JOURNAL OF
CONTEMPORARY MEDICINE

DOI:10.16899/jcm.1345680
J Contemp Med 2023;13(5):836-844

Original Article / Orijinal Araştırma

Evaluation of the Effect of Pelvic Types on Trans-Sacral Screw Corridor Diameter (Retrospective Analysis Using Computerized Tomography Data)

Pelvis Tiplerinin Trans-Sakral Vida Koridor Çapına Etkisinin Değerlendirilmesi (Bilgisayarlı Tomografi Verilerinin Retrospektif Analizi)

Yavuz Selim Karatekin[1], Orhan Balta[2]

[1]Samsun Education and Research Hospital, Department of Orthopaedics and Traumatology, Samsun, Turkey
[2]Gaziosmanpasa University, School of Medicine, Department of Orthopaedics and Traumatology, Tokat, Turkey

Abstract

Aim: The aim of this study was to investigate the effect of pelvis type on the trans-sacral (TS) screw corridor diameter.

Material and Method: Pelvis computed tomography (CT) scans between 2017 and 2020 were retrospectively reviewed. Age, gender, height, weight and body mass index (BMI) of the patients were determined during the CT examination. Pelvic CT scans were examined using the imaging system's multi-plane reconstruction (MPR) mode, and the TS screw corridor was measured for both the upper and second sacral segments. In addition, pelvic incidence (PI), sacral tilt (SS), and pelvic tilt (PT) values were measured. Pelvis typing was performed using the large transverse diameter, anteroposterior diameter, interspinous, intertuberocytosis, transverse outlet diameter, sagittal mid-pelvic diameter, and sagittal outlet values.

Results: 81(38%) male and 132(62%) female patients were included in the study. Gynecoid pelvis type was more common in females and android pelvis in males ($p < 0.001$). The largest diameters in the TS screw corridor at the S1 level belonged to the anthropoid pelvis type. However, in the TS corridor at the S2 level, there was a significant difference between the pelvis-type groups in the mean values of AP and CC ($p < 0.001$). The effect of gender difference on the TS screw corridor width at the S1 and S2 levels was significant. An adequate corridor width for the TS screw corridor was detected in 50.8% of females and 67.9% of males at the S1 level, while in 21.2% of females and 70.4% of males at the S2 level.

Conclusion: There is a significant difference in the dimensions of the trans-sacral screw corridor according to the pelvis type and gender, with the largest diameter observed in the anthropoid pelvis type and males. In critical situations, especially in males and individuals with android-anthropoid pelvis, the trans-sacral screw option can be considered primarily not only for the S1 trans-sacral corridor but also for the S2 trans-sacral corridor in pelvic posterior ring injuries.

Keywords: Trans-sacral screw corridor, pelvis type, android pelvis, sacrum fracture

Öz

Amaç: Bu çalışmanın amacı, pelvik tipin trans-sakral (TS) vida koridor çapı üzerindeki etkisini araştırmaktır.

Gereç ve Yöntem: 2017 ile 2020 yılları arasında elde edilen pelvik bilgisayarlı tomografi (BT) taramaları retrospektif olarak incelendi. Hastaların yaş, cinsiyet, boy, kilo ve vücut kitle indeksi (VKİ) bilgileri BT muayenesi sırasında belirlendi. Pelvik BT taramaları görüntüleme sisteminin çoklu düzlem rekonstrüksiyon (MPR) modu kullanılarak incelendi ve üst ve ikinci sakral segmentler için TS vida koridoru ölçüldü. Ayrıca, pelvik inklinasyon (PI), sakral eğim (SS) ve pelvik eğim (PT) değerleri ölçüldü. Pelvik tiplemesi büyük çap, anteroposterior çap, interspinöz, intertüberokitoz, çapraz çıkış çapı, sagittal orta pelvik çap ve sagittal çıkış değerleri kullanılarak yapıldı.

Bulgular: Çalışmaya 81 (%38) erkek ve 132 (%62) kadın hasta dahil edildi. Ginekoid pelvik tip kadınlarda daha yaygınken, erkeklerde android pelvis daha yaygındı ($p < 0.001$). S1 düzeyinde TS vida koridorundaki en büyük çaplar antropoid pelvik tipine aitti. Bununla birlikte, S2 düzeyinde TS koridorunda, pelvik tip grupları arasında AP ve CC ortalama değerleri bakımından anlamlı fark vardı ($p < 0.001$). Cinsiyet farkının S1 ve S2 düzeylerinde TS vida koridor genişliği üzerindeki etkisi önemliydi. S1 düzeyinde uygun bir koridor genişliği, kadınların %50.8'inde ve erkeklerin %67.9'unda tespit edildi, S2 düzeyinde ise kadınların %21.2'sinde ve erkeklerin %70.4'ünde görüldü.

Sonuç: Trans-sakral vida koridorunun boyutlarında pelvik tip ve cinsiyet açısından önemli bir fark vardır; en büyük çap antropoid pelvik tipinde ve erkeklerde gözlemlenir. Özellikle erkeklerde ve android-antropoid pelvisli bireylerde kritik durumlarda, pelvik posterior halka yaralanmalarında sadece S1 trans-sakral koridor için değil, aynı zamanda S2 trans-sakral koridor için de trans-sakral vida seçeneği öncelikli olarak düşünülebilir.

Anahtar Kelimeler: Trans-sakral vida koridoru, pelvis tipi, android pelvis, sakrum kırığı

Corresponding *(İletişim)*: Yavuz Selim KARATEKİN, Samsun Education and Research Hospital, Department of Orthopaedics and Traumatology, Baris Bulvarı. No: 199, 55090 İlkadım, Samsun, Turkey
E-mail *(E-posta)*: yavuzselimkaratekin@gmail.com
Received *(Geliş Tarihi)*: 18.08.2023 **Accepted *(Kabul Tarihi)*:** 20.09.2023

INTRODUCTION

The incidence of unilateral or bilateral U or H-shaped sacral fractures and pelvic ring fractures due to high-energy traumas has increased in parallel with the development of high technology.[1,2] Additionally, due to the increase in the elderly population, the frequency of sacral fractures caused by osteoporosis, posterior pelvic ring injuries, sacroiliac joint dislocation, and sacrum and pelvis insufficiency fractures is also increasing.[3,4] Some studies in the literature indicate that iliosacral screw fixation may not yield sufficient stability, whereas the placement of transiliac-trans sacral screws could offer an alternative fixation opportunity and provide more effective stability by allowing cortical fixation on the distal side of the injury and a much longer implant.[5,6]

Trans-sacral (TS) screw fixation has recently been routinely used to treat pelvis posterior stabilization.[7] However, despite its clinical importance, applying trans-sacral implants with minimally invasive techniques is challenging due to anatomical variations in the pelvis and sacral regions and dysmorphism. Moreover, the individual variability of sacrum morphological characteristics makes this procedure even more difficult.[8] Therefore, this is a technically complex procedure that requires performers to fully understand the anatomy of the pelvis, pelvic osseous fixation pathways, and their fluoroscopic imaging to ensure safe iliosacral screw placement. The procedure's safe and effective placement of these screws is also essential.[9]

Biomorphometric data on how the TS corridor can change due to changes in pelvic inlet anatomy and how the PI value can affect bone corridors are relatively scarce. In the general population, performing pelvic measurements to describe the feasibility rates of trans-sacral screw placement of android, gynecoid, anthropoid, and platypelloid pelvis morphologies in females and males, and identifying pelvis type-specific differences in trans-sacral corridor dimensions and the impact of pelvis type on the trans-sacral corridor, could improve understanding of patient-specific differences in terms of risks and motivate the development of treatment strategies that take into account anatomical pelvic differences. For this reason, the present study aimed to evaluate pelvic types using CT anatomical scans to determine the feasibility rates of trans-sacral screw fixation in men and women and investigate the effect of pelvis type on TS corridors and PI values.

MATERIAL AND METHOD

The study was designed as a retrospective cohort study in accordance with the World Medical Association Declaration of Helsinki guidelines, after obtaining local institutional ethics committee approval (No: 21-KAEK-236). Pelvic CT images with 1 mm cross-section width taken for diagnosis in trauma patients over the age of 18 who applied to the university hospital emergency department between 2017 and 2020 were examined. Images were analyzed using the PACS (Patient Archiving Computer System, Sectra) system. The exclusion criteria comprised diseases that disrupt proximal femur anatomy, such as spinal deformity, coxarthrosis, developmental dysplasia of the hip, and a history of recent or past fractures of the sacrum, lumbar, pelvis, acetabulum, and proximal femur. The patients' age, gender, height, weight and BMI measurements for both the upper and second sacral segments were retrospectively reviewed.

Four study groups were constituted according to pelvis types: android, anthropoid, platypelloid and gynecoid pelvis. Caldwell et al. described four main pelvis types, each with distinctive anatomical features.[10] The Android pelvis has a larger transverse diameter than the AP diameter and a heart-shaped pelvic inlet. The Gynecoid pelvis has a slightly larger inlet transverse diameter than the AP diameter and a round or slightly oval inlet. The Platypelloid pelvis has a significantly larger transverse diameter than the AP diameter and a slightly flattened kidney-shaped inlet. The Anthropoid pelvis has a larger AP diameter than the transverse diameter and a divergent pelvic inlet (**Figure 1**).

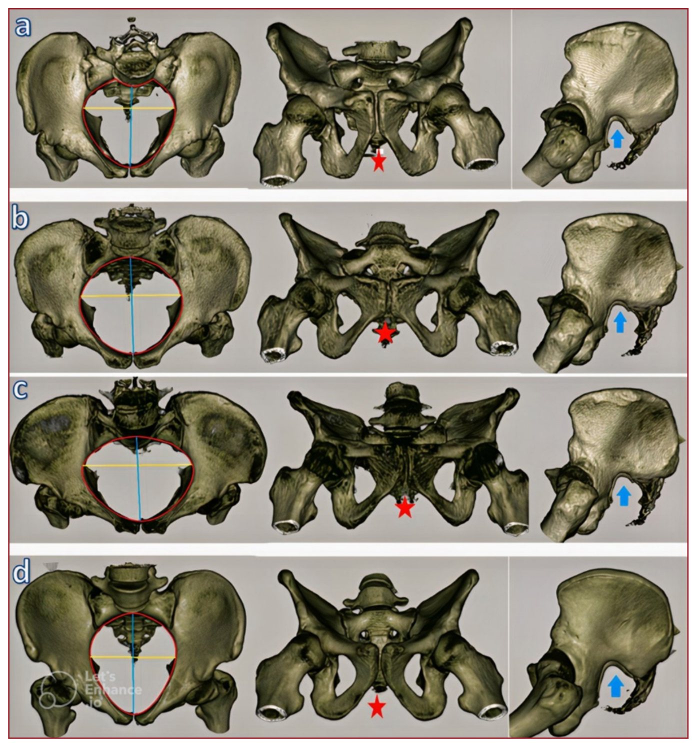

Figure1: Pelvis Types;
a)Android pelvis type, b) Gynecoid pelvis type, c) Platylloid pelvis type, d) Andropoid pelvis type

Pelvis typing was performed on images obtained by multi-planar reconstructions (MPR) and 3D imaging modes of CT scans with the utilization of measurement techniques used in previous studies.[11,12] The pelvic structures that did not exactly match one of the four main pelvis types were included in the pelvis type having the closest similarity. The obstetric conjugate, transverse diameter, interspinous distance, sagittal midpelvic diameter, intertuberous distance and sagittal outlet diameter to be used for pelvis typing were measured using 1 mm MPR images (**Figure 2**).

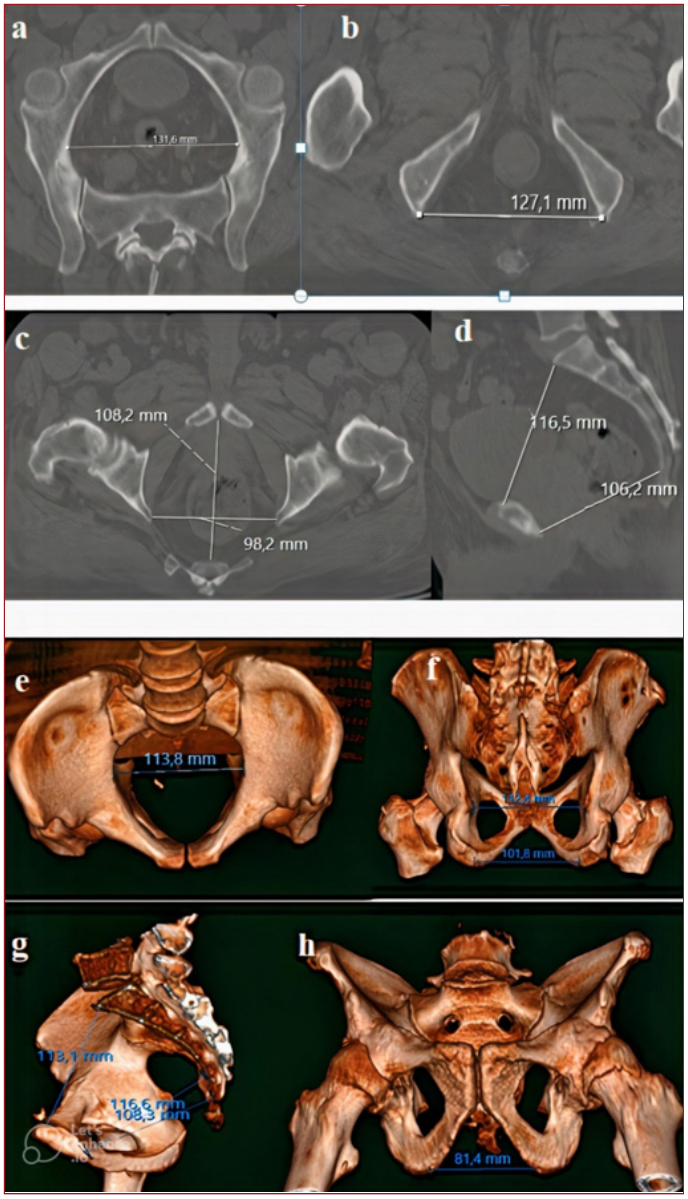

Figure 2: Pelvis typing;
a) Para-axial reconstruction showing the pelvic inlet.Widest transverse diameter of inlet view.
b) Axial slice showing ischial tuberosities and the corresponding measurement.
c)Para-axialreconstruction showing ischial spines, the caudalend of the symphysis and the sacrum so that inter spinal distance and sagittal midpelvic diameter can be measured.
d) Sagittal reconstruction showing the symphysis and the sacrum. Obstetric conjugate and Sagittal outlet distance measurement.
e) Volume-rendered reconstruction in a superior–anteriorview. Measurement of the transverse diameter of the inner pelvis.
f) Posterior view, with lines showing interspinous and intertuberous measurements.
g) Right lateral view of the pelvis split in half in a sagittal plane. Measurement of Obstetric Conjugate, Sagittal Outlet Distance, and Midpelvic Sagittal Distance.
h) Subpubik arc and transvers diamater of outlet

Corridor Measurement Using CT Images

The true coronal (outlet view) and true axial (inlet view) planes of CT images, obtained by manually acquired MPRs, were used to measure trans-sacral corridors in the upper and second sacral segments of pelvic CT images. These images resemble the fluoroscopic outlet (pubic symphysis superimposed on the S2 body) and inlet (anterior cortices of S1 and S2 superimposed) images previously described in the literature and used for trans-sacral corridor measurement. A corridor width of 10 mm or more was considered adequate in both the true coronal and axial planes.[11,12]

First, the midsagittal image was obtained by using the pubic symphysis and sacral median crest as references to identify the midsagittal line in the sagittal CT image. True coronal and axial sacral planes were manually created by reconstructing the standard axis of pelvic CT, which was aligned to be parallel with the anterior cortex according to sacral inclination at the S1 level. Afterwards, the widest corridors were identified for S1 craniocaudal diameter (S1 CC), S2 craniocaudal diameter (S2 CC), S1 anteroposterior diameter (S1 AP), and S2 anteroposterior diameter (S2 AP) while avoiding screw penetration outside the intraosseous corridor (**Figure 3a-d**).

The sagittal tomographic sections were used to determine the pelvic incidence. For this purpose, a line was drawn from the midpoint of the upper endplate of S1 to the midpoint of the line connecting the femoral heads. Similarly, a second line was formed at an angle of 90 degrees downwards from the midpoint of the upper end plate of S1. Then the angle calculated between these two lines was taken as pelvic incidence (**Figure 3e**).

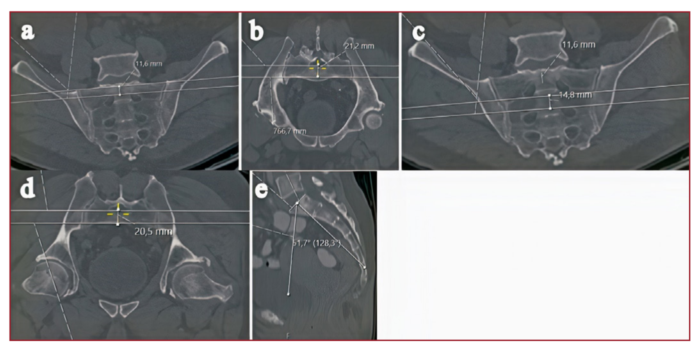

Figure3: Measurement of the horizontal corridor in the S1 sacral segment on reconstructed CT images. A) S1 CC measurement true coronal (outlet view) B) S1 AP measurement true axial (inlet view) C) S2 CC measurement true coronal (outlet view) D) S2 AP measurement true axial (inlet view) E) Pelvic incidence angle

Two specialist surgeons took all measurements with at least ten years of experience in orthopedic trauma surgery. They were trained to increase measurement precision before taking the measurements. The surgeons performed the measurements separately to minimize errors, and the mean values were computed. One of the surgeons repeated all measurements to determine inter-observer variability and confirm measurement validity. After repeated measurements, intra- and inter-observer agreements regarding the measured parameters were calculated.

Statistical Analysis

Interobserver agreement was found to be strong in terms of S1 CC, S1 AP, S2 CC, S2 AP diameters and pelvic incidence, sacral slope and pelvic tilt values (r values:

0.89, 0.88, 0.87, 0,81, 0.84, 0.85 and 0.80 respectively). Regarding the orthopedist who performed the same measurements for the second time one month later, it was detected that intraobserver agreement was very strong for S1 CC, S2 CC and pelvic incidence (r values:0.97, 0.96 and 0.93, respectively), or strong for S1 AP, S2 AP, sacral slope and pelvic tilt (r values: 0.88, 0.85, 0.81 and 0.80, respectively).

The data analysis was conducted using the IBM SPSS statistical analysis software (Version: 23.0). The Kolmogorov-Smirnov test was employed to examine the normality distribution of the variables. The statistical comparison of three or more groups was conducted according to whether the data conformed to the normality distribution. For normally distributed data, the one-way analysis of Variance method was utilized, and multiple comparisons were analyzed with the Duncan and Tamhane's T2 tests, whereas, for non-normally distributed data, the Kruskal Wallis H test was used and multiple comparisons were analyzed with the Dunn test. The Pearson chi-square test was applied to compare categorical variables between the groups, and the Bonferroni corrected z test was performed for multiple comparisons. The analysis results were presented as mean±standard deviation and median (minimum – maximum) for quantitative variables, and frequency (percent) for categorical variables. A p-value less than 0.05 was regarded to be statistically significant in all tests.

RESULTS

Of the CT scans, 132 (62%) belonged to females and 81 (38%) belonged to males. The conducted pelvis typing revealed that there were 98 (46%) android, 80 (37.6%) gynecoid, 7 (3.3%) platypelloid, and 28 (13.1%) anthropoid pelvis types. In the groups created based on pelvis type, there was a significant difference in terms of age distribution between the groups when the patients in the anthropoid group were included, but no difference when they were excluded. No significant difference was detected between the groups in terms of BMI (p=0.848). The sociodemographic data of the study are summarized in **Table 1**.

There was a statistically significant difference between the pelvis type groups in terms of gender distribution (p < 0.001). This difference is due to the fact that the rates of android, gynecoid, platypelloid, and anthropoid pelvis types vary according to gender; in this respect, the highest rate in females was obtained in the gynecoid and platypelloid groups, and the highest rate in males was in the android group (**Table 2**).

The largest AP and CC diameters in the TS corridor at the S1 level (p=0.925 and p=0.123, respectively) belonged to the anthropoid pelvis type. In the TS corridor at the S2 level, on the other hand, there was a significant difference between the pelvis type groups in the mean values of AP and CC (p < 0.001). The largest corridor was observed in the CT scans belonging to the group with anthropoid pelvis type at the S1 level, whereas the smallest corridor diameter was in the pelvic CT scans of the platypelloid group (**Table 1**).

Table 1: Comparison of quantitative data by pelvis types

		Pelvis Type				Test Statistics	p
		Android Type	Gynecoid Type	Platypelloid Type	Andropoid Type		
Age (year)	Mean±SD	58.2±19.76	58.18±20.33	58.86±17.53	42.61±21.05	13.090	0.004*
	Median (Min.-Max.)	62 (21-86)[a]	61.5 (20-89)[a]	58 (24-80)[ab]	29 (20-84)[b]		
Height (m)	Mean±SD	1.68±0.04	1.66±0.02	1.65±0.02	1.68±0.06	21.945	<0.001*
	Median (Min.-Max.)	1.67 (1.63-1.87)[a]	1.65 (1.6-1.73)[b]	1.64 (1.63-1.67)[b]	1.68 (1.63-1.98)[ab]		
Weight (kg)	Mean±SD	74.21±6.61	72.21±6.45	70.86±7.76	72.75±8.75	2.999	0.392*
	Median (Min.-Max.)	74 (58-93)	72 (55-88)	73 (57-79)	72 (56-92)		
BMI (kg/m²)	Mean±SD	26.34±2.44	26.3±2.44	26.07±2.89	25.72±2.68	0.805	0.848*
	Median (Min.-Max.)	26.61 (19.45-31.99)	26.45 (20.05-30.86)	26.18 (21.19-29.73)	25.73 (20.57-29.76)		
S1 AP (mm)	Mean±SD	11.14±4.61	10.69±5.08	10.77±5.6	11.2±4.76	0.156	0.925**
	Median (Min.-Max.)	10.6 (0-23)	10 (3.8-34.5)	7.7 (5.1-16.7)	11.65 (1.3-20.9)		
S1 Axial (mm)	Mean±SD	16.9±4.51	15.7±3.97	15.16±3.77	17.85±4.15	5.771	0.123*
	Median (Min.-Max.)	16.85 (0-26.9)	15.8 (6.7-26.8)	15.9 (7.3-17.9)	17.6 (10.7-24.9)		
S2 AP(mm)	Mean±SD	10.78±3.4	9.05±2.44	8.46±2.99	10.34±3.27	16.668	0.001*
	Median (Min.-Max.)	11 (2.5-24.7)[a]	9.1 (4.5-16.6)[b]	7.8 (4.6-12.1)[ab]	10 (5.5-16.9)[ab]		
S2 Axial (mm)	Mean±SD	12.33±3.66[a]	10.67±2.93[b]	11.29±6.85[ab]	12.58±3.57s[b]	4.442	0.012**
	Median (Min.-Max.)	12.3 (5.5-26.9)	10.2 (6-20.2)	8.3 (4.6-20.9)	12.15 (6-24.9)		
Pelvic Tilt (°)	Mean±SD	17.74±14.63	19.2±16.76	30.77±10.83	15.08±12.8	2.135	0.097**
	Median (Min.-Max.)	16.55 (-22-58)	20.1 (-23.5-60.3)	29.3 (17.2-52.5)	16 (-12.7-39)		
Sacral Slope (°)	Mean±SD	32.7±9.64	40.46±67.43	28.86±8.82	33.09±7.77	0.663	0.663*
	Median (Min.-Max.)	35 (10-57)	34.5 (10-629)	28 (17-45)	34 (17-48)		
Pelvic Incidence(°)	Mean±SD	50.45±10.32	52.58±12.44	59.63±4.87	48.17±7.38	8.688	0.034*
	Median (Min.-Max.)	48.4 (31.2-82.6)[a]	52.7 (31.2-82.6)[ab]	58.3 (55.9-69.5)[b]	48.6 (34.3-59.8)[ab]		

*Kruskal Wallis H test; **One-way Variance Analysis (ANOVA), a-c No significant difference between pelvic types with the same letter. m:meter, mm:millimeter, kg:kilogram, (°):degree

Table 2: Distribution of pelvis types based on gender.

	Android Type		Gynecoid Type		Platypelloid Type		Andropoid Type		Test Statistics	p*
	n	%	n	%	n	%	n	%		
Gender										
Female	30	30.6[a]	80	100.0[b]	7	100.0[bc]	15	53.6[ac]	95.119	<0.001
Male	68	69.4[a]	0	0.0[b]	0	0.0[bc]	13	46.4[ac]		

*Pearson chi-square test; a-cNo significant difference between pelvic types with the same letter.

TS corridors with a diameter of over 10 mm existed in 122 (57.3%) pelvic CTs at the S1 level and 85 (39.9%) at the S2 level. The TS corridor was over 10 mm in both AP and CC planes at the S1 level in 67.9% of the anthropoid pelvis group, 57.1% of the platypelloid pelvis group, 52.5% of the gynecoid pelvis group, and 58.2% of the android pelvis group(p=0,560). At the S2 level, 46.4% of the anthropoid pelvis group, 28.6% of the platypelloid pelvis group, 22.5% of the gynecoid pelvis group, and 53.1% of the android pelvis group had adequate corridor width in the AP and CC planes(p<0,001) (**Table 3** and **Figure 4-6**).

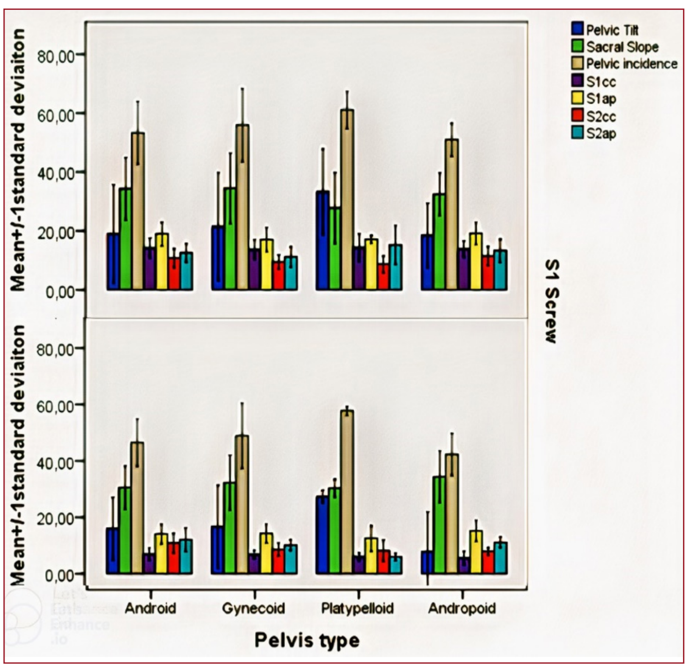

Figure 4: Comparison of pelvis types in terms of pelvic incidence, tilt, sacral slope and corridor width measurements in the patients whom the S1 screw can/cannot be inserted. Bar graph with +/-1 standard deviaiton of variables

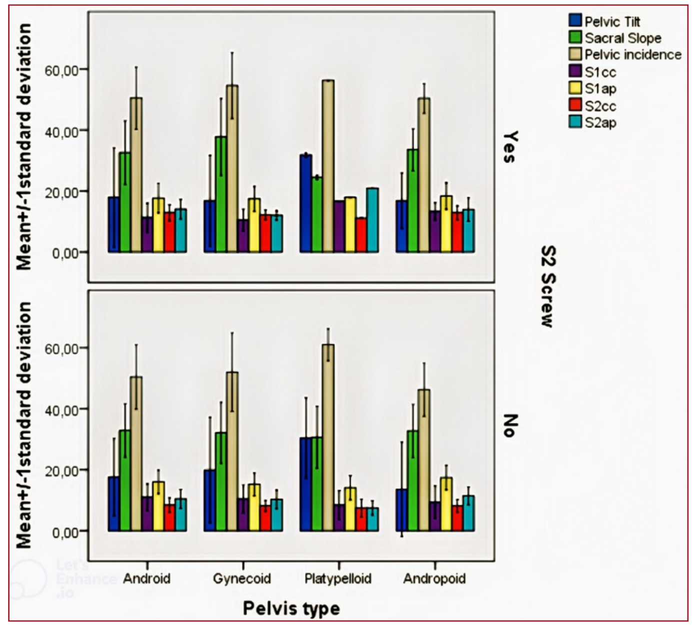

Figure 5: Comparison of pelvis types in terms of pelvic incidence, tilt, sacral slope and corridor width measurements in the patients whom the S2 screw can/cannot be inserted. Bar graph with +/-1 standard deviaiton of variables

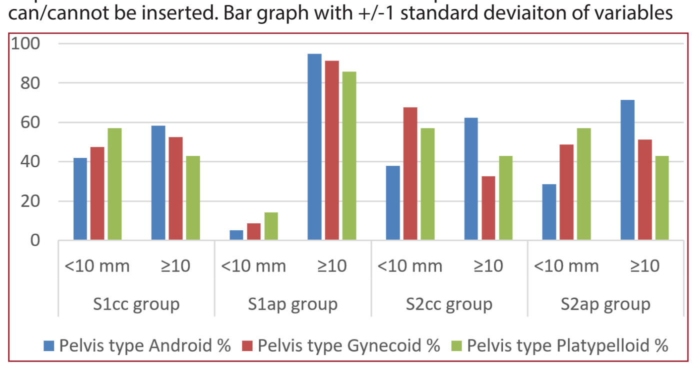

Figure 6: The percentage distribution of the patients with corridor lengths (in axial and frontal CT planes) over 10 mm and below 10 mm according to pelvis types.

Table 3: Distribution of qualitative variables by pelvis types

Variables		Total	Pelvis Type				p
			Android	Gynecoid	Platypelloid	Andropoid	
Gender	Female	132(62)	30(30,6)[a]	80(100)[b]	7(100)[bc]	15(53,6)[ac]	<0,001
	Male	81(38)	68(69,4)[a]	0(0)[b]	0(0)[bc]	13(46,4)[ac]	
S1_Screw	≥10 mm	122(57,3)	57(58,2)	42(52,5)	4(57,1)	19(67,9)	0,560
	<10 mm	91(42,7)	41(41,8)	38(47,5)	3(42,9)	9(32,1)	
S2_Screw	≥10 mm	85(39,9)	52(53,1)[a]	18(22,5)[b]	2(28,6)[ab]	13(46,4)[ab]	<0,001
	<10 mm	128(60,1)	46(46,9)[a]	62(77,5)[b]	5(71,4)[ab]	15(53,6)[ab]	

Pearson chi-square test was used. (ab): In same row, common letter indicates statistical insignificance. mm:millimeter

The effect of gender difference on the TS corridor width at the S1 and S2 levels was significant(p<0,001). An adequate corridor width for the TS screw was detected in 50.8% of females and 67.9% of males at the S1 level, while in 21.2% of females and 70.4% of males at the S2 level (**Figure 7**).

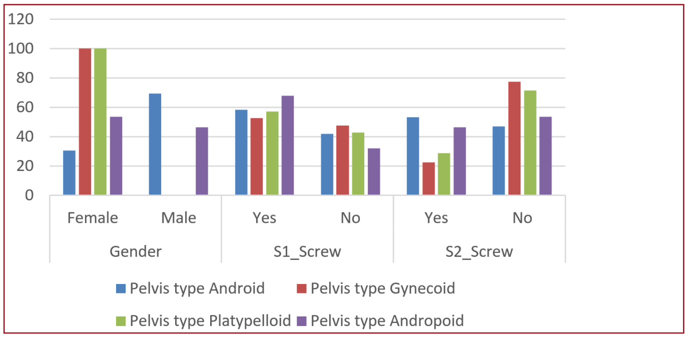

Figure 7: Distribution of pelvis types in terms of gender, adequacy for S1 and S2 screws

No significant difference was determined in terms of the mean values of the pelvic tilt and sacral slope according to the pelvis types (p=0.097 and p=0.663, respectively). It was found that there was a statistical difference in terms of the median values of the pelvic incidence with respect to pelvis types (p=0.034). The median values were determined to be 48.4° in the android group, 52.7° in the gynecoid group, 58.3° in the platypelloid group and 48.6° in the anthropoid group (**Table 1** and **Figure 8**).

DISCUSSION

In summary, according to the results obtained in this study, the anthropoid pelvis has wider S1 and S2 anteroposterior diameters and the largest S1 craniocaudal diameter among other pelvis types. In addition, the android pelvis type was more common in males and was more suitable for TS screw placement with wider TS bone corridors in the CC and AP planes at the S2 level. In the gynecoid pelvis type, which is more common in females, the diameter of the TS bone corridor was narrower at the S2 level in the CC and AP planes. Furthermore, an adequate corridor width for the TS screw was detected in 50.8% of females and 67.9% of males at the S1 level, while 21.2% of females and 70.4% of males at the S2 level.

Since we were unable to find any studies in the literature investigating the relationship between the pelvic inlet type and trans-sacral corridor, we could not directly compare our results with other studies. As well as gender-specific distinctions in the human pelvis can lead to differences in the shape and dimensions of the pelvic, the pelvic characteristics also differ within the same gender due to various external factors. Because of the complicated anatomical structure of the sacrum and the distinctions in the sacral morphology among individuals, performing a safe screw insertion requires this anatomical variability to be well understood.[13,14] It is known that the male pelvis is thick and heavy.[15] In general, gynecoid pelvis with a rounded shape corresponds to a normal female variant and android pelvis to a male variant.[15] Anatomical variances and diversions from the gender-specific characteristics can be observed in the pelvis.[15] The female sacrum is considered to be shorter, wider, and less forward-inclined than the male sacrum, which creates a larger, more oval pelvic inlet.[16] The sacral region has generally been found to be wider than the promontorium in females and narrower in males.[17] It has been stated that in comparison with males, females have a smaller sacral corridor,[18] are more likely to have a sacral dysmorphism.[18,19] On the contrary, in the literature, a study states that sacral dysmorphism is independent of gender despite significant differences in sacral morphology.[20] Although the prevalence of dysmorphic sacra varies between 28% and 53% as reported by Kaiser,

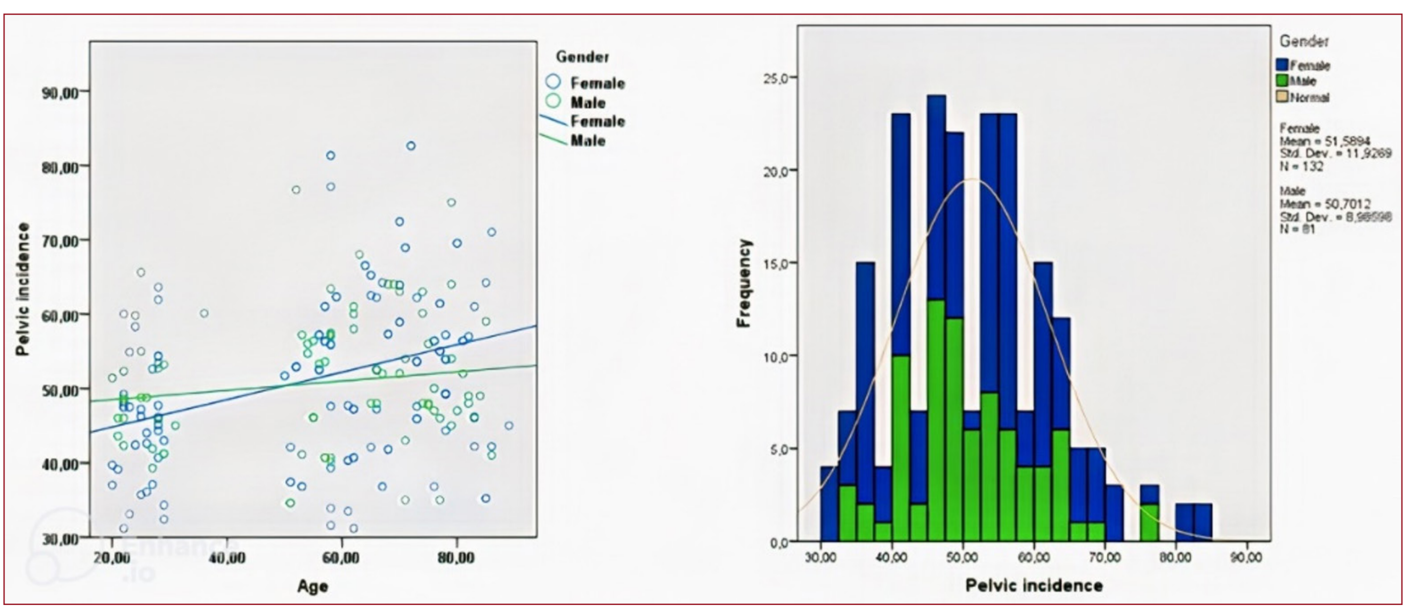

Figure 8: Pelvic incidence values slightly increased with age in both females and males

there are no studies revealing the relationship between pelvis type and sacral dysmorphism and adequate corridor width in patients with sacral dysmorphism.[7] Mendel et al.[22] detected that the S1 trans-sacral corridor in females was narrower than in males. Similarly, König et al.[19] reported significantly larger trans-sacral S2 corridor diameters in males compared to females. The study conducted by Gras et al.[18] revealed more dysmorphism in the female pelvis. In addition, they noted that trans-sacral corridor diameters of the male pelvis were larger than those of the female pelvis.[18] It has been stated in the literature that the corpus of the primary sacral portion of the first sacral vertebra in females is relatively smaller, and the lateral portion, on the other hand, is relatively larger.[23] Our results, which indicated that trans-sacral corridors at the S1 and S2 levels in females are consistent with these studies mentioned above as well as other previous relevant studies.[18,24] In the present research, the android pelvis type was seen in 46% of the study population regardless of gender. The S1 screw could be inserted to 57% of the patients. In the anthropoid pelvis, the rate of the patients with an S1 AP diameter of ≥ 10 mm was 100%, those with an S2 AP diameter of ≥ 10 mm was 89.3% and those with an S1 CC diameter of ≥ 10 mm was 67.9%. Of the patients having anthropoid pelvis type, 53.6% were female and 46.6% were male. In terms of the anatomy of transsacral osseous corridor, anthropoid and android pelvis types were more appropriate for screw insertion.

Determining the appropriate sacra for performing trans-sacral screw insertion procedure is important, however, the highly varied anatomy of the upper sacrum complicates the insertion of an implant at S1. In the literature, the threshold values for the minimal trans-sacral safe zone diameter differ from study to study.[13,25,26] In our study, we regarded that the safe trans-sacral region diameter should be 10 mm and above in both frontal and axial tomographic reconstructions in order not to damage the neurovascular structures and to ensure that the screws remain in the intraosseous corridor. The dissimilarity in the prevalence of trans-sacral S1 corridor in the literature may depend on geographical differences, the distinction of the measured sacral zones for safe zones and the disparity of cut-off values taken for adequate trans-sacral corridor. The adequate corridor width were determined by 8 mm by Gras et al.[18] and 10 mm by Gardner et al.[26] Gras et al.[18] reported that 64% of patients had the adequate S1 corridor and 88% had the adequate S2 corridor. In similar studies, König et al.[19] and Gardner et al.[26] detected that the adequate S1 corridor were present in 68% and 42% of patients, respectively, and the adequate S1 corridor were present in 68% and 72% of patients, respectively. On the other hand, Wagner et al.[27] stated that trans-sacral screws cannot be inserted into the S1 corridor in 26% of patients, whereas the S2 corridor always allows the safe insertion such screws. Another study conducted by Lee et al.[13] indicated that the trans-sacral S2 corridors cannot accommodate two screws due to their small dimensions. In our study, it was found that of the male patients, inserting the S1 screw in 67.9% and the S2 screw in 70.4% were possible.

In the study by Gardner et al.[26] there were adequate S1 and S2 horizontal corridors in 42% and 72% of patients, respectively. In the present study, while 57.3% of the patients had the S1 corridor of 10 mm or more in both planes, 39.9% of the patients had the S2 corridor of 10 mm or more in both planes. We detected that all four pelvis types were present in the female patients. However, there were no male patients with the gynecoid and platypelloid pelvis types. Fischer et al.[28] determined that the shape of the human pelvis is associated with body height. There are also studies indicating that the pelvic inlet of taller people is more oval and that of shorter people is more rounded.[28] In our study, the patients in the gynecoid and platypelloid pelvic groups were shorter.

The pelvic incidence not only shows the width of the pelvis and the balance of entire spine, but also assists us to get acquainted what kind of pelvis to encounter when the pelvis and the sagittal balance of the spine are impaired. In a study conducted by Abola et al.[29] it was shown that there is a relation between an increased pelvic incidence value and a more inclined sacrum, lower sacral-ala width and a SI joint with higher linearity. Inside the pelvis, a large PI value refers to an anteriourly positioned horizontal sacrum; a small PI value, on the other hand, refers to a posteriorly positioned and high vertical sacrum.[30] The results of the present study confirm this difference by revealing that the PI values changed depending on the pelvis type. The PI, which is the link between spinal and pelvic parameters, reflects the orientation of the sacrum within the pelvis, not that of the entire pelvis. Although pelvic incidence is of great significance in the assessment of sagittal parameters in the spinal surgery, the causes of the said large variability in pelvic incidence in the normal population have yet to be discovered. The mean PI values have been reported to be in the range of 41° and 54°. Mehta et al.[31] found that the mean values of pelvic incidence was 48°-55°, the sacral slope was 36°-42°, and the pelvic tilt was 12° and 18°. It has been indicated that the normative value of PI In the Caucasian population is 50°–55° , whereas this value is lower in the Asian population.[32] In the assessments made according to the gender difference, it has been observed that females have higher PI values than males. Likewise, we detected that the pelvic incidence values in females (51.5°) were higher than in males (50.7°). In the present study, the pelvic incidence varied in a wide range from 31.2° to 82.6°. It is considered that the PI gradually increases with the development of gait in childhood.[30] It was seen in our study that the PI values slightly increased with age in both females and males. We also detected that the pelvic incidence was higher in the gynecoid and platypelloid groups.

Our study included certain limitations. First of all, the CT scans examined had been taken with the patient supine and for other medical indications. There were no patients with pelvic ring injury in the study cohort. Therefore, these results do not reflect the condition of patients with prior pelvic injury, or who underwent pelvic surgery. However, the cohort represents a normal population with a broad age range (20-89), except for the group of patients with CT pelvic ring fractures.

When a screw-like cylindrical shaped volume is not used when measuring trans-sacral corridor diameters, the measured diameter does not exactly complies with the screw application and therefore represents only the maximum osseous corridor height. In our study, the cut-off value was taken as 10 mm. In the studies in the literature, different cut-off values such as 7.5 mm, 8 mm, 10 mm and 12 mm have been used, which restricts the comparison of results between studies. Additionally, the frequency of dysmorphic sacral was not discussed in our study. Sacral dysmorphism and narrow sacral corridors complicate the trans-sacral implant insertion.[26,33] It has been stated that the number of patients with inadequate corridor at the s1 level in dysmorphic sacra is higher than normal.[12] Even in sacra that have been classified as non-dysmorphic, a horizontal corridor that can accommodate a screw may be absent in 25% of cases. However, the sacrum which does not allow the trans-sacral insertion of screws with specific sizes is regarded as dysmorphic. There are also studies in which the absence of a trans-sacral corridor at the S1 vertebra is described as sacral dysmorphism.[18,34] Since we assessed the corridor diameter in our study after all, we regarded that the patients with corridors that do not allow trans-sacral screw fixation as dysmorphic, as in the literature. However, it is not clear whether this would have any real value in clinical practice, because the use of navigation systems has provided trans-sacral screw technique to evolve considerably. On the other hand, navigation systems that help to avoid the problem of sacral dysmorphism in almost all cases, are not yet in use in most countries and centers.

CONCLUSION

There is a significant difference in the dimensions of the trans-sacral screw corridor according to the pelvis type and gender, with the largest diameter observed in the anthropoid pelvis type and males. In critical situations, especially in males and individuals with android-anthropoid pelvis, the trans-sacral screw option can be considered primarily not only for the S1 trans-sacral corridor but also for the S2 trans-sacral corridor in pelvic posterior ring injuries.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Tokat Gaziosmanpaşa University Faculty of Medicine Clinical Researches Ethics Committee (Date: 04.11.2021, Decision No: 21-KAEK-236).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Melhem E, Riouallon G, Habboubi K, Gabbas M, Jouffroy P. Epidemiology of pelvic and acetabular fractures in France. Orthop Traumatol Surg Res. 2020;106(5):831-9.
2. Nork SE, Jones CB, Harding SP, Mirza SK, Routt Jr MC. Percutaneous stabilization of U-shaped sacral fractures using iliosacral screws: technique and early results. J Orthop Trauma. 2001;15(4):238-46.
3. Kannus P, Parkkari J, Niemi S, Sievänen H. Low-trauma pelvic fractures in elderly Finns in 1970–2013. Calcif Tissue Int. 2015;97:577-80.
4. Sahito B, Kumar J, Rasheed N, Katto MS. Anterior Pelvic Plate Osteosynthesis And Percutaneous Sacroiliac Joint Screw Fixation In Open-Book Pelvis Fracture. JPUMHS 2021;11(2):70-3.
5. Gardner MJ, Routt Jr MC. Transiliac–transsacral screws for posterior pelvic stabilization. J Orthop Trauma. 2011;25(6):378-84.
6. Routt Jr MC, Simonian PT. Closed reduction and percutaneous skeletal fixation of sacral fractures. Clin Orthop Relat Res (1976-2007). 1996;329:121-8
7. Mears SC, Sutter EG, Wall SJ, Rose DM, Belkoff SM. Biomechanical comparison of three methods of sacral fracture fixation in osteoporotic bone. Spine (Phila Pa 1976). 2010;35(10):E392-E5.
8. Chip Jr MC, Simonian PT, Agnew SG, Mann FA. Radiographic recognition of the sacral alar slope for optimal placement of iliosacral screws: a cadaveric and clinical study. J Orthop Trauma. 1996;10(3):171-7.
9. Wagner D, Kamer L, Rommens PM, Sawaguchi T, Richards RG, Noser H. 3D statistical modeling techniques to investigate the anatomy of the sacrum, its bone mass distribution, and the trans-sacral corridors. J Orthop Res. 2014;32(11):1543-8.
10. Caldwell WE, Moloy HC. Anatomical variations in the female pelvis and their effect in labor with a suggested classification. Am J Obstet Gynecol. 1933;26(4):479-505.
11. Iga T. Iliosacral screw corridors in Japanese subjects: a study using reconstruction CT scans. OTA International. 2021;4(3).
12. Wagner D, Kamer L, Sawaguchi T, Richards RG, Noser H, Hofmann A, et al. Morphometry of the sacrum and its implication on trans-sacral corridors using a computed tomography data-based three-dimensional statistical model. Spine J 2017;17(8):1141-7.
13. Lee JJ, Rosenbaum SL, Martusiewicz A, Holcombe SA, Wang SC, Goulet JA. Transsacral screw safe zone size by sacral segmentation variations. J Orthop Res. 2015;33(2):277-82.
14. Jäckle K, Paulisch M, Blüchel T, et al. Analysis of trans-sacral corridors in stabilization of fractures of the pelvic ring. J Orthop Res. 2022;40(5):1194-202.
15. Leong A. Sexual dimorphism of the pelvic architecture: a struggling response to destructive and parsimonious forces by natural & mate selection. McGill Journal of Medicine: MJM. 2006;9(1):61.
16. Klales AR. Sex estimation using pelvis morphology. Sex estimation of the human skeleton: Elsevier; 2020. p. 75-93.
17. Christensen A, Passalacqua N, Bartelink E. Current methods in forensic anthropology. United Kingdom: Elsevier; 2014.
18. Gras F, Gottschling H, Schröder M, Marintschev I, Hofmann GO, Burgkart R. Transsacral osseous corridor anatomy is more amenable to screw insertion in males: a biomorphometric analysis of 280 pelves. Clin Orthop Relat Res. 2016;474:2304-11.
19. König M, Sundaram R, Saville P, Jehan S, Boszczyk BM. Anatomical considerations for percutaneous trans ilio-sacroiliac S1 and S2 screw placement. Eur Spine J. 2016;25:1800-5.
20. Balling H. Gender-associated differences in sacral morphology do not affect feasibility rates of transsacral screw insertion. Radioanatomic investigation based on pelvic cross-sectional imaging of 200 individuals. Spine (Phila Pa 1976). 2020;45(7):421-30.

21. Kaiser SP, Gardner MJ, Liu J, Routt Jr MC, Morshed S. Anatomic determinants of sacral dysmorphism and implications for safe iliosacral screw placement. JBJS. 2014;96(14):e120.
22. Mendel T, Radetzki F, Wohlrab D, Stock K, Hofmann GO, Noser H. CT-based 3-D visualisation of secure bone corridors and optimal trajectories for sacroiliac screws. Injury. 2013;44(7):957-63.
23. Nastoulis E, Karakasi M-V, Pavlidis P, Thomaidis V, Fiska A. Anatomy and clinical significance of sacral variations: a systematic review. Folia Morphol (Praha). 2019;78(4):651-67.
24. Day C, Prayson M, Shuler T, Towers J, Gruen G. Transsacral versus modified pelvic landmarks for percutaneous iliosacral screw placement--a computed tomographic analysis and cadaveric study. Am J Orthop (Belle Mead, NJ). 2000;29(9 Suppl):16-21.
25. Schultz BJ, Mayer RM, Phelps KD, et al. Assessment of sacral osseous fixation pathways for same-level dual transiliac–transsacral screw insertion. Arch Orthop Trauma Surg. 2023:1-8.
26. Gardner MJ, Morshed S, Nork SE, Ricci WM, Routt Jr MLC. Quantification of the upper and second sacral segment safe zones in normal and dysmorphic sacra. J Orthop Trauma. 2010;24(10):622-9.
27. Wagner D, Kamer L, Sawaguchi T, et al. Critical dimensions of trans-sacral corridors assessed by 3D CT models: relevance for implant positioning in fractures of the sacrum. J Orthop Res. 2017;35(11):2577-84.
28. Fischer B, Mitteroecker P. Covariation between human pelvis shape, stature, and head size alleviates the obstetric dilemma. Proceedings of the National Academy of Sciences. 2015;112(18):5655-60.
29. Abola MV, Teplensky JR, Cooperman DR, Bauer JM, Liu RW. Pelvic incidence is associated with sacral curvature, sacroiliac joint angulation, and sacral ala width. Spine (Phila Pa 1976). 2018;43(22):1529-35.
30. Boulay C, Tardieu C, Hecquet J, et al. Anatomical reliability of two fundamental radiological and clinical pelvic parameters: incidence and thickness. Eur J Orthop Surg Traumatol. 2005;15(3).
31. Mehta VA, Amin A, Omeis I, Gokaslan ZL, Gottfried ON. Implications of spinopelvic alignment for the spine surgeon. Neurosurgery. 2012;70(3):707-21.
32. Le Huec J, Demezon H, Aunoble S. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. Eur Spine J. 2015;24:63-71.
33. Morshed S, Choo K, Kandemir U, Kaiser SP. Internal fixation of posterior pelvic ring injuries using iliosacral screws in the dysmorphic upper sacrum. JBJS essential surgical techniques. 2015;5(1).
34. Conflitti JM, Graves ML, Routt Jr MC. Radiographic quantification and analysis of dysmorphic upper sacral osseous anatomy and associated iliosacral screw insertions. J Orthop Trauma. 2010;24(10):630-6.