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Radiologic and morphologic evaluation of the lateral sacral mass

Lateral sakral kitlenin morfolojik ve radyolojik değerlendirilmesi

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Amaç: İliosakral vida uygulamalarında bölgenin yeterliliğini değerlendirmek için, kuru sakrum kemik örneklerinde, lateral sakral kitle (LSK) ve komşulukları morfolojik ve bilgisayarlı tomografi (BT) kesitlerinde radyolojik ölçümlerle incelendi.

Çalışma planı: Otuz adet kuru sakrum kemik örneğinde LSK'nin morfolojik ölçümleri, milimetre duyarlı kompas kullanılarak yapıldı. Aynı kemiklerin S_1 ve S_2 pedikül-cisim ve intervertebral foramina hizalarında çekilen BT kesitlerinde, LSK'nin nöral kanal ve intervertebral foramina ile ilişkisi milimetre duyarlılığındaki cetvel ile ölçülerek değerlendirildi.

Sonuçlar: Lateral sakral kitlenin posterior yüzdeki genişliği, sağda S_1 düzeyinde 24.1 mm, S_2 düzeyinde 18.4 mm, solda S_1 düzeyinde 24.5 mm, S_2 düzeyinde 18.8 mm; anterior yüzdeki genişliği sağda S_1 düzeyinde 28.9 mm, S_2 düzeyinde 22.6 mm, solda S_1 düzeyinde 29.1 mm, S_2 düzeyinde 23 mm; postero-lateral yerleşimli (oblik) yüksekliği sağda S_1 düzeyinde 39 mm, S_2 düzeyinde 28.6 mm; solda S_1 düzeyinde 37.4 mm S_2 düzeyinde 27.6 mm ölçüldü. Sakral ala'nın derinliği sağda ortalama 50.6 mm, solda 50.7 mm; posterior yüksekliği sağda ve solda ortalama 26 mm bulundu. Radyolojik değerlendirmede, S_1 pedikül-cisim seviyesinde pedikül+sakral ala'nın ortalama genişliği sağda 37.6 mm, solda 36.3 mm; LSK'nin S_1 intervertebral foramina seviyesindeki genişliği sağda 22 mm, solda 22.3 mm; S_2 pedikül-cisim seviyesinde pedikül+LSK'nin ortalama genişliği sağda 27.8 mm, solda 26.4 mm; S_2 intervertebral foramina seviyesinde LSK'nin ortalama genişliği sağda 15.9 mm, solda 16.3 mm bulundu.

Çıkarımlar: Ameliyat öncesinde yapılacak BT incelemeleriyle LSK'nin büyüklüğü belirlendikten sonra, özellikle S_1 pedikül-cisim düzeyinde ve sakral nöral kanal ve intervertebral foramina lateralinde kalacak şekilde, nöral doku ve çevre yapılara zarar vermeden iliosakral vida uygulanabilir.

Anahtar sözcükler: Kemik vidaları; kadavra; ilium/anatomi ve histoloji; sakroiliak eklem/anatomi ve histoloji; sakrum/anatomi ve histoloji/radyografi/cerrahi; bilgisayarlı tomografi.

Objectives: Morphologic measurements of the lateral sacral mass (LSM) and adjacent bone structures were made on dried sacrum specimens, together with radiologic evaluations on computed tomography (CT) scans in order to assess the appropriateness of this area in iliosacral screw applications.

Methods: On thirty dried human sacral bone specimens, morphologic measurements of the LSM were made by a compass sensitive to millimeters. Computed tomographic views of S_1 and S_2 pedicle-bodies and intervertebral foramina were obtained to make radiologic measurements by a millimeter-sensitive ruler to examine the relationship between LSM and the neural canal and intervertebral foramina.

Results: The average widths of the LSM on the posterior and anterior surfaces of the sacrum were as follows. Posterior aspect: 24.1 mm on S_1, 18.4 mm on S_2 levels on the right; 24.5 mm on S_1 and 18.8 mm on S_2 levels on the left. Anterior aspect: 28.9 mm on S_1, 22.6 mm on S_2 levels on the right; 29.1 mm on S_1 and 23 mm on S_2 levels on the left. The average (oblique) heights of LSM on the postero-lateral surface were 39 mm on S_1, 28.6 mm on S_2 levels on the right; 37.4 mm on S_1, 27.6 mm on S_2 levels on the left. The average depth of the sacral ala was 50.6 mm on the right, 50.7 mm on the left. The average posterior alar height was 26 mm on both sides. On CT scans, the average widths of pedicle+sacral ala were measured as 37.6 mm (right) and 36.3 mm (left) at the S_1 pedicle-body level. The average widths of LSM were 22 mm (right) and 22.3 mm (left) at the S_1 intervertebral foramina level. The average widths of pedicle+LSM were 27.8 mm (right) and 26.4 mm (left) at the S_2 pedicle-body level. The average widths of LSM at the S_2 intervertebral foramina level were 15.9 mm (right) and 16.3 mm (left).

Conclusion: Our results suggest that iliosacral screw fixation may be more safely performed, especially at the S_1 pedicle-body level and lateral to the sacral neural canal and intervertebral foramina. Injury to the neural tissues and surrounding structures is more unlikely if preoperative measurements of LSM are made on CT scans.

Key words: Bone screws; cadaver; ilium/anatomy & histology; sacroiliac joint/anatomy & histology; sacrum/anatomy & histology/radiography/surgery; tomography, X-ray computed.

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Sacrum is an important bony structure included in fusion and/or stabilization area of treatments of lumbosacral, sacral and sacroiliac deformities or their traumatic lesions.[1-10] Fairly complicated anatomic structure of sacrum consists of 5 sacral vertebrae, 4 pairs of intervertebral foramina and a pair of lateral sacral mass.[11-13] Lateral sacral mass (LSM) (known as pars lateralis) which is located on the lateral part of intervertebral foramina consists of the fusion of costal elements and transverse processes. The greater lateral sacral mass of 1st sacral vertebra (S_1) is named as sacral ala. [13,14] The postero-superior sacral alar region is sloped (inclined) to lateral and superior and the antero-superior sacral alar region is sloped to inferior. On the coronal plane there is an average angle of 27.1° between the transverse axis of S_1 sacral body and the anterior aspect (edge) of the sacral ala.[15] The lateral part of the lateral sacral mass is seen as a triangle and consists of anteriorly located intra-articular (facies auricularis ossis sacri) and posteriorly located extra-articular (tuberositas sacralis) parts. The outer parts of the uppermost 2 or 3 sacral vertebrae constitute the auricular surface and articulates with the ilium on both sides (Figures 1, 2, 3 and 4). [11-13]

Bone screws can be inserted transpedicularly from posterior of sacrum to promontorium as well as to lateral sacral mass by laterally inclining.[11,16,17] Iliosacral applications of the screws can be directly inserted to sacral ala or through sacral ala to vertebral body.[10,13,18] There are authors who suggest long screw use or bicortical (transcortical) screw applications,[2,18,19] do not find the bony structure of sacrum qualified.[2,5,13] But neurovascular and visceral trauma may develop especially in bicortical screw fixations because of their neighborhood to the sacrum anteriorly. [5,11,15,17,20] Some of the authors [1-10] reported that it's much safer to insert screws to LSM in the application of iliosacral screws and some anatomic studies have been done about this subject. [13,21,22]

In our study, morphologic measurements of LSM in 30 dried sacral bone specimens were evaluated. The association between the sacral neural canal and intervertebral foramina was evaluated in the computed tomographic (CT) scans of S_1 and S_2 pedicle-body and intervertebral foramina levels of the same bones.

Methods

LSM and adjacent structures were evaluated on 30 dried sacral bone specimens obtained from Anatomy Departments of Inonu and Firat Medical Faculties. Besides, LSM is radiologically evaluated on CT scans of S_1 and S_2 pedicle-body and intervertebral foramina levels. Measurements on dried bone specimens were assessed by millimeter sensitive compass (callipers) and on CT scan evaluation by millimeter magnifying ruler. Age and sex differentiation of the dried bone specimens could not made. All symmetric structures measured bilaterally. An anatomist took measurements, by determination of the reference points (landmarks).

Sacral width (sacral breadth), sacral height, S1 body width (transvers diameter of S_1 body), S_1 pedicular depth, sacral alar depth, the posterior height of the sacral ala, the width of LSM on its posterior surface, the width of LSM on its anterior surface, oblique height of inclined (sloped) posterolateral surface of LSM and the measurements of articular surface (fascies auricularis) were assessed as anatomic parameters.

Sacral width (SW) "sacral breadth (SB)" is measured on transverse (horizontal) plane as the distance between far most points of the sacral ala neighboring sacroiliac joints on the anterosuperior surface (Fig.1). [23]

Sacral height (SH) is measured as the vertical distance from the midline of promontorium on the ventral

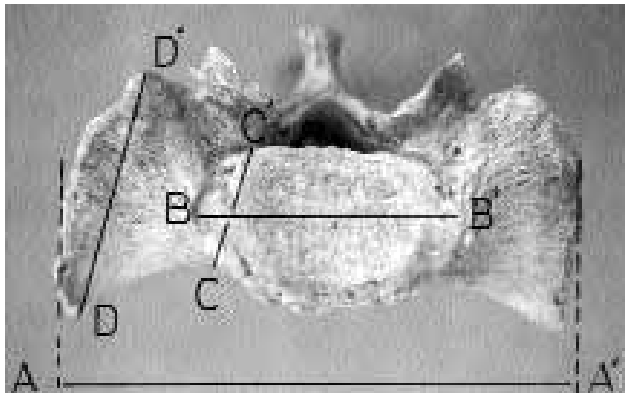

Figure 1. The superior (cephalad) view of S_1 body and sacral ala. Sacral width (A-A'), S_1 body width (B-B'), S_1 pedicle depth (C-C') and sacral alar depth (D-D').

surface (upper edge midline of S_1) to sacrococcygeal joint (Fig. 2).

The width of S_1 body (S_1-BW) "transverse diameter of S_1 body" is measured as the far most points of the superior surface on transverse (horizontal) plane (Fig.1). [23,24]

The depth of S_1 pedicle "S_1 pedicular depth" (S_1-PD) was measured as the distance between anterior and posterior borders of the pedicle on the narrowest part (Fig.1).[18,24]

The depth of sacral ala "sacral alar depth" (SAD) was measured as the distance between the anterior and posterior borders of the sacral ala neighboring to sacroiliac joint (Fig.1).[18]

The posterior height of sacral ala "posterior sacral alar height" (PSAH) is measured as the distance from the uppermost point of the sacral ala neighboring sacroiliac joint on the dorsal surface to the upper border of first sacral foramina (Fig. 3)).[18]

The width of LSM on posterior surface is measured as the distance between the mid points of foramina lateral walls on S_1 and S_2 intervertebral foramina levels and the posterior border of the articular surface on the same horizontal direction, on the dorsal surface of the sacrum (Fig. 3).

The width of LSM on anterior surface is measured as the distance between the lateral walls of the foramina in the direction of transverse line (linea transversalis), on S_1 and S_2 intervertebral foramina levels and the anterior border of the articular surface on the same horizontal direction, on the ventral surface of the sacrum (Fig. 2).

"The oblique height of inclined (sloped) posterolateral surface" of LSM is measured as the greatest distance between the midpoints of the lateral walls of S_1, S_2 and S_3 intervertebral foramina on the dorsal surface of sacrum and the articular surfaces in the same direction on the horizontal plane and also in the direction of LSM slope. The elongation of the short arm forming articular surface, through sacral ala to posterior and superior was matching with the depth of sacral ala (Fig. 4a).

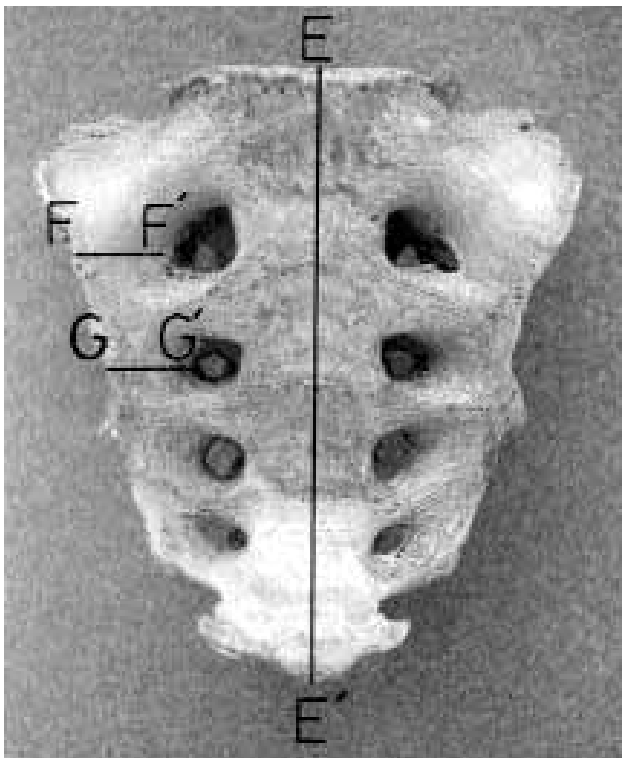

Figure 2. The anterior (ventral) view of sacrum. Height of sacrum (E-E'), width of LSM in the anterior surface in S_1 intervertebral foramina level (F-F') and at S_2 intervertebral foramina level (G-G').

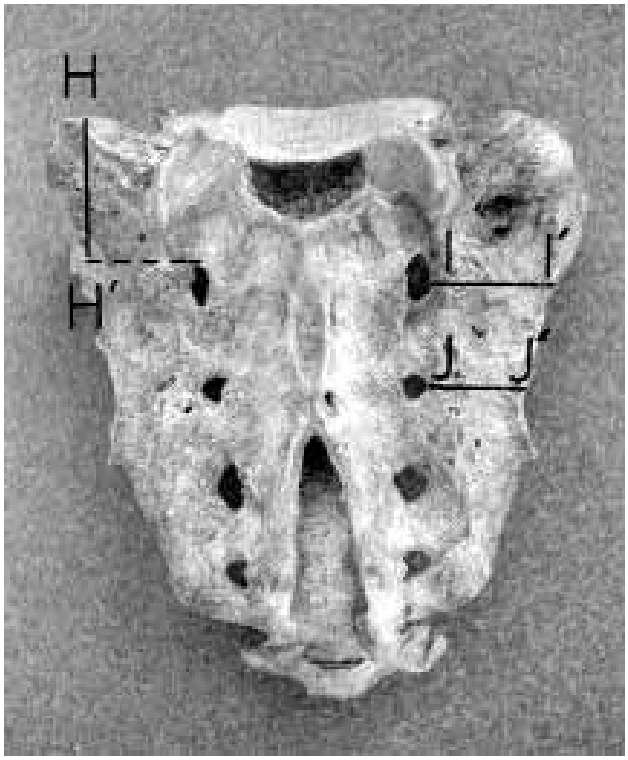

Figure 3. The posterior (dorsal) view of sacrum. Posterior height of sacral ala (H-H'), width of LSM in the posterior surface in S_1 intervertebral foramina level (I-I') and at S_2 intervertebral foramina level (J-J').

The values of articular surface (facies auricularis), the lengths of the long arm parallel to long axis of sacrum, the short arm parallel to sacral ala, and oblique arm joining them are measured (Fig. 4b)

Statistical Evaluation: SPSS 7.5 software program was used in the evaluation of the calculations and Pentium II 800 processor Computer was utilized. Descriptive statistic test was used to determine medians and standard deviation slope values. T-test of doubled specimens was used as left-right comparison in bilaterally measured symmetric structures. If the values found are at <0.005 level they are accepted as significant.

Results

Morphologic Evaluation

The following values are found as mean value±standard deviation (min. and max. limits) for the measurements of anatomic dried sacrum bones. (Tables 1, 2 and 3).

- The width of sacrum 110.3±5.5 mm (range 100-121 mm);

- The height of sacrum 105.7±11.4 mm (range 78-124 mm);

- The width of S1 body 51.1±5.1 mm (range 41-62 mm);

- The depth of S1 pedicle: 23.4±2.5 mm (range 18-28 mm) on the right, 24±2.6 mm (range 17-29 mm) on the left;

- The depth of sacral ala (sacral alar depth): 50.6±5.6 mm (range 41-60 mm) on the right, 50.7±4.6 mm (range 41-60 mm) on the left;

- The posterior height of sacral ala: 26±4 mm (range 17-32 mm) on the right, 26±3.7 mm (range 17-33 mm) on the left;

- The width of LSM on posterior surface: 24.1±3.5 mm (range 16-29 mm) in S_1 level and 18.4±2.1 mm (range 14-22 mm) in S_2 level on the right; 24.5±3.6 mm (range 15-33 mm) in S_1 level and 18.8±2.5 mm (range 12-23 mm) in S_2 level on the left;

- The width of LSM on anterior surface: 28.9±3.9 mm (range 22-37 mm) in S_1 level and 22.6±4.1 mm (range 15-29 mm) in S_2 level on the right; 29.1±4.3 mm (range 22-38 mm) in S_1 level and 23±3.7 mm (range 16-30 mm) in S_2 level on the left;

- "The oblique height of inclined (sloped) posterolateral surface" of LSM: 39±5 mm (range 30-48 mm) in S_1 level, 28.6±5 mm (range 18-40 mm) in S_2 level and 17.5±3.7 mm (range 10-26 mm) in S_3 level on the right; 37.4±5.1 mm (range 28-48 mm) in S_1 level, 27.6±3.8 mm (range 18-33 mm) in S2 level and 16.1±3 mm (range 8-22 mm) in S_3 level on the left;

- Value of the articular surface (facies auricularis): 33.8±6 mm (range 23-46 mm) in short arm, 48.3±5.9 mm (range 33-59) in long arm and 56.7±4.9 mm (range 47-67 mm) in oblique arm on the right; 33.2±4.5 mm (range 24-42 mm) in short arm, 47±5.7 mm (range 38-58) in long arm; 55.4±5.2 mm (range 48-68 mm) in oblique arm on the left.

When bilateral structures evaluated by the t-test of

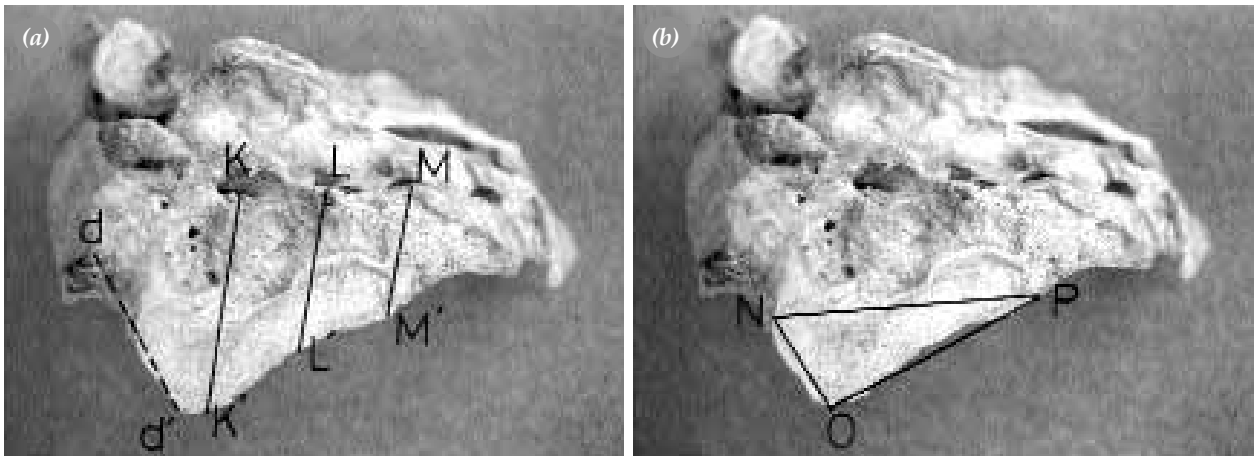

Figure 4. The view of lateral sacral mass. **(a)** Height of LSM at the levels of S_1 (K-K'), S_2 (L-L') and S_3 (M-M') and depth of sacral ala shown with dashed line (d-d'). **(b)** Measurement of the articular surface (facies auricularis): short arm (N-O), long arm (O-P) and oblique arm (N-P).

Table 1. The values of width of sacrum, height of sacrum, width of S_1 body, depth of S_1 pedicle, depth of sacral ala, posterior height of sacral ala in milimeters

		Mean value	Minimum	Maximum	Standart deviation
Width of sacrum		110.3	100	121	5.5
Height of sacrum		105.7	78	124	11.4
Width of S1 body		51.1	41	62	5.1
Depth of S1 pedicle	Right side	23.4	18	28	2.5
	Left side	24	17	29	2.6
Depth of sacral ala	Right side	50.6	41	60	5.6
	Left side	50.7	41	60	4.6
Posterior height of	Right side	26	17	32	4
sacral ala	Left side	26	17	33	3.7

Table 2. The values of of lateral sacral mass; width of posterior surface and anterior surface, oblique height of posterolateral surface on milimeters

			Mean value	Minimum	Maximum	Standard deviation
Width of posterior surface	Right side	S_1	24.1	16	29	3.5
		S_2	18.4	14	22	2.1
	Left side	S_1	24.5	15	33	3.6
		S_2	18.8	12	23	2.5
Width of anterior surface	Right side	S_1	28.9	22	37	3.9
		S_2	22.6	15	29	4.1
	Left side	S_1	29.1	22	38	4.3
		S_2	23	16	30	3.7
Oblique height of	Right side	S_1	39	30	48	5
posterolateral surface		S_2	28.6	18	40	5
		S_3	17.5	10	26	3.7
	Left side	S_1	37.4	28	48	5.1
		S_2	27.6	18	33	3.8
		S_3	16.1	8	22	3

doubled specimens, pedicular depth (p=0.003) and height of LSM in S_1 and S_2 (p=0.003 and p=0.001 in order) showed significance; while the other values calculated between 0.008 and 0.952 showed no significance.

Radiologic Evaluation

The axial CT scans of morphologically evaluated 30 dried sacrum bone specimens was performed on S_1 and S_2 pedicle body and intervertebral foramina levels. Cross section were performed as paralel to

Table 3. Values of articular surfaces (facies auricularis) in millimeters

		Mean value	Minimum	Maximum	Standard deviation
Short arm	Right side	33.8	23	46	6
	Left side	33.3	24	42	4.5
Long arm	Right side	48.3	33	59	5.9
	Left side	47	38	58	5.7
Oblique arm	Right side	56.7	47	67	4.9
	Left side	55.4	48	68	5.2

superior surface of S_1 (end plate) as possible.

The width of pedicle and LSM surrounding the neural canal is measured on millimeters on the horizontal line that connects the widest points that extends through anterior in the cross sections of CT in the level of S_1 and S_2 pedicles-bodies (Fig. 5a and c). "LSM-IVF that fits to S_1 or S_2 parts-IVF-LSM" is measured on millimeters on the horizontal line that connects neighboring anterior edges (limits), in S_1 and S_2 IVF (intervertebral foramina) levels (Fig. 5b and d). Measurements are evaluated as mean value±standard deviations (min. and max. limits) (Tables 4 and 5).

In the level of S_1 pedicle-body, the width of pedicle+LSM was found 37.6±4.2 mm (range 27-46 mm) on the right, 36.3±4.2 mm (range 26-41 mm) on the left; the width of neural canal was found 31.7 ±4.3 mm (range 23-38 mm). In the level of S_1 intervertebral foramina, the width of LSM was 22±3.8 mm (range 15-31 mm) on the right, 22.3±5.2 mm (range 14-31 mm) on the left; the width of intervertebral foramen was 13.4±2.7 mm (range 7-19 mm) on the right, 13.2±2.6 mm (range 9-19 mm) on the left; the width of S_1 body was 35.5±5.4 mm (range 28-50 mm).

In the level of S_2 pedicle and body, pedicle+LSM width is measured as 27.8±6.9 mm (range 17-40 mm) on the right, 26.4±6.4 mm (range 17-40 mm) on the left; the width of neural canal 29.8±5 mm (range 22-40 mm).

In the level of S_2 intervertebral foramina, the width of LSM was found average of 15.9±3.1 mm (range 10-22 mm) on the right, and average of 16.3±4.3 mm (range 9-25 mm) on the left; the width of intervertebral foramen was found average of 16.2±2.9 mm (range 10-22 mm) on the right, average of 15.9±3.4 on the left; the width of S2 body was found average of 32.8±4.7 mm (range 25-46 mm).

When bilateral structures were evaluated by the t-test of doubled specimens, it's seen that all values had shown a distribution between 0.085 and 0.725 ($p>0.005$).

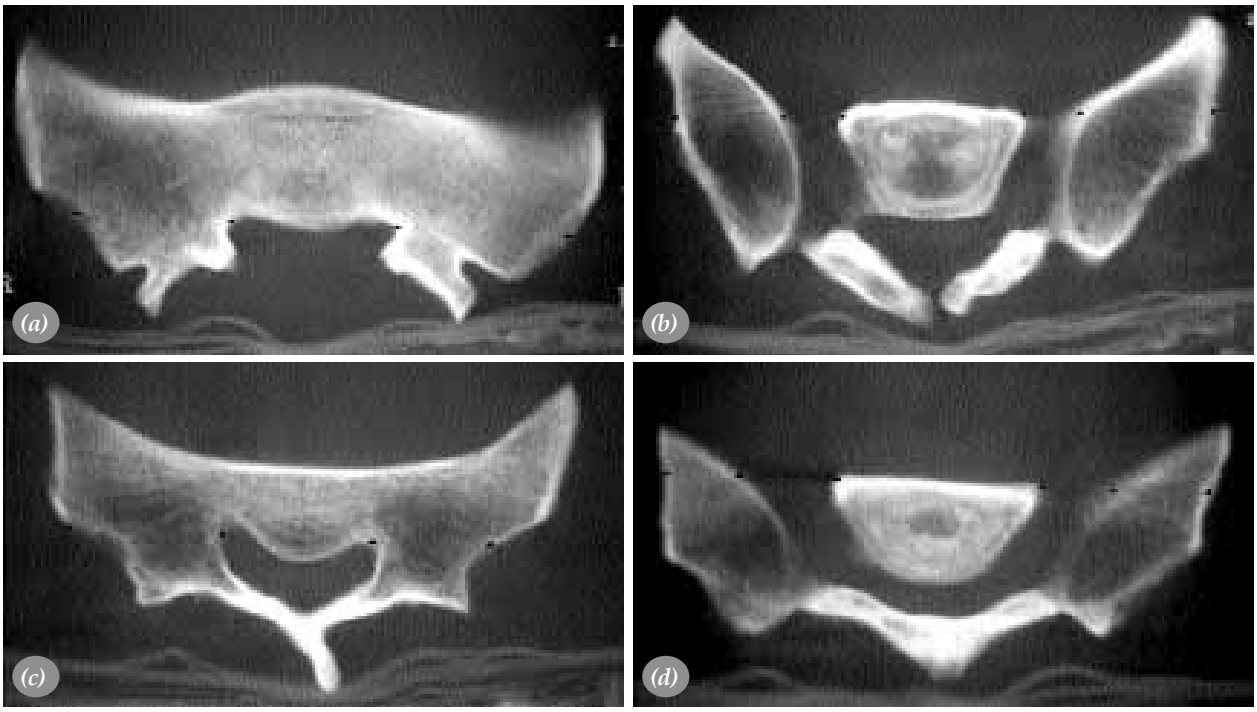

Figure 5. In the cross sections of CT; **(a)** the view of lateral sacral masses on both sides and neural canal in the center of the cross section at S_1 pedicle-body level, **(b)** the view of "LSM-IVF- S_1 corpus-IVF-LSM" in the cross section at S_1 intervertebral foramina/foramen level, **(c)** the view of S_2 pedicle and LSM on both sides and neural canal in the center of the cross section at S_2 pedicle-body level, **(d)** the view of "LSM-IVF- S_2 corpus-IVF-LSM" in the cross section at S_2 intervertebral foramina/foramen (IVF) level.

Table 4. The values found in the measurements of S_1 pedicle-body and intervertebral foramina levels on CT cross section in millimeters

		Mean Value	Minimum	Maximum	Standard deviation
Pedicle-body level					
Width of pedicle-lateral sacral mass	Right Side	37.6	27	46	4.2
	Left Side	36.3	26	41	4.2
Width of neural canal		31.7	23	38	4.3
Intervertebral foramina level					
Width of lateral sacral mass	Right Side	22	15	31	3.8
	Left Side	22.3	14	31	5.2
Width of intervertebral foramina	Right Side	13.4	7	19	2.7
	Left Side	13.2	9	19	2.6
	Width of S_1 body	35.5	28	50	5.4

Table 5. The values found in the measurements of S_2 pedicle-body and intervertebral foramina levels on CT cross section in millimetres

		Mean Value	Minimum	Maximum	Standard deviation
Pedicle-body level					
Width of pedicle-lateral sacral mass	Right Side	27.8	17	40	6.9
	Left Side	26.4	17	40	6.4
Width of neural canal		29.8	22	40	5
Intervertebral foramina level					
Width of lateral sacral mass	Right Side	15.9	10	22	3.1
	Left Side	16.3	9	25	4.3
Width of intervertebral foramina	Right Side	16.2	10	22	2.9
	Sol taraf	15.9	7	22	3.4
	Width of S_2 body	32.8	25	46	4.7

Discussion

The posterior iliosacral screw fixation is a method performed on the treatment of lumbosacral deformities, displaced sacral fractures and traumatic sacroiliac dislocations.[2,3,7-10] Instrumented fusion and stabilization, which extend to sacrum, may be necessary in degenerative diseases of the low (inferior) lumbar region whether there is a deformity or not. [2,4-6,18,24] Several biomechanical studies have been performed about target application point of screw and the depth of screw in the stabilization of lumbosacral or iliosacral fixations. Some authors [2,25,26] found the bone stock and strength of the sacral ala and LSM inadequate and suggested to direct the screw to the vertebral body instead; however some other authors [1,4-6,10,13,21-23] stated that application of screw or other systems to LSM can provide adequate fixation and carry less complication risk. Neurovascular and visceral trauma can occur especially in bicortical screw applications to sacrum because of their neighborhood in the anterior zone (region).[5,11,15,17,20] Borrelli et al. [1] and Tile [10] reported that LSM is safer zone in screw application about neurovascular structures and visceral trauma. Asher and Strippgen [23] have developed the posterior transsacral implant, which is fixated by the long screws extend from the zone between the 1st and 2nd dorsal intervertebral foramina to LSM on the posterior part of sacrum. McCarthy et al.[6] reported that they have used sacral ala by giving a special bending (inclination) to the bottom ends of Luque rods that fits to sacrum. Cecil et al. [22] stated that the fixation by a 6.5 mm diameter cancellous screw from posterolateral ilium to sacral ala or S1 vertebral body is adequate for interfragmentary injury of sacroiliac joint. Jackson et al.

[4,5] applied intra-sacral rod to inside of LSM and defined it as "iliac buttressing". They determined the measuring values of LSM and sacroiliac interosseous angles by examining sacrum and sacroiliac joint on CT scan.[5] Consequently they stated that a 7 mm diameter Cotrel rod or an implant (intra-sacral rod) in the same size can be applied in the cases where the minimum distance between posteromedial border of sacroiliac joint and lateral border of S_1 intervertebral foramina (on CT scan cross section) is 17 mm (average of 28 mm). [4,5] We evaluated the size of LSM in dried bone specimens by taking into account of these studies which inform the adequacy and reliability of LSM.

By defining the projection area of LSM on posterior ilium, studies about iliosacral screw application has done from this area.[13,21] Xu et al. [13] defined this area as an isosceles triangle with average height of 61.4 mm, and average base width of 56.8 mm. And they reported that the screws inserted on the line from mid point of base to triangle vertex in the projection zone of this area on posterior ilium, would not damage the important structures especially in the anterior surface. They also reported that, because the inferior zone of the triangle base includes completely intraarticular compartment and some part of extraarticular compartment of LSM; the screws that would inserted from iliac wing to this area on the frontal plane (because of the concavity of sacral ala), should be applied on horizontal plane. The superior half that fits to triangle vertex, which also fits to extraarticular area of LSM commonly, is a safe zone for screw applications in multiple directions.[13] In an analogous study by dried bone specimens, Esenkaya [21] stated that screws can be applied without damaging the neurovascular and important structures via a plate embedded to the lateral intervertebral foramina and sacral neural canal in S_1 and S_2 levels on the projection zone of LSM in posterior ilium.[21] But there are things that should be kept in mind even if an iliosacral screw application from this safe point and areas. Xu et al.[13] and Mirkovic[14] reported that because of the concavity of sacrum in the anterior side the screw applications from the anterior part can damage the intrapelvic structures in the anterior of sacrum more in comparison with the projection of LSM in the posterior iliac wing. And Mirkovic also stated that the projection of the superior part on iliac wing fits to extraarticular area of the LSM; screws inserted to this area have high mobility and an adequate stability may not be provided.[14] When an iliosacral screw application to LSM is thought, it would be useful to know the size of this mass, to prevent the possible complications. Consequently we evaluated LSM and its neighborhood on dried bone specimens morphologically and radiologically on cross sections of CT scan.

Ebraheim et al.[18] has found the pedicular depth average of 27.8 mm (range 24-32 mm), the posterior alar height average of 28.7 mm (range 20-37 mm), and sacral alar depth average of 45.8 mm (range 43-48 mm) in the anatomic study performed on adult pelvis cadavers. In our study, we have found these values as; the depth of pedicle average of 23.4 mm (range 18-28 mm) on the right, average of 24 mm (range 17-29 mm) on the left; the posterior height of sacral ala average of 26 mm (range 17-32 mm) on the right, average of 26 mm (range 17-33 mm) on the left; the depth of sacral ala average of 50.6 mm (range 41-60 mm) on the right and average of 50.7 mm (range 41-60 mm) on the left. However it was impossible to mark the accepted reference measuring points (landmarks) of the bone specimens without damaging by a dotted or pointed metal or an opaque object while we were making an anatomic evaluation on sacrum bone specimens, so cross sectioning of the same points was impossible on CT scans too, consequently a compared study could not be done between the morphologic and radiologic measurement values. We have thought that besides the anatomic variations, the numerical differences between the left and right sides of the dried bone specimens should be related with the abrasion (wearing and tearing) on the surface, corners or end points by the time. We also thought that with the differences between left and right sides on CT cross section scans, lesser differences are related with the less abrasion on these cross section scans, extraction from deeper areas and measurements on the horizontal line which is obtained by connection of determined reference points.

Cecil et al.[22], have found the distance, in the screw application to anterior at 60°, from the outer cortex on posterolateral ilium in S_2 level, to the lateral border of S_2 intervertebral foramen average of 55.2 mm (range 49.5-60 mm). In our study, since

only sacrum is evaluated, we have found the distance between the lateral wall border of neural canal and facies auricularis as average of 28.9 mm on the right and 29.1 mm on the left in anterior at S_1 level; average of 24.1 mm on the right and 24.5 on the left in posterior at S_1 level; average of 22.6 mm on the right and 23 mm on the left in anterior at S_2 level; average of 18.4 mm on the right and 18.7 mm on the left in posterior at S_2 level. In our study on CT cross sections we have observed LSM is widest especially at the level of S_1 pedicle-body; the size of LSM diminishes as it gets closer to S_1 intervertebral foramina; the distance between the lateral cortex of LSM and the lateral wall of neural canal diminishes on the sections that pass from the middle of S_1 intervertebral foramina; LSM re-widens because of its connection with the vertebral body at S_2 level; but the distance between the lateral cortex of LSM and the lateral wall of intervertebral foramen further decreases (it almost transforms to transverse process and costal structures as it once embriologically oriented) at the S_2 intervertebral foramina level (Fig. 5).

Zindrick et al.[19], in one of the biomechanic studies to investigate the effect of the applied screw depth on stability, reported that the screws inserted to the sacral ala with 45 degrees to lateral have the strongest pull-out test; the screws inserted to S_1 pedicle follows it; and the third is the screws directly inserted to sacral ala with 0 degrees; and the screws applied on S_2 pedicle have the worst pull-out values. Same authors also noted according to the biomechanic study they performed with 4.5 mm cortical and 6.5 mm full-threaded cancellous screws, that there is no significant difference in the stability of the screws which inserted to a depth 50% of vertebral body diameter and to anterior cortex yet non-transcortical; transcortical screws inserted to the anterior cortex stabilize a significantly strong structure in comparison with the non-transcortical ones; cancellous screws that inserted to the anterior cortex provide better purchase in according to cortical screw in the cancellous bone.[19] Taking into account of the screw applications (that stay inside the LSM laterally to sacral foramina) of Xu et al.[13] and Cecil et al.[22] and intra-sacral rod application (to LSM lateral to the sacral foramina) results of Jackson et al.[4,5]; we consider that LSM, especially sacral ala that fits to S_1 level can be chosen as screw application zone. Because the distance between the neural canal or lateral wall of intervertebral foramina and outer wall of the iliac wing in the same level can show variability, appropriate size of screw and direction and/or angle of screw insertion can be determined by pre-operative CT cross sections.

Although it is stated that because of the inadequate bone quality of sacral ala, screws applied to this area does not provide stabilization in adequate tightness in some studies, [2,3,13,18,19,25,26] there are also studies against this.[1,4-6,10,13,21-23] Determination of the trabecular bone structure of this zone and required measurements in the views that include sacroiliac area is done with the help of pre-operative CT cross section scans. After that procedure, especially in iliosacral screw applications at S_1 level, applied screws should stay laterally to the neural canal and intervertebral foramina, should not pass the cortex and should not damage the neurovascular and visceral structures that have neighborhood with the sacrum in anterior plane.

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