ORIGINAL ARTICLE

SURGICAL TECHNIQUE

ANATOMICAL STUDY OF THE IDEAL POSITIONING OF THE S2 ILIAC SCREW

ESTUDO ANATÔMICO DO POSICIONAMENTO IDEAL DO PARAFUSO S2 ILÍACO

ESTUDIO ANATÓMICO DE LA POSICIÓN IDEAL DEL TORNILLO S2 ILÍACO

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ABSTRACT

Objective: To evaluate the morphometry of the pelvis to determine the safe trajectory for the insertion of the S2-iliac screw, and to correlate it with studies reported in the literature for other populations. Method: The computed tomography (CT) pelvic exams of 36 Brazilian patients without congenital malformations, tumors, pelvic ring fractures or dysplasias were selected from the database of a radiological clinic. To define the ideal trajectory of the S2-iliac screw, the following variables were measured: 1- maximum sacroiliac screw length; 2- thickness of the iliac dipole for planning the choice of screw dimensions (length and diameter); 3 - distance between the insertion point of the iliac S2 screw and the posterior sacral cortex; 4 - angulation for insertion of the screw in the mediolateral direction, representing the angle formed between the "iliac line" and the anatomical sagittal plane; 5- Angulation for insertion of the screw in the craniocaudal direction. The Pearson's chi squared and student's t tests were used for statistical analysis. Results: The sample consisted of 36 patients, 50% (18/36) of whom were women. The mean age was 63.7 years, ranging from 23 to 96 years. All the pelvic morphometric variables analyzed presented values similar to those described in the literature for other populations. Conclusion: Prior evaluation of the tomography exams was important for preoperative planning, and there was a statistically significant difference between the sexes only in relation to the variables left craniocaudal and length of the left internal table. ***Level of evidence III; Observational cross-sectional study.***

Keywords: Spinal Arthrodesis; Anatomy; Tomography; Iliac Bones; Pelvic Bones.

RESUMO

Objetivo: Avaliar a morfometria da pelve para determinar a trajetória de segurança de introdução do parafuso S2-ilíaco e correlacionar com estudos relatados na literatura para outras populações. Métodos: A partir do banco de dados de uma clínica radiológica, foram selecionados 36 exames de tomografia computadorizada (TC) da pelve de pacientes brasileiros sem achados de malformações congênitas, tumorações, fraturas do anel pélvico ou displasias. Para definição da trajetória ideal do parafuso S2-ilíaco foram mensuradas as seguintes variáveis: 1 - comprimento máximo do parafuso sacro-ilíaco; 2 - espessura da díploe ilíaca para planejar a escolha das dimensões do parafuso (comprimento e diâmetro); 3 - distância entre o ponto de inserção do parafuso S2-ilíaco e a cortical posterior do sacro; 4 - angulação para inserção do parafuso no sentido médio-lateral, representando o ângulo formado entre a "reta ilíaca" e o plano sagital anatômico; 5 - angulação para inserção do parafuso no sentido craniocaudal. Para análise estatística foram usados os testes Qui-quadrado de Pearson e t de Student. Resultados: A amostra foi constituída de 36 pacientes, sendo 50% (18/36) mulheres. A média de idade foi de 63,7 anos, variando de 23 a 96 anos. Todas as variáveis morfométricas pélvicas analisadas apresentaram valores semelhantes aos descritos na literatura para outras populações. Conclusões: A avaliação prévia dos exames de tomografia foi importante para o planejamento pré-operatório, assim como a diferença estatisticamente significante entre os sexos somente com relação às variáveis craniocaudal esquerda e comprimento da tábua interna esquerda. ***Nível de evidência III; Estudo observacional de corte transversal.***

Descritores: *Artrodese de Coluna; Anatomia; Tomografia; Osso Ilíaco; Ossos da Pelve.*

RESUMEN

Objetivo: Evaluar la morfometría de la pelvis para determinar la trayectoria de seguridad de introducción del tornillo S2-ilíaco y correlacionarla con estudios relatados en la literatura para otras poblaciones. Método: A partir de la base de datos de una clínica radiológica, se seleccionaron 36 exámenes de tomografía computarizada (TC) de la pelvis de pacientes brasileños sin hallazgos de malformaciones congénitas, tumores, fracturas del anillo pélvico o displasias. Para definir la trayectoria ideal del tornillo S2-ilíaco, se midieron las siguientes variables: 1- longitud máxima del tornillo sacro-ilíaco; 2- espesor del díploe ilíaco: para planificar la elección de las dimensiones del tornillo (longitud y diámetro); 3- distancia entre el punto de inserción del tornillo S2ilíaco y la cortical posterior del sacro; 4- angulación para inserción del tornillo en el sentido medio-lateral, que representa el ángulo formado entre la "recta ilíaca" y el plano sagital anatómico; 5- angulación para inserción del tornillo en el

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sentido craneocaudal. Para el análisis estadístico se utilizaron las pruebas Chi-cuadrado de Pearson y t de Student. Resultados: La muestra fue constituida de 36 pacientes, siendo 50% (18/36) mujeres. La edad promedio fue de 63,7 años, variando de 23 a 96 años. Todas las variables morfométricas pélvicas analizadas presentaron valores similares a los descritos en la literatura para otras poblaciones. Conclusiones: Fue importante la evaluación previa de los exámenes de tomografía para la planificación preoperatoria; así como la diferencia estadísticamente significativa entre géneros sólo en relación a las variables craneocaudal izquierda y longitud de la tabla interna izquierda. ***Nivel de evidencia III; Estudio observacional de corte transversal.***

Descriptores: *Artrodesis Espinal; Anatomía; Tomografía; Hueso Ilíaco; Huesos Pélvicos.*

INTRODUCTION

Despite technological advances, pelvic fixation continues to be a big challenge for the spine surgeon. Anatomical variations, biomechanical forces involved in long instrumentations, as well as low bone mineral density, point to a possible need for inclusion of the pelvis in instrumentation planning.[1] Various pathologies, such as neuromuscular scoliosis with pelvic inclination, osteoporosis, degenerative adult scoliosis, and osteotomies to correct sagittal imbalance, among others, may require inclusion of the sacrum in the fixation.[2]

Kim et al*.* demonstrated that, in cases of long instrumentations, distal fixations with sacral pedicle screws have high rates of mechanical complications. As a result, they suggest using some form of complementary fixation when lumbopelvic instrumentation is necessary.[3]

Kebaish et al*.,* state that long fusions extending to the sacrum should be complemented with pelvic instrumentation to reduce stress on the sacral pedicle screws in S1. Additionally, when associated with poor bone quality, instrumentation not fixed to the pelvis will have high failure rates.[4]

Among the mechanical complications described in the literature for cases of long instrumentations that include only the sacrum, osteolysis with loosening of the implant, implant breakage, and pseudoarthrosis stand out. High failure rates are related to the significant pullout momentum generated by the long lumbar instrumentation offset only by the short resistant lever arm provided by the sacral screws.[5-7]

In order to minimize the high lumbosacral fixation failure rates, several techniques suggest complementary iliac fixation.[8] Among the techniques described, the following stand out: the RP Jackson and AC McManus[9] sacral rod technique, the Galveston technique,[5,6] the MW (maximum width) spinopelvic assembly,[7] the sacral bar, and the iliac screw placed starting at the posterior-superior iliac spine. The choice of technique will depend on the experience of the surgeon.[2]

The iliac screw technique has been indicated because insertion of the long, greater diameter pedicle screw into the iliac diploe has proved, in vitro, to be superior to the Galveston technique.[10,11]

The S2 alar-iliac (S2AI) screw technique described by O'Brien et al*.,*[10] has advantages over the conventional iliac screw because it causes less tissue damage during local dissection and reduces the prominence of the implant, making better tissue coverage possible after the procedure.[12]

Also, according to Kostuik et al., the S2 alar-iliac (S2AI) screw technique is an interesting alternative to the conventional iliac fixation technique because it can reduce the occurrence of adverse effects and make not using additional connectors possible, minimizing the complexity of the procedure.[13]

Kwan et al., suggest increasing the resistance of the pedicle screw fixation system with additional S2AI screw fixation. However, they stress the importance of knowledge of the sacropelvic anatomy and morphometric characteristics to prevent violation of the spinal canal and/or neurovascular lesions.[14]

Miller et al*.,* point out the difficulties that spine surgeons face implanting S2AI screws safely and effectively. According to the authors, there is no uniform standard for parameters like the point of entry and the trajectory of the S2AI screw.[15]

Sponseller et al*.* determined the best trajectory for S2AI screws using pelvic CT.[10] To date, only international studies have measured pelvimetric parameters in their respective populations. Some of these studies have reported important anatomical variations for the definition of ideal S2 iliac screw positioning.[16-18]

Due to the absence of national studies on the anatomical theme of the ideal trajectory of the S2 iliac screw, specifically for the Brazilian population, the objective of this study is to describe the autochthonous pelvimetric parameters and to determine the measures of central tendency of the parameters used by the spine surgeon to assist them when inserting the S2AI screw.

METHODS

An observational, descriptive, cross-sectional study was conducted, in which pelvic CT images of individuals treated at a radiology clinic located in the city of Recife-PE during the period from January 2015 to December 2017 were analyzed.

The tomographic images of 36 patients (18 males and 18 females) treated by the radiology clinic for pelvic examinations were randomly selected. Images with signs of dysplasia, congenital malformations, tumors, or pelvic ring fractures were excluded from the study.

In all the cases studied, tomographic images were obtained in the para-sagittal, axial, and coronal planes, with 1 mm slices, in which predefined morphometric variables were measured using Horos/JPEG2000L software and a multislice tomographic device (MX 16 Philips Healthcare, Germany).

The data collected were compiled and presented in tables, as well as submitted to statistical treatment, in which the measures of central tendency were described, and the Pearson´s chi squared test and the student's t test were applied using the SPSS (Statistical Package for the Social Science) for Windows program, version 21.0. Results with p-values less than 0.05 were considered statistically significant.

To define the preoperative planning of the safe trajectory for insertion of the S2AI screws, so as not to violate neurovascular and articular structures, the identification of stereotaxic references in each CT of the pelvis was systematized through two moments. In the first moment, the parameters of the techniques described by O'Brien et al*.*[10] and Zhu et al.[17], in which the entry point of the screw would be located 1 mm inferior to and 1 mm laterally to the S1 dorsal foramen, were reproduced. From this starting point, the screw should be directed towards the homolateral greater trochanter. In the second moment, it was established in 3 sequential stages: Step 1 – using a coronal transsacral slice that shows the sacral and sacroiliac bodies/foramina, bilateral vertical line segments, "D", are drawn that connect the homolateral centers of the S1 and S2 sacral foramina. Next, the *sacral interforaminal points* (PIS) are located on the respective straight lines referred to above. Finally, a *horizontal sacral line* (RHS) that connects the right and left PISs is drawn (Figure 1A); Step 2 – using the axial slice, the *midpoint of the diploe* (PMD) is defined in the narrowest region between the internal tables of each ilium. Next, an "iliac line – R" is drawn from the PMD parallel to the anatomical anterior posterior axis of the ilium and in the direction of the sacrum until it crosses the RHS. The point of intersection between these two lines will be the *insertion point of the S2AI screw* (PS2AI) (Figure 1B); Step 3 – using the parasagittal slice of the ilium, a *point 0.5 cm above the anterior inferior iliac spine* (PEIAI) is defined. Then, the line segment that connects the PEIAI to homolateral PS2AI is defined (Figure 1C).

Then, five quantitative variables (stereotaxic and morphometric) were obtained that help in choosing the dimensions of the screw, as well as its direction: 1 – *maximum sacroiliac screw length* and 2 – *thickness of the iliac diploe*: measured in millimeters, they allow planning for the screw dimensions (length and diameter, respectively) – Figure 1A; 3 – *distance between PS2AI and PIS*: measured in centimeters over the posterior cortex of the sacrum, it allows locating the point of entry of the iliac screw using the sacral foramina as an anatomical reference; 4 - *angulation for screw insertion in the mediolateral direction*: measured in degrees, it represents the angle formed between the “iliac line” and the anatomical sagittal plane (Figure 1B); 5 - *angulation for screw insertion in the craniocaudal direction*: measured in degrees, it represents the angle (29.51º) formed between the line segment (PEIAI and PS2AI) and the line “T” formed by the longitudinal axis of the sacrum, perpendicular to the upper sacral endplate (Figure 1C).

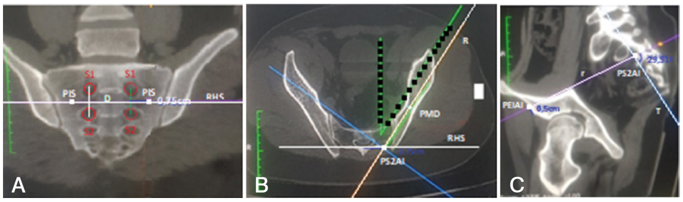

Figure 1. Tomographic slices of the pelvis for planning of the point of entry and ideal trajectory of the S2-iliac screw. A. Coronal transsacral slice showing the horizontal sacral line (RHS) obtained from the bilateral sacral interforaminal points (PIS). Also observe the bilateral vertical lines that connect the centers of the S1 and S2 homolateral sacral foramina. B. Axial slice of the pelvis showing the point of insertion of the S2AI screw obtained from the “iliac line” and the horizontal sacral line (RHS). Also observe the location of the midpoint of the diploe (PMD) in the region of the least distance between the internal tables of the ilium. C. Parasagittal slice of the ilium showing a location point 0.5 cm above the anterior inferior iliac spine (PEIAI). Also observe the line segment “r” that connects the PEIAI to the homolateral PS2AI and the line “T”, the longitudinal axis of the sacrum perpendicular to the upper endplate of the sacrum.

RESULTS

The mean age was 63.7 years, ranging from 23 to 96 years of age and 50% (18/36) of the patients were women. The morphometric and stereotaxic variables and their respective results can be viewed in Tables 1 and 2. It is worth highlighting the mean values obtained for these variables: 1 – maximum sacroiliac screw length: 10.33 cm; 2 – thickness of the iliac diploe: 9.66 mm; 3 – distance between PS2AI and PIS: 0.75 cm; 4 – angulation for screw insertion in the mediolateral direction: 33.99º; and 5 - angulation for screw insertion in the craniocaudal direction: 29.51º. A statistically significant difference was observed between the sexes only in relation to the variables angulation for screw insertion in the craniocaudal direction on the left and midpoint of the diploe on the left.

DISCUSSION

In the literature, a significant number of authors affirm that cases of lumbosacral arthrodesis with proximal extension above segment

Table 1. Measurements of central tendency of the morphometric variables obtained in the pelvic tomographs of 36 patients evaluated in a radiology clinic in Recife-PE during the period between 2015 and 2017.

	Sex	N	Mean	Median	Standard Deviation	Minimum	Maximum
Age	Male	18	66.67	66.5	13.41	.35	96.
	Female	18	60.67	66.5	18.20	.23	85.
	Total	36	63.67	66.5	16.04	.23	96.
* Angulation for screw insertion in the right craniocaudal direction	Male	18	64.84	66.62	10.91	41.80	85.50
	Female	18	60.61	61.03	7.78	38.88	69.88
	Total	36	62.73	63.80	9.58	38.88	85.50
* Angulation for screw insertion in the left craniocaudal direction	Male	18	67.41	70.27	9.00	49.60	84.10
	Female	18	60.53	61.43	7.55	41.71	73.76
	Total	36	63.97	64.21	8.90	41.71	84.10
Thickness of the right iliac diploe (cm)	Male	18	1.25	1.28	.27	.82	1.79
	Female	18	1.06	1.02	.31	.54	1.58
	Total	36	1.15	1.19	.30	.54	1.79
Thickness of the left iliac diploe (cm)	Male	18	1.17	1.17	.23	.65	1.61
	Female	18	.90	.88	.21	.51	1.24
	Total	36	1.03	1.03	.25	.51	1.61
Angulation for screw insertion in the right mediolateral direction (º)	Male	18	39.02	37.81	5.75	30.97	52.91
	Female	18	35.61	34.59	6.06	27.99	46.69
	Total	36	37.31	36.41	6.07	27.99	52.91
Angulation for screw insertion in the left mediolateral direction (º)	Male	18	40.77	40.98	4.76	33.24	49.51
	Female	18	38.59	39.29	5.64	30.56	50.61
	Total	36	39.68	39.74	5.26	30.56	50.61
Maximum right sacroiliac screw length (cm)	Male	18	9.38	9.22	.68	8.41	10.39
	Female	18	9.44	9.16	.89	8.07	11.04
	Total	36	9.41	9.20	.78	8.07	11.04
Maximum left sacroiliac screw length (cm)	Male	18	9.89	9.55	.86	8.76	11.67
	Female	18	9.92	9.70	.98	8.37	12.47
	Total	36	9.90	9.62	.91	8.37	12.47
Distance between the point of insertion of the S2 iliac screw and the posterior cortex of the right sacrum (cm)	Male	18	1.02	.98	.15	.81	1.32
	Female	18	1.08	1.04	.19	.74	1.39
	Total	36	1.05	1.03	.18	.74	1.39
Distance between the point of insertion of the S2 iliac screw and the posterior cortex of the left sacrum (cm)	Male	18	1.03	.97	.21	.78	1.53
	Female	18	1.06	1.07	.15	.81	1.28

*Angulation complementary to a 90º angle.

Table 2. Comparison by sex of the morphometric and stereotaxic variables obtained from the pelvic tomographs of 36 patients treated in a radiology clinic in Recife - PE during the period between 2015 and 2017.

Variables	Men		Women		p*
	Mean (SD)	**CI95%**	**Mean (SD)**	**CI95%**	
Angulation for screw insertion in the craniocaudal direction	25.16 (10.9)	(35.58 – 19.73)	29.39 (7.8)	(33.26 – 25.52)	0.189
Angulation for screw insertion in the craniocaudal direction	22.59 (9.0)	(27.07 – 18.12)	29.47 (7.6)	(33.22 – 25.71)	0.018*
Thickness of the right iliac diploe (cm)	1.25 (0.3)	(1.11 – 1.38)	1.06 (0.3)	(0.90 – 1.21)	0.055
Thickness of the left iliac diploe (cm)	1.17 (0.2)	(1.05 – 1.28)	0.90 (0.2)	(0.79 – 1.00)	0.001*
Angulation for screw insertion in the right mediolateral direction (°)	39.02 (5.8)	(36.16 – 41.88)	35.61 (6.1)	(32.59 – 38.62)	0.092
Angulation for screw insertion in the left mediolateral direction (°)	40.77 (4.8)	(38.40 – 43.14)	38.59 (5.6)	(35.79 – 41.39)	0.219
Maximum right sacroiliac screw length (cm)	9.38 (0.7)	(9.04 – 9.72)	9.44 (0.9)	(8.99 – 9.88)	0.816
Maximum left sacroiliac screw length (cm)	9.89 (0.9)	(9.46 – 10.32)	9.92 (1.0)	(9.43 – 10.41)	0.922
Distance between the point of insertion of the S2 iliac screw and the posterior cortex of the right sacrum (cm)	1.02 (0.2)	(0.94 – 1.09)	1.08 (0.2)	(0.98 – 1.18)	0.287
Distance between the point of insertion of the S2 iliac screw and the posterior cortex of the left sacrum (cm)	1.03 (0.2)	(0.93 – 1.14)	1.06 (0.2)	(0.98 – 1.14)	0.648

SD: Standard Deviation; CI95%: Confidence Interval of 95% for the mean; * Statistically significant ($p < 0.05$).

L3 should be complemented by fixation that includes the ilium.[9] Another group of authors suggests that pelvic fixation should be indicated only for fusions that extend above the thoracolumbar junction.[16] Regardless of the controversy regarding the proximal extension of the arthrodesis, all of them justify inclusion of the ilium in their lumbopelvic fixations in order to reduce the rate of regional biomechanical complications (sacral pedicular osteolysis, S1 screw pullout, implant failure, and pseudoarthrosis).

O'Brien et al., described lumbopelvic fixation with sacroiliac screws. According to these authors, the screw entry point would be located 1 mm inferior to and 1 mm lateral to the dorsal S1 foramen. From this starting point, the screw should be directed towards the homolateral great trochanter, which corresponds to approximately 40 degrees of mediolateral angulation and 30 degrees of craniocaudal angulation.[10] In a study to identify the radiographic parameters for positioning the S2-iliac screw in the Chinese population, Zhu et al.,[17] found the same results as those reported by O'Brien et al. On the other hand, in the Japanese population, Yamada et al.,[16] determined that the ideal insertion point for the S2-iliac screw would be 2 mm medial to the apex of the lateral sacral crest and equidistant from the dorsal foramina of S1 and S2.[16] Finally, Park et al*.,*[15] defined the point of entry for the S2AI screw as the midpoint between the S1 and S2 foramina and 2 mm medial to the lateral sacral crest, directing it approximately 20 degrees caudally and 30 degrees laterally in relation to the line that connects the posterior superior iliac spines (PSIS).

In the present study, the initial challenge was to try to assess the precision of using the software for pelvic scans for preoperative planning of the ideal S2AI screw positioning. However, reproduction of the technical parameters suggested in the literature showed that, in some exams, the suggested trajectory would not be safe, as it could violate neurovascular or articular structures. In this first moment of the present study, the parameters of the techniques described by O'Brien et al*.,*[7] and Zhu et al.,[14] were reproduced. Measurements were performed bilaterally for a better screw trajectory in the 36 pelvic CT examinations. Of the 72 measurements, 24 trajectories were observed that could violate neurovascular structures: 10 cases of invasion of the right internal iliac table and 14 cases of invasion of the left internal iliac table. Such violations may have occurred, in part, due to anatomical variations found in the exams, in addition to the values of 1 mm as a starting point for insertion of the screws into the sacrum. It is assumed that such great intraoperative accuracy is also not feasible and that the screws could go beyond the safety margins in the recommended surgical procedure.

To resolve the above-mentioned tomographic technical difficulties, the choice of the point of insertion of the screw into the sacrum was defined in a retrograde manner, that is, first an "arrival point" to be reached by the screw was defined. The point chosen was the midpoint of the diploe in the narrowest area of the ilium, as it is a critical location for perforations of the internal and external tables. The projection of the midpoint of the iliac diploe on the posterior sacral cortex can be defined considering the orientation of a line parallel to the iliac cortices. Following this methodology, it became possible to define a sacral point for screw insertion, as well as the angulation for mediolateral insertion, which would allow prediction of the ideal trajectory for avoiding intrapelvic screw penetration.

In a biomechanical study, Miller et al.,[15] demonstrated that the supra-acetabular iliac region accommodates the longest S2AI screw trajectory and has the highest bone density, and, therefore, offers better resistance to traction forces. However, due to technical difficulties reaching the supra-acetabular region during the surgical procedure, the same study reported acetabular invasion from the S2AI screw in 25% of cases. Because of this last finding, the authors proposed the center of the ilium, which would be reached by inserting the screw via the targeted trajectory from the point of entry in S2 to the anterior inferior iliac spine, as the most suitable location for iliac fixation.[11]

To minimize the risk of perforation of the acetabulum, the craniocaudal orientation of the screw trajectory was defined in the present study, and a point 0.5 cm above the EIAI was chosen. This methodology allows us to simultaneously standardize an anatomical point of reference, to allow a margin of acetabular safety for possible intraoperative variations in the angulation of free-hand screw insertion, and to keep the screw as close as possible to the area of greatest biomechanical resistance.

The works conducted on lumbopelvic fixation conducted in different populations present only sporadic divergences in their findings. While Chang et al., in an anatomical study using CT images in the North American population, did not report significant differences in the angulation of the trajectory between the sexes,[1] Zhu et al., concluded that, in the Chinese population, the angulation of the trajectory was significantly more caudal in females.[17]

Although there is great ethnic miscegenation in Brazil resulting from immigrations, and anthropomorphic characteristics can vary among different ethnicities, the results obtained in the present study were similar to those described in the world literature. It should be noted, however, that the authors of the present study do not know of any other study that has addressed the subject specifically for the Brazilian population.

Although male and female pelvises have structural differences, the morphometric and stereotaxic results obtained in the present study reveal that the same surgical technique can be applied to both sexes. We believe that the possible statistical differences found for the variables thickness of the left diploe and angulation of screw insertion in the craniocaudal orientation between the sides of the body could result from discreet pelvic asymmetries.

We emphasize that the present study diverged from the literature only in relation to the values obtained relative to the point of screw insertion in the sacrum. Such disagreement is perhaps due to the different techniques used to determine the trajectory of the screw as mentioned above.

While in the studies by Yamada et al.,[16] Zhu et al.,[17] and Chang et al.,[1] the trajectories of the screws in their respective techniques were evaluated prospectively using postoperative control CTs, the present study was limited to the preoperative evaluation, as observed in Table 3. We hope to evaluate postoperative results in future studies.

CONCLUSION

The present study suggests that, for the anatomical study of the ideal positioning of the S2 iliac screw, planning should be conducted with a tomographic study from the anterior inferior iliac spine as the starting point in the direction of the midpoint of the iliac diploe, in order to measure the trajectory for the best positioning of the S2 iliac screw. It can also be stated that there was a significant statistical difference between the sexes only in relation to the variables left craniocaudal and length of the left internal table.

All authors declare no potential conflict of interest related to this article.

Table 3. Comparison of the mean values by study.

	*Present study		Yamada 2017		Zhu 2013		Chang 2009	
Age (years)	**23 to 96**		**58 to 81**		**20 to 60**		**12 to 18**	
Sex	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Sample Size	18	18	40	40	30	30	13	7
Screw length (cm)	9.63	9.68	9.89	9.16	9.51		6.95	7.31
Medial/lateral (°)	39.89	37.11	37.9	32.8	36.5	35.7	39.4	38
Cranial/caudal (°)	23.87	29.43	27.5	33.4	29.2	34.5	36.7	41.6
Internal iliac table (cm)	1.21	0.98	1.21	1.13	1.21	1.14	1.05	1.06
Lateral point to the sacrum (mm)	10.2	10.7	2		1		1	

*Means of the right and left sides.

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REFERENCES

1. Chang T-L, Sponseller PD, Kebaish KM, Fishman EK. Low Profile Pelvic Fixation Anatomic Parameters for Sacral Alar-Iliac Fixation Versus Traditional Iliac Fixation. Spine. 2009;34(5):436–40.
2. Arlet V, Ouellet J, Vialle R. Lumbosacral fixation techniques. Revista Coluna/Columna. 2003;2(1):11.
3. Kim YJ, Bridwell KH, Lenke LG, Cho KJ, Edwards CC 2nd, Rinella AS. Pseudarthrosis in adult spinal deformity following multisegmental instrumentation and arthrodesis. J Bone Joint Surg Am. 2006;88(4):721–728.
4. Kebaish KM. Sacropelvic fixation: techniques and complications. Spine. 2010;35(25):2245–51.
5. Allen BL Jr, Ferguson RL. The Galveston technique of pelvic fixation with L- rod instrumentation of the spine. Spine. 1984;9(4):388-94.
6. Allen BL Jr, Ferguson RL. The Galveston experience with L - rod instrumentation for adolescent idiopathic scoliosis. Clin Orthop Relat Res. 1988;229:59–69.
7. Arlet V, Marchesi D, Papin P, Aebi M. The MW sacropelvic construct: an enhanced fixation of the lumbosacral junction in neuromuscular pelvic obliquity. A technical note. Eur Spine J. 1999;8(3):229–31.
8. Erickson MA, Oliver T, Baldini T, Bach J. Biomechanical assessment of conventional unit rod fixation versus a unit rod pedicle screw construct. A human cadaver study. Spine. 2004;29(12):1314–9.
9. Jackson RP, McManus AC. The iliac buttress: a computed tomographic study of sacral anatomy. Spine. 1993;18(10):1318–28.
10. O'Brien JR, Yu WD, Bhatnagar R, Sponseller P, Kebaish KM. An anatomic study of the S2 iliac technique for lumbopelvic screw placement. Spine. 2009;34(12):E439-42.
11. Lebwohl NH, Cunningham BW, Dmitriev A, Shimamoto N, Gooch L, Devlin V, et al. Biomechanical comparison of lumbosacral fixation techniques in a calf spine model. Spine. 2002;27(21):2312–20.
12. Park J-H, Hyun S-J, Kim K-J, Jahng T-A. Free Hand Insertion Technique of S2 Sacral Alar-Iliac Screws for Spino-Pelvic Fixation: Technical Note, Acadaveric Study. J Korean Neurosurg Soc. 2015;58(6):578-81.
13. Kostuik JP. Spinopelvic fixation. Neurol India. 2005;53(4):483–8.
14. Kwan MK, Jeffry A, Chan CYW, Saw LB. A radiological evaluation of the morphometry and safety of S1, S2 and S2-ilium screws in the Asian population using three dimensional computed tomography scan: an analysis of 180 pelvis. Surg Radiol Anat. 2012;34(3):217–27. DOI 10.1007/s00276-011-0919-2.
15. Miller F, Moseley C, Koreska J. Pelvic anatomy relative to lumbosacral instrumentation. J Spinal Disord. 1990;3(2):169-73.
16. **Yamada K, Higashi T, Kaneko K, Ide M, Sekiya T, Saito T. Optimal trajectory and insertion accuracy of sacral alar iliac screws. Acta Orthop Traumatol Turc. 2017;51(4):313-8.**
17. Zhu F, Bao HD, Yuan S, Wang B, Qiao J, Zhu ZZ. Posterior second sacral alar iliac screw insertion: anatomic study in a Chinese population. Eur Spine J. 2013;22(7):1683–9.
18. Ebraheim NA, Lu J, Yang H, Heck BE, Yeasting RA. Anatomic considerations of the second sacral vertebra and dorsal screw placement. Surg Radiol Anat. 1997;19(6):353–7.