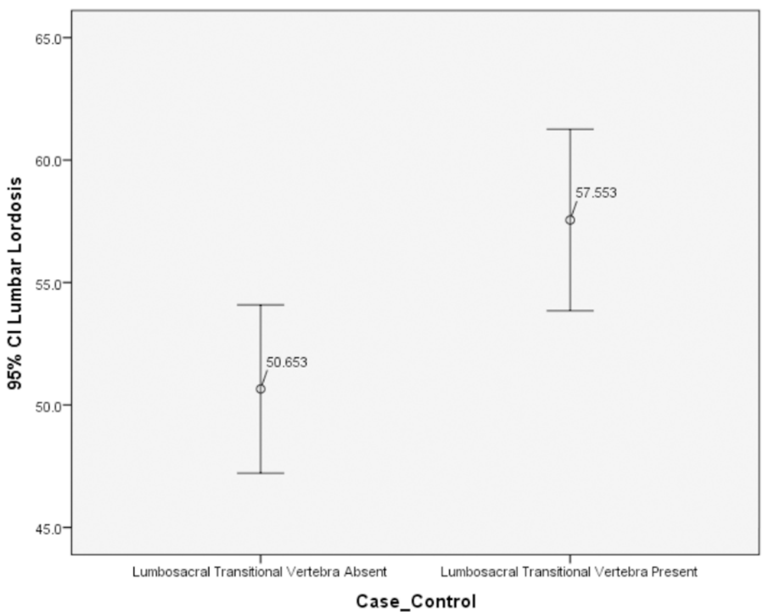

Figure 6. Error bar for lumbar lordosis in the two groups of patients. There was a significant increase in the lumbar lordosis in patients with LSTV.

daily activities and long-term changes brought on by degeneration [18].

The degree of lumbar lordosis (LL) and the posture-dependent pelvic parameters sacral slope (SS) and pelvic tilt (PT) all correlate with PI [15, 19]. The surgical procedure's choice and invasiveness are influenced by the PI-LL mismatch [20].

It was found in this study that the pelvic incidence (PI) showed a statistically significant difference in the group with LSTV (58.5+9.3) when compared to the group without LSTV (50+8.8) with *p*-value (<0.001).

This is consistent with the investigations by Price [21] and Yokoyama et al. [22], which showed increase in PI in patients with lumbosacral transitional vertebrae. Haffer et al. [20] also showed there was a significant increase in PI in the LSTV group (n=53) compared to the matched control group. In contrast, Abola et al. [23] could not find a significant difference of PI in transitional vertebra patients.

PI is a crucial anatomic parameter that represents the anatomy of the pelvis and has a significant impact on the sagittal configuration of the spine and, consequently, of the sagittal spinopelvic balance, as previously shown in literature. In a study by Labelle et al. [24], they discovered that PI, SS, PT, and LL were considerably higher (P 0.01) in participants with developmental spondylolisthesis. The study examined the role of pelvic architecture and its impact on the global balance of the trunk in developmental spondylolisthesis. This led to the conclusion that patients with a greater pelvic incidence appeared to be at an increased risk of presenting with a spondylolisthesis and that a higher PI may be a significant risk factor for progression in developmental spondylolisthesis.

According to Borkar et al. [25], patients with failed back surgery syndrome and lumbar spondylolisthesis revealed statistically significant differences in the pelvic incidence when compared to a healthy, asymptomatic group.

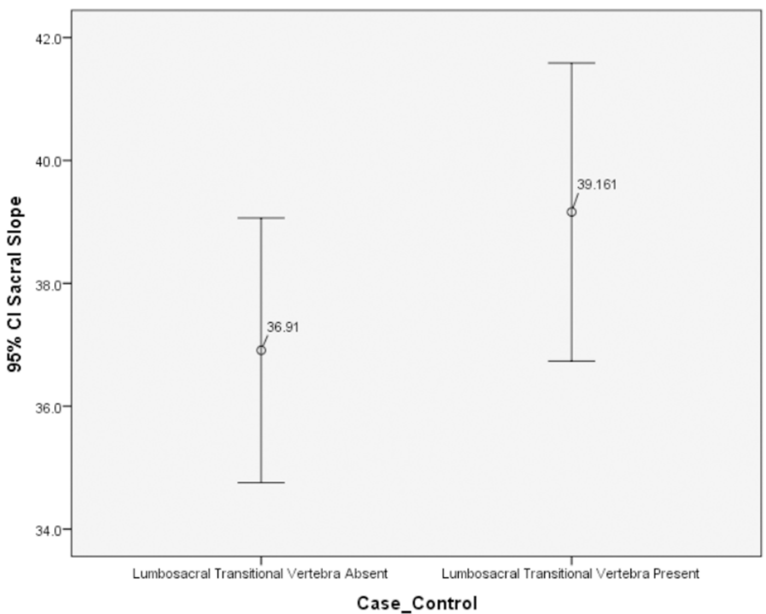

Figure 7. Error bar for sacral slope in the two groups of patients. There was no significant difference in the sacral slope between the two groups.

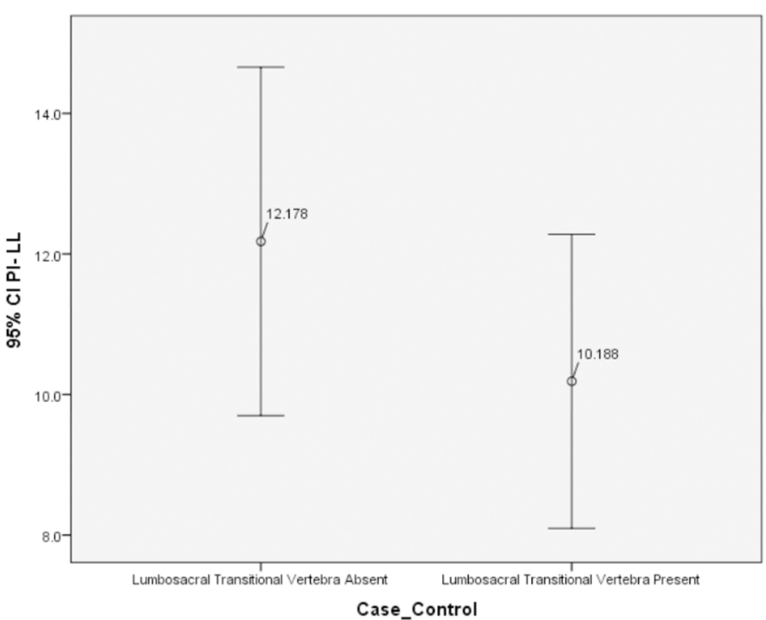

Figure 8. Error bar for PI-LL mismatch in the two groups of patients. There was no significant difference in the PI-LL mismatch between the two groups.

These findings were equivalent to those of the Barrey et al. study [26]. The morphology of the pelvis is the basis for PI, according to Lim and Kim [27], who also observed that there are substantial variations between lumbar spinal stenosis and lumbar spondylolisthesis in terms of PI.

They showed that individuals with lumbar spondylolisthesis had PIs that were considerably higher than those with lumbar spinal stenosis and asymptomatic participants. PT also revealed a substantial difference in addition to PI.

Low back pain has been linked to the sagittal curvature of the spine, and PI has been found to be correlated with spondylarthrosis.

53 patients with spondyloptosis had an elevated PI, according to Curylo et al. [28]. Marty et al. [29] observed a higher PI and SS in a cohort of 39 subjects (mean age, 30 years) with spondylolysis and low-grade (I or II) spondylolisthesis and hypothesised that this increased PI could predispose to spondylolisthesis because PI is unique to each individual and remains constant after childhood.

Oh YM et al. [30] in their study said high pelvic incidence, sacral slope and lumbar lordosis could be considered not only as risk factors of further slip, but also as aggravating factors of disc degeneration.

In a cohort of 48 people with low-grade isthmic spondylolisthesis with an average age of 43 years, the same results were reported by Rajnics et al. [31].

Additionally, Hanson et al. [32] observed that pelvic incidence exhibited a significant association with the Meyerding-Newman grades and was significantly greater in 40 patients with low- and high-grade isthmic spondylolisthesis compared to controls.

The most detailed analysis on sagittal spinopelvic alignment has been published in a retrospective review of 75 adults with spondylolytic spondylolisthesis, with a mean age of 44 years and the vast majority having Grades I or II.

They also report similar results with significantly different LL, pelvic lordosis, and lumbopelvic lordosis between normal and affected subjects, indicating that the pelvis' contribution to lordosis (pelvic lordosis) appeared to be important and that pelvic anatomy may play a role in the causation of L5-S1 spondylolisthesis.

The results from this study showed that the pelvic tilt and lumbar lordosis was significantly higher in the group with LSTV. A high PI is typically correlated with a strong SS and higher LL in the general population. The level of lordosis found in these patients exerts forces on the posterior articular joints and most likely leads to excessive mechanical loads on the posterior facets, speeding up the progression of arthrosis.

In a study by Cheng [33], it was discovered that Castellvi III and IV protected the transitional discs from age-related degeneration while predisposing the neighbouring spinal segments to degeneration. Type 2 significantly contributed to the deterioration of neighbouring and transitional segments.

A popular technique for treating hip osteoarthritis in its advanced stages is total hip replacement (THR). In a biomechanical chain, the hip and spine are connected, necessitating particular synchronisation between them. The lumbosacral joint connects the spine to the pelvis. The spine-pelvic-hip linkages that the hip joint and sacroiliac joint create on either side of the body are essential for pelvic motion and maintaining proper balance during bipedal locomotion.

Reduced lumbar lordosis, increased thoracic kyphosis, contractures in the hips or knees, and alterations in the pelvic parameters listed above are the causes of the sagittal imbalance, which has a connection to disability and discomfort. In order to avoid negative effects of imbalance, human organisms adapt to their surroundings and create compensation mechanisms [26].

Pelvic retroversion, in which the pelvis becomes more horizontal, thinner, and wider over the course of a lifetime, results from the exhaustion of compensating mechanisms. The depth or shallowness of the thoracic kyphosis, lumbar lordosis, and cervical lordosis may change.

A common post-THR complication is the dislocation of the hip prosthesis. The rate varies from 0.2 to 10% per year. Other risk factors for dislocations include advanced age, gender, concomitant conditions such rheumatoid arthritis (RA), or surgical technique. Cup and stem position also play a significant impact in dislocations following THR.

Surgeons must be aware that the position of the acetabulum changes and depends on the position of the patient while planning a complete hip replacement. The positioning of the acetabulum should be adjusted to accommodate both supine and standing position, which differs slightly from a sitting one as well.

One of the most crucial was establishing a link between acetabulum and pelvic tilt (PT). A strong indication of how PT affects the position of the cup is the rise in anteversion of the acetabular cup, which is equal to roughly 0.7 for each degree of posterior PT [34]. This parameter is hence essential during preoperative planning.

Cup inclination is a second crucial factor that rises by around 0.3 degrees for every degree of pelvic tilt, although this relationship appears to be nonlinear and more complex because cup inclination is more closely related to anteversion and the change does not appear to be linear [35].

A thorough awareness of the spinopelvic motion, acetabulum position, and impingement risk factors is required to obtain satisfactory outcomes following THR.

Due to the LSTV's strong influence on pelvic morphology and spinopelvic characteristics, the accurate identification of the LSTV as well as the appropriate selection of measurement points are of major clinical value.

After identification, the measurement of spinopelvic parameters and its application in the preoperative planning for the restoration of sagittal balance is to be given its due importance.

The limitations of the study are that the sample size was relatively small and a large scale population with LSTV is needed to shed light on this phenomenon and its association with other spine pathologies.

Conclusion

In this study, it was found that: 1. Pelvic incidence, pelvic tilt and lumbar lordosis were higher in the group with LSTV. These differences were statistically significant. 2. Sacral slope and PI-LL mismatch did not show a statistically significant difference on comparison between the two groups. 3. It is hence essential to identify the patients with transitional vertebra and to identify their spinopelvic parameters.

Disclosure of conflict of interest

None.

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