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Original Research

# Evaluation of Sacrum Measurements in Healthy Individuals and Patients with L5-S1 Spondylolisthesis

Esin Erbek [1,*], Nadire Unver Dogan [1], Mehmet Ozturk [1], Neriman Akdam [2], Zeliha Fazliogullari [1], Ahmet Kagan Karabulut [1]

[1] Department of Anatomy, Faculty of Medicine, Selcuk University, Konya, Türkiye
[1] Department of Radiology, Faculty of Medicine, Selcuk University, Konya, Türkiye
[2] Department of Biostatistics, Faculty of Medicine, Selcuk University, Konya, Türkiye

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**Corresponding Author**
Esin Erbek, PhD
**Address:** Department of Anatomy, Faculty of Medicine, Selcuk University, Konya, Türkiye
**E-mail:** esinerbek89@gmail.com

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**ABSTRACT**

**Objective:** In recent studies, the relationship between sacrum morphology and orientation and spondylolisthesis has gained importance. The present study aimed to compare the morphometry of the sacrum between patients with L5-S1 spondylolisthesis and healthy subjects on multidetector computed tomography (MDCT) images.

**Methods:** In this study, abdominopelvic MDCT images of 191 individuals (age range 20-92 years; 101 males and 90 females; 56 patients diagnosed with L5-S1 spondylolisthesis and 135 healthy individuals) were retrospectively evaluated. In this study, the sacrum parameters (Intercornual distance (ICD), sacral hiatus length (LHS), anteroposterior diameter of hiatus at the apex of sacral hiatus(APCWHSA), sacral height (SH), sacral table angle (STA), sacral table index (STI), S1 superior angle (S1A), sacral slope(SS)) evaluated morphometric and morphological in healthy individuals and patients with L5-S1 spondylolisthesis. Kolmogorov–Smirnov test was used to test the normality, which is one of the parametric test assumptions, of the data.

**Results:** Age parameter was found statistically significant higher in the patient group (p<0.001). STA, S1A, SH, LHS and APCWHSA measurements were found to be significantly higher in the healthy group. (p<0.001, p<0.001, p=.008, p=.005, and p=.002, respectively). STI and ICD were found to be significantly higher in women in the healthy group (p=.031, p=.010), while SH parameter was found statistically significant higher in men in the healthy group (p=.007). SS was found statistically significant lower in the healthy group (p<0.001). S1A, L5-S1 spondylolisthesis was found statistically significant higher than Grade 1, Grade 2 according to the degree of slippage (p=.045).

**Conclusion:** The results of this study showed that sacral morphology is important in the development or at least progression of spondylolisthesis.

**Keywords:** Morphology, multidetector computed tomography, L5-S1 spondylolisthesis, sacrum, spinopelvic

## INTRODUCTION

The lumbar vertebrae in the sagittal plane should continue the row aligned with each vertebral body lower and upper vertebral body. In other words, the anterior-inferior endplate of the upper vertebral body should be aligned with the anterior-superior endplate of the lower vertebral body. Spondylolisthesis occurs when the upper vertebral body slips over the lower vertebral body, or there is an anterior subluxation. Many cases and symptoms are associated with chronic spondylolisthesis [1]. Spondylolisthesis begins to be seen over the age of 50 and many factors such as joint degeneration, spinal sagittal imbalance, excess weight, sedentary lifestyle and subsequent muscle weakness have been reported to affect the progression of Spondylolisthesis [2]. The sagittal spinal alignment is affected by various factors, including age, posture, spinal diseases, the pelvis, and the entire lower extremity.

Previous studies have shown that sagittal spinal alignment is of great importance in treating degenerative spinal diseases and examining pathomechanisms [2,3]. In studies on the sacro-pelvic morphology of L5-S1 spondylolisthesis, abnormal sacro-pelvic morphology has been shown to cause deterioration of the global sagittal balance and sacro-pelvic orientation of the spinal cord. Studies have reported that findings related to sacro-pelvic morphology significantly influence the evaluation and treatment of patients with spondylolisthesis showing a high degree of slippage [4-6].

**Main Points:**

- In people with L5-S1 spondylolisthesis, the morphology of the sacrum is disrupted and thus the sagittal balance of the spine is impaired.
- In this study, STA and S1A values were lower in people with spondylolisthesis and SS values were higher in people with spondylolisthesis.
- We think that STA, SS and S1A values are important in the development of spondylolisthesis and S1A value is effective in the progression of the disease.We think that low SH is an important factor for the development of spondylolisthesis, but it is not associated with the progression of the disease.
- The SH value was found to be lower in people with spondylisthesis.

In our study, it was aimed to evaluate the relationship between multiple detector computed tomography (MDCT) images and the sacrum morphology of the patient group with L5-S1 spondylolisthesis and to compare the sacro-pelvic anatomical parameters with the group of healthy individuals.

## MATERIALS AND METHODS

The study was started with the decision taken by Selcuk University Ethics Committee with the date 23.08.2017 and number 2017/255. Informed Consent Form was obtained from the participants. MDCT images of a total of 191 cases (101 males and 90 females), consisting of 56 patients diagnosed with L5-S1 spondylolisthesis and 135 healthy individuals by radiologists at the Department of Radiology, Selçuk University Faculty of Medicine, were included in the study. The data of the cases were obtained from retrospective abdominopelvic images obtained by MDCT with 128 slices of 1 mm slice thickness from the sacral region between 2010 and 2017. According to the cross-sectional study design, people who met the inclusion and exclusion criteria between 2010 and 2017 were included in our study. Abdominopelvic images of a total of 201 patients were evaluated.

A total of 10 patients under 19 years of age (3 cases) and patients with outliers between observations (7 cases) were excluded. Patients diagnosed with spondylolisthesis at the lumbosacral level by radiologists in the MDCT reports were named as the patient group with L5-S1 spondylolisthesis, and the patients aged between 20 and 92 without sacral pathology were named as the healthy group. Patients with previous spinal surgery, trauma findings, lumbar scoliosis, osteoporosis, spinal metastatic or primary tumor, and severe congenital anomalies were not included in either group.The sacropelvic parameters used in the morphometric evaluation are the measurement parameters made in the literature and were made in the computer environment. These measurements were evaluated according to gender and age in healthy subjects and patients with spondylolisthesis.

Our study aimed to compare the age range (between 20-92 years) with the parameters examined while the cases were screened. Care was taken to ensure that the distribution of both genders was close to each other in the groups. In the group of healthy individuals, the gender distribution was close to each other, while in the group of patient individuals, the number of women was higher than the number of men.

**Measurements**

Grading of spondylolisthesis: In the group of patients with L5-S1 spondylolisthesis, evaluation was made using the method that Meyerding staged according to the amount of vertebral slippage in patients with spondylolisthesis. Meyerding spondylolisthesis was divided into stages according to the percentage of slippage. According to the degree of Meyerding slip, grade 1 (0-25%) and grade 2 (26-50%) slip were detected in the spondylolisthesis group [7] (Figure 1).


**Figure 1.** Spondylolisthesis slip value measurement on sagittal CT

**Measurements of the Sacrum**

Sacral table angle (STA): It is the angle between the line drawn along the sacral endplate and the line drawn along the posterior wall of the S1 vertebral corpus. Sacral table index (STI): It is the percentage of the anterior-posterior diameter of the superior endplate of the L5 vertebra to the maximum anterior-posterior diameter of the sacral endplate. S1 superior angle (S1A): It is the angle between the line drawn in the middle of the S1 vertebra and the perpendicular line drawn in the middle of the superior endplate of the S1 vertebra [8]. Sacral slope angle (sacral slope (SS)): It is the angle formed between the sacral endplate and the horizontal plane [9] (Figure 2).

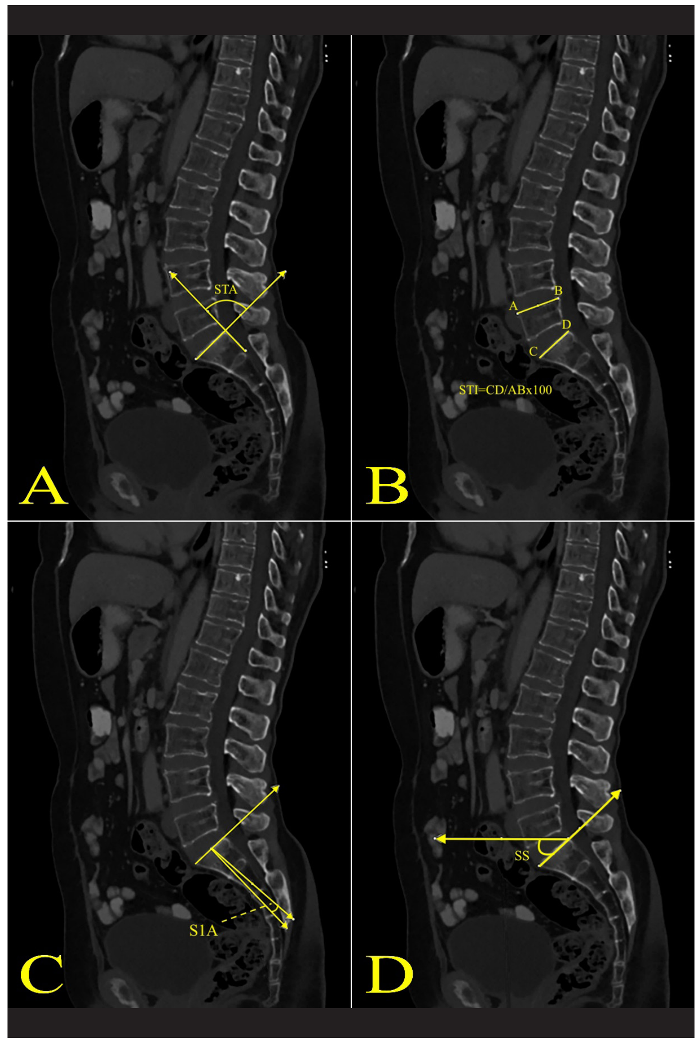


**Figure 2. A.** STA measurement on sagittal CT, **B.** STI measurement on sagittal CT, **C.** S1A angle on sagittal CT, **D.** SS angle measurement on sagittal CT

Sacrum height (SH): It is the distance measurement between the promontorium and apex ossis sacri notes of the anterior os sacrum [10]. Anterior posterior canal width of hiatus sacralis apex (APCWHSA): It is the distance between the anterior wall and posterior wall of the hiatus apex [11]. Intercornual distance (ICD): It is the distance between the bilateral cornu sacrales at their apex [12] (Figure 3).

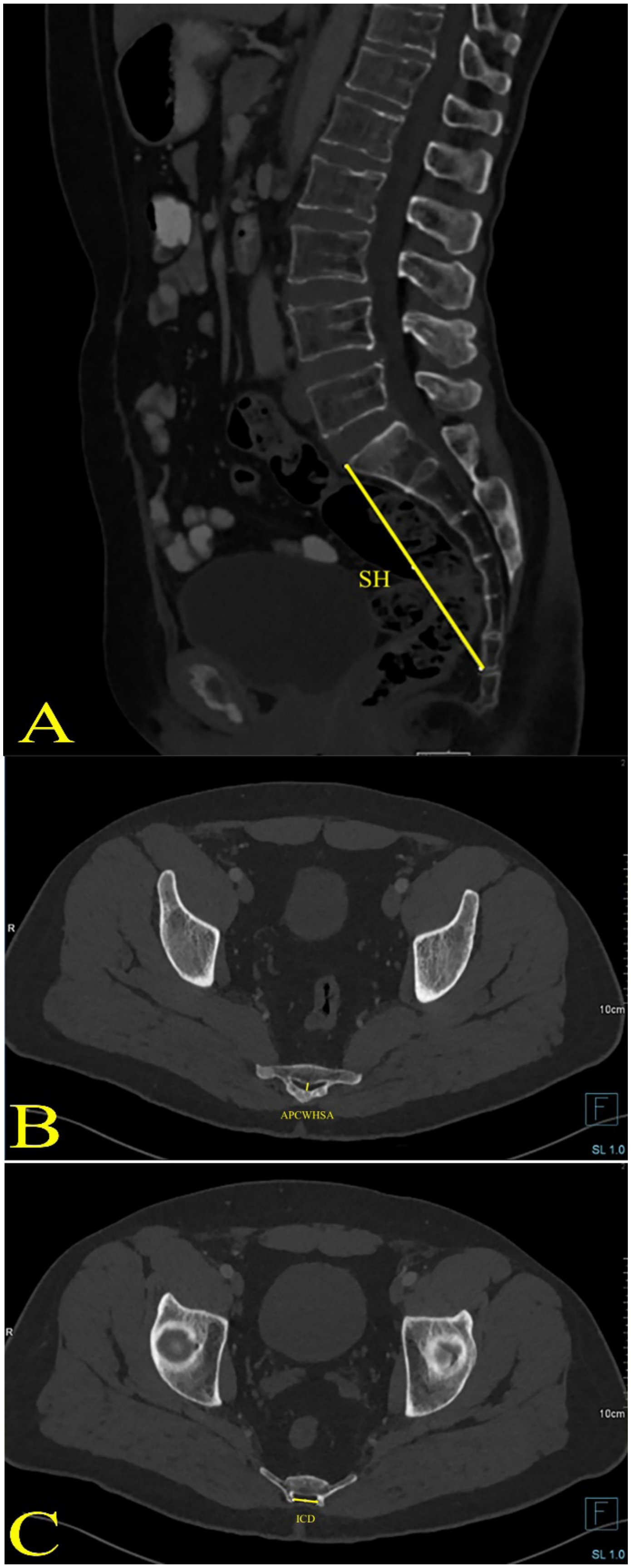


**Figure 3. A.** SH measurement on sagittal CT, **B.** APCWHSA measurement on axial CT, **C.** ICD measurement on axial CT

The length of the hiatus sacralis (LHS): It is the distance between the midpoint of the lower opening of the canalis sacralis and the midpoint of the part of the os sacrum that articulates with the os coccygis [13]. It was calculated by multiplying the number of sections between the first section where the hiatus sacralis begins (A) and the section at the level it ends (B) on the axial CT (Figure 4).


**Figure 4.** LHS measurement on axial CT. **A.** Hiatus sacralis starting place, **B.** Hiatus sacralis ending point.

**Statistical Analysis**

Statistical analysis was performed using the software IBM SPSS Statistics 21. Descriptive statistics were presented as minimum-maximum, mean±standart deviation, median, 1. Quartile and 3. Quartile. Kolmogorov–Smirnov test was used to test the normality, which is one of the parametric test assumptions, of the data. It was statistically accepted that the distribution of the data of age, STA, STI, SS, SH, APCWHSA, ICD distance variables for each group was in accordance with the normal distribution ($p>0,05$). In additioan, the distribution of S1A, LHS variables was not suitable with normal distribution ($p<0.05$). Independent

Samples T test was used to compare means of groups with normality and Mann-Whitney U test was used to compare groups with non-normality for all parameters. All analyses were evaluated at α=0.05 significance level (95% confidence level). p<0.05 is statistically significant.

**RESULTS**

**Findings Related to Age Variable**

The age value was found to be significantly higher in patient individuals (p<0.001) (Table 2). The age value was not statistically significant between the genders in the patient and healthy groups (p=.162, p=.625, respectively) (Table 1). When the age variable was analyzed according to the L5-S1 spondylolisthesis slippage grade, it was found to be higher in grade 2 than in grade 1, which was not statistically significant (p=.748) (Table 3).

**Morphometric Findings of Os Sacrum**

The mean values of STA and S1A of healthy individuals were determined as 94.8±7.24˚ and 12.39±4.75˚, respectively. The mean values of LHS, APCWHSA and SS in the healthy group were 29.32±9.06 mm and 5.5±0.20 mm and 41.26±8.90˚, respectively. While STA, S1A, LHS, SH and APCWHSA parameters were found to be significantly higher in the healthy group (p<0.001, p<0.001, p=.005, p=.008 and p=.002, respevtively), SS value was found statistically significant lower in the healthy group (p=.000). While STI and ICD values were found to be significantly higher in the healthy group of women (p=.031, p=.010), SH value was found statistically significant higher in the healthy group of men (p=.007). Comparison of parameters between healthy and patient groups and between genders are presented in Table 2 and Table 3.

The mean values of grade 1 and grade 2 of S1A were 6.41±4.45%, 4.12±4.15%, respectively. When S1A, L5-S1 spondylolisthesis was examined according to the degree of slippage, grade 1 was found statistically significant higher than grade 2 (p=.045). No significant difference was detected between grade 1 and grade 2 in all other measurements. Comparison of parameters according to grade 1 and grade 2 is presented in Table 3.

**Table 1.** Comparison of age and sacrum parameters according to gender and healthy- spondylolisthesis group

| | Group | Gender | Min.-Max. | Mean±SD | Median | p |
|---|---|---|---|---|---|---|
| AGE | Healthy | Female(n=65) | 22-92 | 50,54±16,15 | 49,0 | 0,162 |
| | | Male(n=70) | 20-82 | 46,90±16,40 | 43,0 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 24-84 | 58,28±15,30 | 60,0 | 0,625 |
| | | Male(n=20) | 39-82 | 57,3±15,12 | 50,5 | |
| STA (°) | Healthy | Female(n=65) | 79-109 | 94,38±7,05 | 95,0 | 0,523 |
| | | Male(n=70) | 80-120 | 95,19±7,44 | 95,0 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 76-104 | 88,69±7,24 | 88,0 | 0,588 |
| | | Male(n=20) | 73-101 | 87,60±7,11 | 86,0 | |
| STI (%) | Healthy | Female(n=65) | 84-11,5 | 98±0,65 | 0,98 | **0,031*** |
| | | Male(n=70) | 81-10,8 | 96±0,59 | 0,96 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 85-12,1 | 99±0,92 | 0,99 | 0,246 |
| | | Male(n=20) | 88-10,9 | 97±0,63 | 0,97 | |
| S1A (°) | Healthy | Female(n=65) | 2-24 | 12,92±4,50 | 13,0 | 0,152 |
| | | Male(n=70) | 1-24 | 11,89±4,95 | 11,0 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 0-16 | 5,78±4,86 | 4,5 | 0,712 |
| | | Male(n=20) | 0-14 | 5,6±3,72 | 5,0 | |
| SS (°) | Healthy | Female(n=65) | 26-64 | 41,98±9,44 | 42,0 | 0,364 |
| | | Male(n=70) | 18-64 | 40,59±8,40 | 40,5 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 30-76 | 49,64±10,55 | 49,0 | 0,307 |
| | | Male(n=20) | 29-62 | 46,65±10,08 | 49,0 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| SH (cm) | Healthy | Female(n=65) | 7,84-12,85 | 10,80±1,12 | 10,78 | **0,007*** |
| | | Male(n=70) | 8,83-13,83 | 11,30±1,02 | 11,31 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 7,68-12,46 | 10,44±1,26 | 10,64 | 0,156 |
| | | Male(n=20) | 8,34-13,49 | 10,95±1,30 | 10,97 | |
| APCWHSA (cm) | Healthy | Female(n=65) | 0,12-1,01 | 0,54±0,21 | 0,53 | 0,476 |
| | | Male(n=70) | 0,17-1,30 | 0,57±0,20 | 0,56 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 0,0-0,96 | 0,46±0,21 | 0,44 | 0,786 |
| | | Male(n=20) | 0,15-0,72 | 0,45±0,16 | 0,45 | |
| LHS (mm) | Healthy | Female(n=65) | 14,2-48,5 | 27,60±7,44 | 27,0 | 0,078 |
| | | Male(n=70) | 11,0-52,0 | 30,93±10,14 | 30,6 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 9,0-50,0 | 25,66±8,50 | 24,0 | 0,832 |
| | | Male(n=20) | 12,0-45,0 | 25,15±8,44 | 22,5 | |
| ICD (cm) | Healthy | Female(n=65) | 0,79-2,00 | 1,36±0,25 | 1,37 | **0,010*** |
| | | Male(n=70) | 0,66-2,06 | 1,48±0,30 | 0,56 | |
| | L5-S1 Spondylolisthesis | Female(n=36) | 0,70-1,90 | 1,35±0,28 | 1,35 | 0,750 |
| | | Male(n=20) | 0,71-1,93 | 1,38±0,34 | 1,34 | |

*STA* sacrum table angle, *STI* sacrum table index, *S1A* S1superior angle, *SS* sacral slope, *SH* sacrum height, *APCWHSA* anterior posterior canal width of hiatus sacralis apex, *LHS* length of the hiatus sacralis, *ICD* intercornual distance, min. minimum, max. maximum, show statistical signifcance (*) p<0.05, SD—standard deviation.

**Table 2.** Comparison of age and sacrum parameters according to healthy-spondylolisthesis group

| | Group | Min.-Max. | Mean±SD | Median | p |
|---|---|---|---|---|---|
| AGE | Healthy(n=135) | 20-92 | 48,65±16,32 | 47,0 | **<0,0001*** |
| | Spondylolisthesis(n=56) | 24-84 | 57,93±15,10 | 59,0 | |
| STA (°) | Healthy(n=135) | 79-120 | 94,8±7,24 | 95,0 | **<0,0001*** |
| | Spondylolisthesis(n=56) | 73-104 | 88,3±7,15 | 87,5 | |
| STI (%) | Healthy(n=135) | 81-11,5 | 97±0,63 | 0,97 | 0,083 |
| | Spondylolisthesis(n=56) | 85-12,1 | 99±0,84 | 0,99 | |
| S1A (°) | Healthy(n=135) | 1-24 | 12,39±4,75 | 12,0 | **<0,0001*** |
| | Spondylolisthesis(n=56) | 0-16 | 5,71±4,45 | 5,0 | |
| SS (°) | Healthy(n=135) | 18-64 | 41,26±8,90 | 41,0 | **<0,0001*** |
| | Spondylolisthesis(n=56) | 29-76 | 48,57±10,39 | 49,0 | |
| SH (cm) | Healthy(n=135) | 7,84-13,83 | 11,06±1,09 | 11,11 | **0,018*** |
| | Spondylolisthesis(n=56) | 7,68-13,49 | 10,62±1,29 | 10,76 | |
| APCWHSA (cm) | Healthy(n=135) | 0,12-1,30 | 0,55±0,20 | 0,53 | **0,002*** |
| | Spondylolisthesis(n=56) | 0-0,96 | 0,46±0,19 | 0,45 | |
| LHS (mm) | Healthy(n=135) | 11-52 | 29,32±9,06 | 29,0 | **0,005*** |
| | Spondylolisthesis(n=56) | 9-50 | 25,48±8,41 | 23,5 | |
| ICD (cm) | Healthy(n=135) | 0,66-2,06 | 1,42±0,28 | 1,43 | 0,168 |
| | Spondylolisthesis(n=56) | 0,70-1,93 | 1,36±0,30 | 1,35 | |

*STA* sacrum table angle, *STI* sacrum table index, *S1A* S1superior angle, *SS* sacral slope, *SH* sacrum height, *APCWHSA* anterior posterior canal width of hiatus sacralis apex, *LHS* length of the hiatus sacralis, *ICD* intercornual distance, min. minimum, max. maximum, show statistical signifcance (*) p<0,05, SD-standard deviation.

**Table 3.** Comparison of age and sacrum parameters according to grade 1 and grade 2.

| | Group (%) | Min.-Max. | Mean±SD | Median | p |
|---|---|---|---|---|---|
| AGE | Grade1 (n=39) | 24-84 | 57,74±15,78 | 59,0 | 0,748 |
| | Grade2 (n=17) | 26-78 | 58,35±13,87 | 59,0 | |
| STA | Grade1 (n=39) | 73-104 | 88,79±7,67 | 88,0 | 0,441 |
| | Grade2 (n=17) | 76-100 | 87,18±5,83 | 87,0 | |
| STI | Grade1 (n=39) | 0,85-1,21 | 0,99±0,082 | 0,98 | 0,482 |
| | Grade2 (n=17) | 0,85-1,16 | 0,98±0,088 | 0,97 | |
| S1A | Grade1 (n=39) | 0-16 | 6,41±4,45 | 5,0 | **0,045*** |
| | Grade2 (n=17) | 0-13 | 4,12±4,15 | 4,0 | |
| SS | Grade1 (n=39) | 29-69 | 48,44±9,58 | 49,0 | 0,884 |
| | Grade2 (n=17) | 29-76 | 48,88±12,38 | 49,0 | |
| SH | Grade1 (n=39) | 8,84-13,07 | 10,75±1,24 | 10,86 | 0,262 |
| | Grade2 (n=17) | 8,84-13,07 | 10,75±1,24 | 10,86 | |
| APCWHSA | Grade1 (n=39) | 0,15-0,96 | 0,48±0,19 | 0,45 | 0,216 |
| | Grade2 (n=17) | 0-0,82 | 0,41±0,19 | 0,39 | |
| LHS | Grade1 (n=39) | 12-50 | 25,61±8,73 | 22,0 | 0,721 |
| | Grade2 (n=17) | 9-42 | 25,18±7,86 | 24,0 | |
| ICD | Grade1 (n=39) | 0,70-1,93 | 1,33±0,30 | 1,30 | 0,235 |
| | Grade2 (n=17) | 0,73-1,90 | 1,43±0,30 | 1,44 | |

*STA* sacrum table angle, *STI* sacrum table index, *S1A* S1superior angle, *SS* sacral slope, *SH* sacrum height, *APCWHSA* anterior posterior canal width of hiatus sacralis apex, *LHS* length of the hiatus sacralis, *ICD* intercornual distance, min. minimum, max. maximum, show statistical signifcance (*) p<0.05, SD—standard deviation.

## DISCUSSION

Among the studies to understand the anatomy and relationships of the os sacrum, methods such as dry bone, radiography, and MDCT are used. Because MDCT provides high-resolution images, it is very effective in revealing the anthropometric features of the sacrum [14]. There is a lot of data in the literature on the relationship between other anatomical parameters and the prevalence of spondylolisthesis. This applies in particular to the parameters defining the morphology of the appendages and joint surfaces. This feature is crucial in maintaining the stability of the spine and the appropriate distribution of loads acting on its elements because facet joints are responsible for the transmission of 35% of the static load and 33% of the dynamic load affecting the spinal column [15].

Degenerative spondylolisthesis is seen after the age of 40 and mostly in women. It is considered one of the major causes of low back pain among the elderly and is a major cause of spinal canal stenosis associated with low back and leg pain [16]. Kong et al. [17] reported that the mean value of age was significantly higher in individuals with spondylolisthesis and that there was a positive correlation between age and spondylolisthesis. In our study, individuals between the ages of 20-92 were examined. Similar to this study, the mean age in the patient group (57.93±15.10) was found to be significanty higher than in the healthy group (48.65±16.32) (p<0.001). However, no significant difference was detected between genders. The STA parameter is among the descriptors of sacral morphology, and the difference in sacral morphology in patients with L5-S1 spondylolisthesis in the literature has increased the importance of STA. In the literature, it has been observed that the STA value decreases as the degree of spondylolisthesis slippage increases between spondylolisthesis and the control group, and it has been reported that lower STA value is an influential factor for disease progression and development [18].

Ergun et al. [19] study reported that STA was low in the degenerative spondylolisthesis group and reported that having a low STA parameter could be used to identify individuals with a tendency to develop degenerative spondylolisthesis. Sugawara et al. [20] STA of end-stage L5 spondylolysis (95.4 ± 1.5) was statistically significant lower than that of patients with low back pain (100.4 ± 0.8). We reported that STA was observed at a significantly higher angle in the healthy group (94.8±7.24˚)

than in the patient group (88.3±7.15˚). In our study, unlike the studies in the literature, no statistically significant difference was found in grade 2 compared to grade 1. This makes us think that STA is important in the development of spondylolisthesis but is not associated with its progression. Literature studies observed a strong correlation between pelvic incidence (PI) and STA. A high PI is seen in people with spondylolisthesis, and it has also been positively correlated with the percentage of slippage. It has been observed that STA is more closely related than PI in the development of spondylolysis and increased a decreased STA accompanies PI. In a cohort study, high PI was observed in people with spondylolisthesis, while a decrease in STA was observed [21,22].

Few studies are available in the literature for the STI parameter, one of the sacrum morphological evaluation parameters. The STI value is one of the parameters that help us understand the sagittal structure of the sacrum. Inoue et al. reported that STI was higher in people with spondylolisthesis (>102.5%) than in normal people (≤102%) [23]. However, another study reported that STI was higher in normal people (106±4%) than in people with spondylolisthesis (99±3%) [19]. In our study, the STI parameter was compared with the healthy and patient groups, and no significant difference was detected between them. However, the mean STI parameter was significantly higher in women (98±6.5%) than in men (96±5.9%) in the healthy group. We think this difference is due to the normal anatomical difference between the male and female pelvises. In addition, we think that STI may be important in gender determination. S1A, among the other important parameters we use to evaluate sacrum morphology, help define the sacrum sagittal structure. Marty et al. [9] showed that S1 and S2 vertebrae differ significantly in the adult population with spondylolisthesis. When Wang et al. [8] compared the spondylolisthesis group with the normal group on lateral radiographic images, it was found that the S1A value was lower in the spondylolisthesis group. In our study, similar to the literature, the mean of S1A in healthy individuals (12.39±4.75˚) was found statistically significant (p<0.001) higher than the mean of individuals with spondylolisthesis (5.71±4.45˚).

It was statistically significant lower in grade 2 than in grade 1 (p=.045). We think that the S1A value is important in the development and progression of spondylolisthesis. In people with spondylolisthesis, changes are observed in the SS, PI and PT angles as the pelvic positions change. It is thought that the increase in SS, PI and PT angles leads to the progression of spondylolisthesis and many spinal problems [24]. People with L5-S1 spondylolisthesis have an increased SS angle, which affects the progression of spondylolisthesis. In active young people, SS is an important cause of the development of isthmic spondylolysis. In a study of 37 people with spondylolysis and 37 people in a control group, radiographs were analyzed. This study, which consisted of active young people in both groups, found that the SS angle was statistically 5° larger in the group with spondylolysis [25]. In our study, the SS value was found statistically significant higher in people with spondylolisthesis, which is consistent with the literature study (p<0.001). In the literature, the relationship of PI, PT, and SS spinopelvic parameters between age and gender was examined, but no relationship was found between men and women. In the literature, no statistically significant difference has been found between age and gender in PI, PT and SS parameters in normal adult individuals [26,27].

Our study showed no significant difference between the genders in the SS value in the healthy and patient groups. We reported that the mean SS was found to be significantly higher in the spondylolisthesis patient group. (p=.000). Labella et al. [28] grouped the degree of spondylolisthesis according to Newman's grades I and IV and found that PI, PT and SS mean values increased as the grade increased. Unlike Labella et al. [28] no statistically significant difference was found between grade 1 and grade 2 of spondylolisthesis in our study. In some studies in the literature, no statistically significant difference was found between grades in the SS mean value measured according to Meyerding in spondylolisthesis grading [29-31].

In our study, the grade was classified according to Meyerding, and the mean SS value was not statistically significant between grade 1 and grade 2 (p=.884). However, the S1A parameter was found statistically significant higher than Grade 1 (p=.045). It was concluded that as the spondylolisthesis grade increased, the SS value was not affected, but the S1A value decreased. In addition, previous studies on normal subjects have reported a strong correlation between PI and SS [32,33]. In the MDCT studies conducted in the literature, the mean SH of men and women were higher than in the dry bone studies. In all studies, men's mean SH value was higher than women's [34,35].

In our study, SH value of healthy individuals was found statistically significant higher in males (11.30±1.02cm) than in females (10.80±1.12cm) (p=.007). The SH mean value of healthy individuals was statistically significant higher than those with spondylolisthesis (p=.018). This study was determined that SH was lower in patients with spondylolisthesis and women (within the healthy group). We think that low SH is an important factor for the development of spondylolisthesis, but it is not associated with the progression of the disease. Caudal epidural block is widely used in diagnosing and treating lumbar spinal disorders in the orthopedic field [36]. It may become complicated by weight gain, advancing age, and congenital and shape variations in the sacrum. Therefore, reaching the epidural space for a safe caudal epidural block is possible by knowing well the anatomical structure of the SH. In this application, the depth of the sacral canal at the apex and the intercornual distance are the most frequently used anatomical landmarks and require good anatomical knowledge of this region [13].

In the literature, LHS, APCWHSA, and ICD measurements were made on MDCT, (Ultrasonography) USG, and dry bone [37,38]. The literature found that the mean values of LHS and APCWHSA decreased with age while the mean value of ICD increased. In MDCT and dry bone studies, the mean value of LHS in men was higher than in women. In MDCT studies, the mean value of APCWHSA was similar in men and women, and it was higher in men in studies conducted with USG. In studies conducted in MDCT, the mean value of male and female ICD was found to be lower than in studies performed with USG [39-41]. We think that the differences seen in USG-guided interventions should be taken into consideration. This study observed that LHS was similar to studies in the literature. LHS in the healthy group (29.32±9.06 mm) was found statistically significant higher than the mean value of the patient group (25.48±8.41mm) (p=.005). In healthy individuals, LHS was statistically significantly higher in men (p=.078). We think that the differences in LHS may be related to the similarity to the differences in SH (lower in women and the group with spondylolisthesis). It is reported in the literature that the average anterior-posterior diameter of APCWHSA varies between 4.6 ± 2 mm and 6.1 ± 2.1 mm, and the diameter decreases with age. It has been reported that this diameter is less than 3.7 mm at the apex in the procedure of needle insertion into the caudal epidural space, and less than 1.6 mm in the case of USG. It has been said that this attempt cannot be made in the variant where the hiatus sacralis is completely closed. The incidence of this variation has been reported as 2-3% in dry sacral bone studies [42].

In our study, APCWHSA in the healthy group (5.5±2 mm) was found to be significantly higher than the mean value of the patient group (4.6±1.9mm) (p=.002). The mean APCWHSA value was statistically insignificant higher in healthy male subjects than in female subjects (p=.476). In our study, ICD in healthy women was statistically significant higher than in men (p=.010). In the patient group with spondylolisthesis, there was no statistically significant difference in the mean value of ICD in men and women. No significant difference was detected between the spondylolisthesis and healthy groups (p=.168).

### Limitations

In our study, we could not find the opportunity to measure and evaluate PI and PT angles, which are important for sagittal spinopelvic balance, due to the technique we chose. In addition, since our study was a retrospective study, we could not evaluate important information such as body mass indexes, occupations, and sports activities of individuals in our groups. For these reasons, we aim to conduct prospective studies that will include PI and PT parameters in our future studies.

## CONCLUSIONS

In conclusion, the mean age value was statistically significantly higher in the patient group. This result shows that the likelihood of spondyloisthesis increases with increasing age. The results obtained in this study demonstrated that sacrum morphology is important in the development of spondylolisthesis and spinal sagittal balance of the spine. As seen in previous studies, decreased STA, one of the important morphologic parameters of the sacrum, is effective in the development of spondylolisthesis and the likelihood of this disease is high. We think that a prospective and longitudinal study should be done to demonstrate this recommendation. A good knowledge of the changes in the normal anatomy of the sacrum is very important in terms of preventing complications in interventions to be performed in patients with spondylolisthesis. For this reason, we think that studies on patient groups with altered sacrum anatomy such as spondylolisthesis should be increased and the changes in the anatomical structure should be fully revealed.

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