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Sacro-pelvic anthropometry in the Portuguese population and its implication for screw placement in spinal surgery: a CT-based study

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Abstract

Introduction: The sacrum is the target of lumbosacropelvic instrumentation in fractures, deformities and instabilities. These surgical interventions require detailed knowledge of the anatomy of the sacrum. Also, there are no anatomic references in sacropelvic trajectories for screw placement in the Portuguese population.

Objective: Assess the sacro-pelvic anthropometry in the Portuguese population, through the study of pelvic CT scans.

Methods: Forty individuals pelvic CT scans were analysed and measurements were performed according to predefined screw trajectories of S1 anterior (S1A), anterolateral (S1AL) and anteromedial (S1AM), S2 anterolateral (S2AL) and anteromedial (S2AM), S2 alar iliac (S2AI), iliac and sacroiliac (SI) screws. For each trajectory, length and angles were measured and comparisons between genders were made.

Results: The S1A screw trajectory mean length was 30,80 ± 3,31mm. The S1AL screw trajectory mean length and lateral angle were 36,48 ± 5,39mm and 33,13° ± 6,06, respectively, and the S1AM´s were 46,23 ± 3,36mm and 33,21° ± 3,86. The S2AL screw trajectory mean length was 28,66 ± 2,46mm and mean lateral angle was 26,52° ± 3,31 and the S2AM were 29,99 ± 4,05mm and 33,61° ± 3,53. The S2 alar iliac mean length, lateral and caudal angles were 125,84 ± 8,19mm, 36,78° ± 3,27 and 28,66° ± 5,78, respectively. The iliac screw mean length, lateral and caudal angles were 136,73 ± 8,75mm, 23,86° ± 3,00 and 24,01° ± 5,34, respectively. The sacroiliac screw trajectory mean length was 75,50 ± 4,75mm. Additionally, with regard to gender analysis, the length of the screws was longer in men than in women, except for the S1A and SI screws, in which there were no differences between genders.

Conclusion: This study describes sacropelvic anatomical specifications. These defined morphometric details should be taken into consideration during surgical procedures.

Key words: Sacro-pelvic anthropometry, sacro-pelvic screw placement, screw trajectory, spinal surgery, Portuguese population

Resumo

Introdução: O sacro é alvo de instrumentação lombo-sacro-pélvica em fraturas, deformidades e instabilidades. Estas intervenções cirúrgicas requerem um conhecimento detalhado da anatomia do sacro. Para além disso, na bibliografia atual, não existem referências anatómicas para colocação de parafusos nas trajetórias sacro-pélvicas na população portuguesa.

Objetivo: Avaliar a antropometria sacro-pélvica na população portuguesa, através do estudo de tomografias axiais computorizadas pélvicas (TACs).

Métodos: As TACs pélvicas de quarenta indivíduos foram analisadas e foram realizadas medições de acordo com trajetórias pré-definidas, nomeadamente, S1 anterior (S1A), anterolateral (S1AL) e anteromedial (S1AM), S2 anterolateral (S2AL) e anteromedial (S2AM), S2 alar ilíaca (S2AI), ilíaca e sacroilíaca (SI). Para cada trajetória, foram medidos o comprimento e os ângulos e foi feita a comparações entre os géneros.

Resultados: O comprimento médio da trajetória do parafuso S1A foi de 30,80 ± 3,31mm. O comprimento médio e o ângulo lateral da trajetória do parafuso S1AL foram 36,48 ± 5,39mm e 33,13° ± 6,06, respetivamente, e os do S1AM foram 46,23 ± 3,36mm e 33,21° ± 3,86. O comprimento médio do parafuso S2AL foi de 28,66 ± 2,46mm e o ângulo lateral médio foi de 26,52° ± 3,31 e os do S2AM foram 29,99 ± 4,05mm e 33,61° ± 3,53. O comprimento médio, os ângulos lateral e caudal da trajetória S2 alar ilíaca foram 125,84 ± 8,19mm, 36,78° ± 3,27 e 28,66° ± 5,78, respetivamente. O comprimento médio, os ângulos lateral e caudal da trajetória ilíaca foram 136,73 ± 8,75mm, 23,86° ± 3,00 e 24,01° ± 5,34, respetivamente. O comprimento médio da trajetória sacroilíaca foi de 75,50 ± 4,75mm. Adicionalmente, no que concerne às diferenças entre géneros, o comprimento dos parafusos foi maior nos homens do que nas mulheres, exceto nos parafusos S1A e SI, nos quais não houve diferenças.

Conclusão: Assim, este estudo descreve referências anatómicas sacropélvicas que devem ser levados em consideração durante os procedimentos cirúrgicos.

Palavras-chave: Antropometria sacro-pélvica, colocação de parafusos sacro-pélvicos, trajetória de parafusos, cirurgia da coluna vertebral, população portuguesa

Abbreviation list

AIIS - Antero inferior iliac spine

CT - Computerized tomography

F - Female

M - Male

PSIS - Posterior superior iliac spine

S1A - S1 anterior

S1AL - S1 anterolateral

S1AM - S1 anteromedial

S2AI - S2 alar iliac

S2AL - S2 anterolateral

S2AM - S2 anteromedial

SI - Sacroiliac

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Introduction

The sacrum is an irregular bone formed by the fusion of five vertebrae with fused transverse processes that make up two large lateral bony masses called the alae. The five vertebrae gradually decrease in diameter toward its caudal end, giving it a unique inverted triangular appearance, with its base superior and apex inferior and with an anterior concavity and posterior convexity. Through the centre of the sacral body passes the triangular-shaped sacral canal, which is the continuation of the lumbar vertebral canal. It terminates inferiorly at the sacral hiatus and contains sacral and coccygeal nerve roots, spinal meninges (to the level of S2) and filum terminal.[1] The sacrum, serving as the foundation of the spine, transmits the stress between the spine and the pelvis through the sacroiliac joints.

Lumbo-sacro-pelvic instrumentation is frequently performed in posterior pelvic ring injuries such as sacroiliac joint disruptures, unstable sacral fractures, scoliosis, spondylolisthesis, other forms of deformity or instability and also in long fusion constructs.[2] Each of these indications require spinopelvic instrumentation in order to restore optimal spino-pelvic-lower extremity alignment, to provide a secure lumbosacral fixation that can resist cantilever flexion movements, thereby reducing the risk of failure[3] and allow proper weight-bearing.[4]

In spinal injuries correction preservation of lower spine mobility may result in implant failure, rod breakage, pseudarthrosis or neurological deficits. Therefore, extension of spine fusion to the sacrum represents a significant improvement in clinical outcomes and decreases major complications. Long fusion constructs are defined as fusions that extend from the sacrum to L2 or higher and require the addition of pelvic fixation in order to achieve optimal spinal stabilization[3]. Lumbopelvic fixation produces an arthrodesis of the lumbosacral junction that immobilizes the joints at the level of the fusion.[5]

Patients that require sagittal spinal realignment and/or neurological decompression, especially in those that undergo pedicle subtraction osteotomy, stabilization through pelvic instrumentation is recommended.[3] In cases of high grade spondylolisthesis, surgical treatment shows high rates of screw pull-out and loss of reduction when instrumentation is used without sacropelvic fixation. When applied, it may improve outcomes and reduce neurologic complications. In patients with neuromuscular deformities, like scoliosis, requiring pelvic obliquity correction, additional pelvic fixation is needed as lumbar or sacral fixation are often insufficient, especially when the deformity reaches the lower levels of the lumbar spine.[1]

In patients with multiple injuries from high energy trauma with unstable sacral fractures or sacro-iliac joint disruption, a rapid intervention is essential. Because of its close proximity to the sacrum, neurovascular structures may be injured in a sacral fracture, leading to hemodynamic instability.[6] While pelvic stabilisation with external fixation may be performed in the emergency setting, ilio-sacral or spino-pelvic instrumentation may be required as definitive treatment and to allow for faster weightbearing and avoid complications related to prolonged immobilization (deep vein thrombosis, pneumonia, bed ulcers...).[3]

Instrumentation of the sacrum is challenging. The lumbosacral junction is not easy to manipulate because it connects the lumbar spine to the pelvis, which is less mobile. So, due to the sacral slope, movements in different planes apply enormous pressure on the sacrum. Furthermore, when approaching the sacrum posteriorly, screw fixation may place anterior anatomic structures at risk if anterior cortical penetration by an orthopaedic implants occurs. This is mainly due to poor screw placement because of the irregular bony morphology and the proximity to neurovascular structures such as the internal iliac vessels, lateral sacral artery, middle sacral artery, hypogastric plexus and sympathetic trunk, that are responsible for normal bowel, bladder, and sexual function and can cause notable morbidity if damaged.[7]

The goal of this study was to assess the sacro-pelvic anthropometry in the Portuguese population, through the study of pelvic CT scans in patient's clinical and imagiological records from Centro Hospitalar Universitário do Porto's database, and to analyze its implication in screw placement, namely length and orientation, to aid in spinal surgery.

Methods

This is a single-centre retrospective medical record review in which clinical files from 53 patients were analysed. The SECTRA IDS7® (version 17.3.2086) database was utilized. The selected population included all patients in the database categorized as having performed a pelvic CT-scan from November 25 2019 to February 29 2020. The study was approved by the local ethics committee (REF: 2019.354(289-DEFI/308-CE)).

From the 53 patients, 13 were excluded for the following reasons: incomplete/ absent CT scans, active fractures, bone neoplasms, osteomyelitis, osteopenic disorders (osteoporosis, osteomalacia), lumbar scoliosis (Cobb angle > 20°), spina bifida, in situ spinal or pelvic implants, age <18 years old and history of lumbar-sacral-pelvic surgery.[8]

The remaining CT scans from 40 patients were analysed by running the DICOM files through the software Surgimap® (v2.3.2.1, Nemaris Inc., New York, NY).

Measurements of the sacro-pelvic anthropometry were made based on pre-defined screw trajectories such as S1 pedicle, in its anterior (S1A), anterolateral (S1AL) and anteromedial (S1AM) trajectories, S2 pedicle anterolateral (S2AL) and anteromedial (S2AM) trajectories, S2 alar iliac (S2AI), iliac and sacroiliac (SI) trajectories.

The trajectories were measured on the right side of every pelvis and the measurements were made by 2 investigators in order to reduce bias and minimize errors. Each individual measurement was then confirmed and reanalysed when needed. All measurements were performed without crossing the bone`s cortical layer but with the maximum length allowed. In addition to the length, lateral and caudal angles were also measured, in the axial and sagittal plane, respectively, according to the trajectory being measured. Also, in all screw trajectories it was ensured that the bone corridor was wide enough for the screw to perforate, using a screw diameter with minimum 6mm.

S1 pedicle screws

Three trajectories were analysed for the S1 screw. The S1A trajectory was directed into the junction of the sacral ala and vertebral body, with the trajectory making a 90° angle with the horizontal line in the axial plane (Figure 1). The S1AL screw was directed into the sacral ala (Figure 2) and the S1AM into the sacral promontory (Figure 3).

The starting point used was the inferolateral aspect of S1 facet joint.[9]

S2 pedicle screws

The starting point of both S2 pedicle screw trajectories was the fusion between the sacral lamina and the lateral sacral ala with the S2AL being directed laterally (Figure 4) and the S2AM being directed medially (Figure 5).[7]

Measurements in both S1 and S2 trajectories were performed after aligning the screw trajectory parallel to the superior endplate in the sagital plane since such positioning of the screw allows for a reduction in screw breakage in axial loading and provides stronger stability.[10]

S2 alar iliac screw

The S2AI screw trajectory starting point used was 1mm inferior and 1mm lateral to the S1 dorsal foramen. The direction used was based on the lateral (between screw trajectory and the vertebra`s middle line in the axial plane) and caudal angle (between screw trajectory and the horizontal line in the sagittal plane) described in existent literature (Figure 6). The mean lateral angles used as reference were 32,40° to 52,20° and the mean caudal angles were 27,50° to 39°.[11]

Iliac screw

The Iliac screw trajectory starting point was the posterior superior iliac spine (PSIS) into the anterior inferior iliac spine (AIIS) without crossing the cortical layer (Figure 7).[12]

Sacroiliac screw

The SI screw starting point was on the outer table of the ilium 3cm anterior to the PSIS and 4cm cephalad to the greater sciatic notch, through a corridor of bone in the ilium, SI joint, sacral ala and into the sacral promontory, through the S1 joint. The screw was directed perpendicularly to the outer surface of the table (Figure 8).[13]

Statistical analysis

Testing for inter-observer correlations was performed with the estimation of Cronbach`s alpha and the intercorrelation matrix.

In order to get a better understanding of the results obtained, the mean length and angles for each gender were also calculated and a statistical comparison was made between these parameters, using the t-test for independent samples, to identify statistically significant differences. A $p<0,05$ was considered to be significant.

Data was collected in Microsoft Excel® (Version 2013, Microsoft Inc, Redmond, WA, USA) and transferred to SPSS® (Version 26, IBM, Armonk, New York, USA) for descriptive and analytical statistics.

Results

The studied population was composed of 24 men and 16 women (60 vs 40% respectively), the mean age at the date of data collection was 63.88 ± 15,23. In males the mean age was 65,50 ± 15,18, respectively and in females the mean age was 61,44 ± 15,46 (Table I).

There was good correlation ($\alpha>0.5$) between the measurement performed by the two investigators for all measurements and angles except for the S2AL screw length (Table II). Therefore, for each individual, the mean length and mean angulation for each trajectory (Table III) and for each gender (Table IV) were calculated.

The correlation between male and female demonstrated that mean screw length in males was higher than in women for the S1AL, S1AM, S2AL, S2AM, S2AI and Iliac screws. There were no gender differences for the S1A and SI screw length (p>0,05). There were no significant differences between the angles in each gender (Table V).

S1 pedicle screw

The S1A screw trajectory´s mean length was 30,80 ± 3,31mm. In males the distance was 31,35 ± 3,50mm and 29,97 ± 2,91mm in females (p=0,198).

The S1AL screw trajectory´s mean length and lateral angle were 36,48 ± 5,39mm and 33,13° ± 6,06, respectively. In males were 38,26 ± 5,58mm and 32,73° ± 5,74 and in females were 33,81 ± 3,88mm (p=0,009) and 33,73° ± 6,66 (p=0,614).

The S1AM screw trajectory´s mean length and lateral angle were 46,23 ± 3,36mm and 33,21° ± 3,86, respectively. In males were 47,58 ± 3,15mm and 33,84° ± 3,85 and in females were 44,19 ± 2,62mm (p=0,001) and 32,27° ± 3,80 (p=0,209).

S2 pedicle screw

The S2AL screw trajectory´s mean length was 28,66 ± 2,46mm and mean lateral angle was 26,52° ± 3,31. In males were 29,35 ± 2,56mm and 27,11° ± 3,23 and in females were 27,63 ± 1,93mm (p=0,027) and 25,63° ± 4,80 (p=0,166).

The S2AM screw length was 29,99 ± 4,05mm and the lateral angle was 33,61° ± 3,53. In males was 31,01 ± 4,41mm and 33,10° ± 2,33 and in females was 28,45 ± 2,96mm (p=0,049) and 34,36° ± 4,80 (p=0,276).

S2 alar iliac screw

The S2 alar iliac mean length, lateral and caudal angles were 125,84 ± 8,19mm, 36,78° ± 3,27 and 28,66° ± 5,78, respectively. In males were 128,83 ± 7,61mm, 36,79° ± 3,17 and 28,18° ± 6,09 and in females were 121,34 ± 7,06mm (p=0,003), 36,77° ± 3,51 (p=0,981) and 29,39° ± 5,38 (p=0,522).

Iliac screw

The iliac trajectory´s mean length, lateral and caudal angles were 136,73 ± 8,75mm, 23,86° ± 3,00 and 24,01° ± 5,34, respectively. In males were 140,69 ± 7,80mm, 23,98° ± 2,70 and 24,15°

± 5,09 and in females were 130,78 ± 6,58mm (p<0,001), 23,69° ± 3,48 (p=0,767) and 23,81° ± 5,85 (p=0,849).

Sacroiliac screw

The sacroiliac trajectory´s mean length was 75,50 ± 4,75mm. In males it was 75,35 ± 4,56mm and 75,72 ± 5,17mm in females (p=0,816).

Discussion

Pedicle screw fixation using S1 and S2 pedicle screws has been relatively successful especially in lower spine fixation. Nevertheless, there are still instrumentation failures and pseudarthrosis with this procedure.[14]

The low bone mineral density of the sacral bone, the large loads acting in the lumbar spine and pelvis result in a high risk of pullout and loosening of the instrumentation, mostly in long fusion constructs in the treatment of spondylolisthesis or scoliosis. Therefore, some modified techniques have been introduced to improve the fixation strength, provide appropriate biomechanical support and decrease failure rates with screw fixation. Those techniques are the S2AI screw and the iliac screw, which reduce the stress in the S1/S2 screw. Fusion rates in the lumbosacral junction have improved over 90% using these two techniques.[1] Conversely, it is important to realize that additional fixation comes with increased risks such as neurovascular injury, screw related complications or sacroiliac joint disruption.[14, 15]

In addition, injuries like posterior pelvic ring fractures and SI joint disruptions are difficult to manage because the pelvis has an irregular and complex cortical surface and is also a weight-bearing structure supporting 70% of body weight. Dynamic imbalance of the pelvis caused by poor fracture reduction often results in dysfunctions of weight bearing, which are also serious complications. In view of these, challenges still exist, for orthopedic surgeons, to acquire high-quality reduction of the posterior pelvic ring.[16]

The accuracy of free hand techniques of screw placement relies on visible and palpable anatomic landmarks and requires a standardized approach in order to be safe and reliable. Comparatively, the use of spinal navigation for routine insertion of screws is still being debated, however it has become the gold standard in many hospitals and there is a consensus concerning the higher accuracy rate, improved clinical outcome, and decreased complication rate in spinal deformity.[17]

The freehand technique would be preferable to obviate the need for intraoperative fluoroscopy or image guidance, potentially reducing operative time and radiation exposure.[18] However, many surgeons are not familiarized with free hand screw placement.[2] The learning curve for freehand screw fixation is steep and the surgeon's experience, therefore, has become a key factor, with senior and more experienced surgeons being the most promising candidates to achieve a favourable outcome.[17] As a result, in the freehand technique there is greater risk of complications with screw placement and, despite improved outcomes, even with image-guided screw placement there are still some complications.[19]

Due to increasingly sophisticated techniques for sacral instrumentation, it is of vital importance to have anatomic references, especially related to length and angle for screw insertion in order to reduce complications, provide augmented load bearing stability to the patient`s pelvis and maintain patient safety.

There are several studies that described the anthropometric traits of some of the sacropelvic screw trajectories. Despite that, none of them had a complete description of all the major screw trajectories in the same population. Furthermore, there are no anatomic references for sacropelvic screw placement in the Portuguese population. Therefore, it is important to provide those references and also, to integrate this knowledge with that from the available international literature (Table VI).

In this study the S1A screw length was approximately 31mm. However, this screw trajectory is rarely used as it has less resistance pull out load as a screw inserted laterally into the ala or medially[20]. In Xu et al. the distance measured in this trajectory was 30mm.[21]

Asher et al. conducted a similar anthropometric study using cadaver specimens and determined that the S1AL screw length was 39mm in males and 37mm in females, while using a fixed lateral angle of 25°.[22] In the current study the distance was 38mm in males and 34mm in females with a 33° and 34° lateral angle, respectively.

In addition to screw length, which is important with regard to biomechanical stability and risk of neurovascular injury, the usage of appropriate angulation must also be considered. Mirkovic et al. concluded that the length of laterally-oriented sacral screws depends mainly on the degree of orientation, using a 30° angle the mean screw length was 38mm and with a 45° angle the length was 44mm for the S1AL. However, achieving maximum distance in screw trajectory does not provide the best outcome as it was reported that 45° laterally oriented screws to the sacral wing had a high potential for lumbosacral trunk impingement (55%) and the rate of sacroiliac joint injury was 10%.[23] Hence a well positioned shorter screw is preferable than longer but poorly placed one.

Ota et al. compared two surgical approaches to the S1 pedicle screw entry point and concluded that the technique used has influenced by the insertion angle of the screw, which had an effect in trajectory distance. The distance measured for the S1AM was 46mm with a 23° angle using the same entry point as in the current study. The S1AM measurements in Asher et al. were 50mm in males and 47mm in females with a predetermined angulation of 35°.[22] It is generally agreed that the anteromedial trajectory provides greater stability than S1A and S1AL, because the bone density in the central region of the sacrum is greater than in the sacral ala by 30 to 60%.[14] Here, the length and angle for males and females were 48mm and 34° and 44mm and 33°, respectively.

In the current study, the S2AL screw measured 29mm with a 27° angle and the S2AM 30mm with a 34° angle. Xu et al. analysed five cadaveric pelvis and 40 dry bony specimens to assess the feasibility of the lumbosacral plate fixation extending beyond the S1 region and to evaluate the posterior sacroiliac region and the dimensions of S1 and S2 pedicle and lateral mass and found that the S2AL and S2AM screw lengths were 34 and 32mm, respectively, using a 30° angle for either trajectory.[21]

Zhu et al. used CT-scans to determine the sacral anthropometry of the Chinese population in order to understand the feasibility of placing S2AI screw. In their study (which also analysed the right side of the pelvis) the screw length was 121mm with a 37° lateral and 30° caudal angles in males and 116mm with 46° lateral and 35° caudal angles in females.[24] In the current study the length was 129mm with 37° lateral and 28° caudal angles in males and 121mm with 37° lateral and 29° caudal in females. Importantly, the same entry point was utilized in the Chinese and in the current study.

Berry et al. analysed two trajectories for iliac screw placement: the starting point was the PSIS into either the AIIS or the superior rim of the acetabulum, measuring 147mm in males and 141mm in females, and 128mm in males and 124mm in females, respectively. The study concluded that the trajectory into the AIIS was safer because it was longer and provided more security while, conversely, the other trajectory had risk of acetabular penetration.[12] Therefore, in the current study, the trajectory used was into the AIIS and the distance measured was 141mm in males and 131mm in females. The lateral and caudal angles measured were 24° for either angle and gender.

S2AI and iliac screws are both used for sacro-pelvic stabilisation. The iliac screw has been widely used but its entry point at the PSIS requires considerable soft tissue dissection in order to remove the bone block for screw insertion, which has the potential to increase the risk of wound complications, and increase post-operative pain secondary to the extensive soft tissue manipulation.[11] Previous studies have shown that 44% of patients treated with iliac screws suffer from complications related to implant failure or prominence over the PSIS.[24] The S2AI screw has been more recently described to obviate some of these caveats.[25] Its entry point is medial to the iliac screw, requiring less soft tissue dissection, and avoiding instrumentation prominence, among other advantages.[11]

The last trajectory analysed in this study was the sacroiliac trajectory that in Ebraheim et al measured at 80mm[13] and in the current study measured 76mm. This screw is most often used to stabilize sacro-pelvic joint disruptions and has the advantage of percutaneous insertion.[26]

Sacral dysmorphism is defined by variations in the normal sacral anatomy such as angulated upsloping sacral ala, transverse processes termed "mamillary bodies", incomplete upper sacral segment disk space, deformed noncircular-appearing upper sacral neural foramina, and tongue-in-groove undulating sacroiliac joint surfaces.[27] In this study, sacral dysmorphism was not an exclusion criteria because almost half (44%) of the adult population is classified as having a dysmorphic sacrum.[26] The sacroiliac screw trajectory is the most affected by sacral dysmorphism. In dysmorphic sacral bones, the upper sacral segment safe zone is significantly smaller and more obliquely oriented, which can constitute a problem for proper screw placement. However, the bone corridor is still large enough to accommodate an iliosacral screw in nearly all patients.[26] In 97% of males and 94% of females with dysmorphic pelves there is a wide enough bone corridor (>7,5mm) for oblique sacroiliac screw fixation in the S1 vertebra.[8] Therefore, excluding those cases would not constitute an advantage or allow the sample to be representative of the population.

This study has some limitations. First, only the right side of the patient's pelvis was measured. Secondly, whereas the Surgimap® software used is reliable and user friendly, all measurements were made manually and are investigator-dependent. To overcome this limitation, 2 independent investigators measured the screw trajectory lengths and angles and a good concordance was obtained for all but for one measurement.

In summary, this study is, to our knowledge, the first to provide a full characterization of the major screw trajectories for sacropelvic fixation in the same population. Also, it is the first study conducted in the Portuguese population that can provide a reference regarding iliosacral morphology in both males and females. As it is sometimes difficult to confirm the position and length of these screws intraoperatively, especially if there is no intra-operative navigation, the data described here provides references for sacropelvic anthropometry of the population and may aid in proper screw placement. This data, however, does not eliminate the need for proper anatomic extensive anatomic analysis of each patient before considering screw implantation.

Tables

Table I - Descriptive analysis of the sample´s age by gender

	N	Age (mean ± std. deviation)
Total	40	63,88 ± 15,23
Male	24	65,50 ± 15,18
Female	16	61,44 ± 15,46

Table II - Inter-investigator reliability test, for each screw trajectory and angles

Screw trajectory	Inter-Observer Reliability	Trajectory angles	Inter-Observer Reliability
S1A	0,596		
S1AL	0,843	Lateral	0,756
S1AM	0,689	Lateral	0,701
S2AL	0,280	Lateral	0,516
S2AM	0,806	Lateral	0,554
S2AI	0,784	Lateral	0,630
		Caudal	0,753
Iliac	0,772	Lateral	0,435
		Caudal	0,546
Sacroiliac	0,806		

Table III - Results for each trajectory measured considering length and angulation

	N	Minimum	Maximum	Mean	Std. Deviation
S1A Length	40	23,50	39,50	30,80	3,31
S1AL Length	40	27,50	49,50	36,48	5,39
S1AL Ang	40	20,50	46,00	33,13	6,06
S1AM Length	40	39,50	53,00	46,23	3,36
S1AM Ang	40	25,00	41,00	33,21	3,86
S2AL Length	40	23,50	36,50	28,66	2,46
S2AL Ang	40	18,50	33,25	26,52	3,31
S2AM Length	40	24,25	42,00	29,99	4,05
S2AM Ang	40	25,00	42,75	33,61	3,53
S2alar Length	40	106,50	145,00	125,84	8,19
S2alar Lat Ang	40	29,75	46,25	36,78	3,27
S2 alar Cau Ang	40	15,75	39,75	28,66	5,78
Iliac Length	40	120,00	156,00	136,73	8,75
Iliac Lat Ang	40	17,00	30,25	23,86	3,00
Iliac Cau Ang	40	14,25	33,25	24,013	5,34
Sacroiliac Length	40	62,0	83,50	75,50	4,75

Table IV - Results for each trajectory measured considering length and angulation by gender

	N	Gender	Mean	Std. Deviation	Std. Error Mean
S1A	24	M	31,35	3,50	0.71
	16	F	29,97	2,91	0.73
S1AL	24	M	38,26	5,58	1.14
	16	F	33,81	3,88	0.97
S1AL angle	24	M	32,73	5,74	1.17
	16	F	33,73	6,66	1.67
S1AM	24	M	47,58	3,15	0.64
	16	F	44,19	2,62	0.65
S1AM angle	24	M	33,84	3,85	0.79
	16	F	32,27	3,80	0.95
S2AL	24	M	29,35	2,56	0.52
	16	F	27,63	1,93	0.48
S2AL angle	24	M	27,11	3,23	0.66
	16	F	25,63	3,32	0.83
S2AM	24	M	31,01	4,41	0.90
	16	F	28,45	2,96	0.74
S2AM angle	24	M	33,10	2,33	0.48
	16	F	34,36	4,80	1.20
S2AI	24	M	128,83	7,61	1.55
	16	F	121,34	7,06	1.76
S2AI lateral angle	24	M	36,79	3,17	0.65
	16	F	36,77	3,51	0.88
S2AI caudal angle	24	M	28,18	6,09	1.24
	16	F	29,39	5,38	1.34
Iliac	24	M	140,69	7,80	1.59
	16	F	130,78	6,57	1.64
Iliac lateral angle	24	M	23,98	2,70	0.55
	16	F	23,69	3,48	0.87
Iliac caudal angle	24	M	24,15	5,09	1.04
	16	F	23,81	5,85	1.46
Sacroiliac	24	M	75,35	4,56	0.93
	16	F	75,72	5,18	1.29

Table V - Correlational analysis between genders for each screw measurement

	Sig. (2-tailed)	Mean Difference	Std. Error Difference
S1A	0,198	1,39	1.06
S1AL	0,009	4,45	1.61
S1AL angle	0,614	-1,01	1.98
S1AM	0,001	3,40	0.95
S1AM angle	0,209	1,59	1.24
S2AL	0,027	1,73	0.75
S2AL angle	0,166	1,49	1.05
S2AM	0,049	2,56	1.26
S2AM angle	0,276	-1,26	1.14
S2AI	0,003	7,49	2.39
S2AI lateral angle	0,981	0,03	1.07
S2AI caudal angle	0,522	-1,21	1.88
Iliac	0,000	9,91	2.37
Iliac lateral angle	0,767	0,29	0.98
Iliac caudal angle	0,849	0,33	1.74
Sacroiliac	0,816	-0,36	1.55

Table VI - Comparison between the current study measurements and international literature

Trajectory	Current Study			Xu et al.	Asher et al.	Ota et al.	Zhu et al.	Berry et al.	Ebraheim et al.
	Gender		Total						
S1A	M	31,35	30,80	30	-	-	-	-	-
	F	29,97							
S1AL	M	38,26	36,48	-	39	-	-	-	-
	F	33,81			37				
S1AL angle	M	32,73	36,48	-	25	-	-	-	-
	F	33,73							
S1AM	M	47,58	46,23	-	50	46	-	-	-
	F	44,19			47				
S1AM angle	M	33,84	33,21	-	35	23	-	-	-
	F	32,27							
S2AL	M	29,35	28,66	34	-	-	-	-	-
	F	27,63							
S2AL angle	M	27,11	26,52	30	-	-	-	-	-
	F	25,63							
S2AM	M	31,01	29,99	32	-	-	-	-	-
	F	28,45							
S2AM angle	M	33,10	33,61	30	-	-	-	-	-
	F	34,36							
S2AI	M	128,83	125,84	-	-	-	121	-	-
	F	121,34					116		
S2AI lateral angle	M	36,79	36,78	-	-	-	37	-	-
	F	36,77					46		
S2AI caudal angle	M	28,18	28,66	-	-	-	30	-	-
	F	29,39					35		
Iliac	M	140,69	136,73	-	-	-	-	147	-
	F	130,78						141	
Iliac lateral angle	M	23,98	23,86	-	-	-	-	-	-
	F	23,69							
Iliac caudal angle	M	24,15	24,013	-	-	-	-	-	-
	F	23,81							
Sacroiliac	M	75,35	75,50	-	-	-	-	-	80
	F	75,72							

Figures

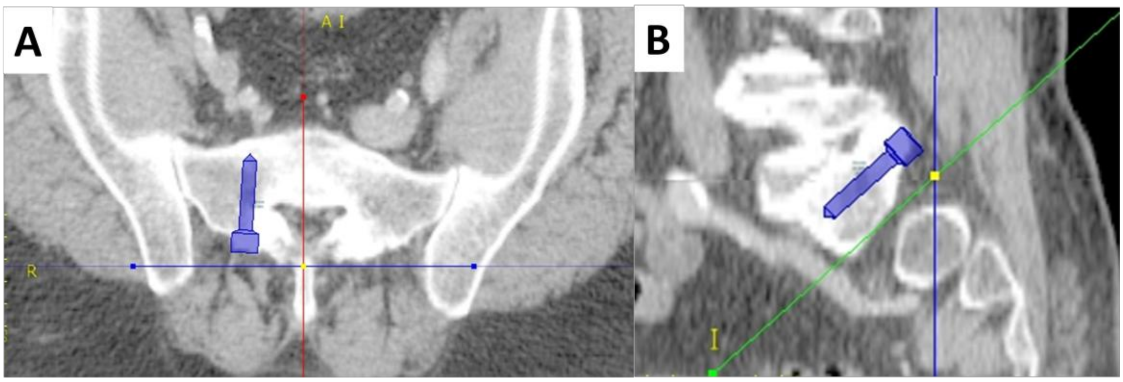

Figure 1 - Illustration of the measurement of the S1A screw trajectory. A) Axial view; B) Sagittal view

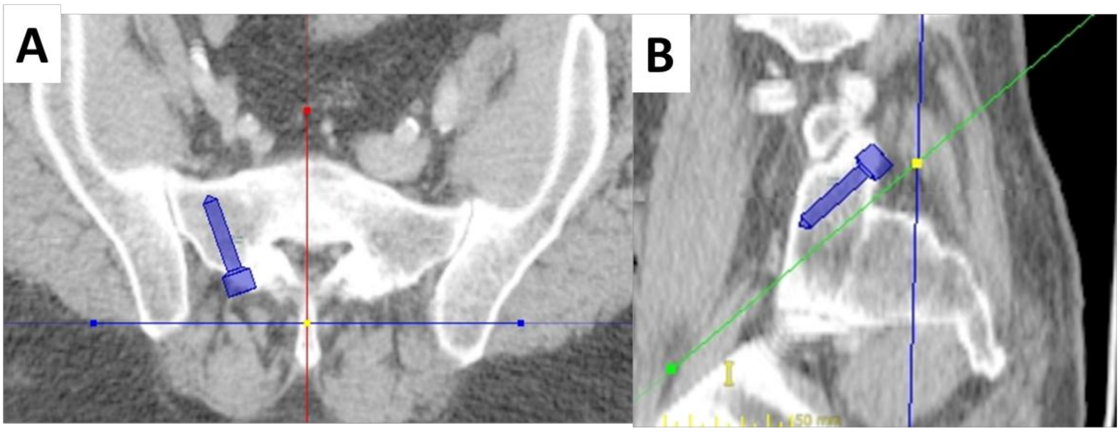

Figure 2 - Illustration of the measurement of the S1AL screw trajectory. A) Axial view; B) Sagittal view

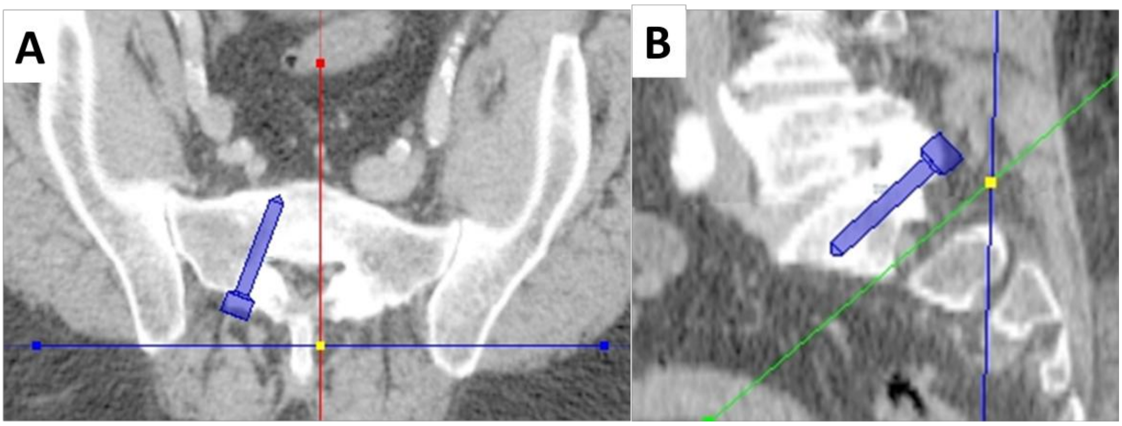

Figure 3 - Illustration of the measurement of the S1AM screw trajectory. A) Axial view; B) Sagittal view

Figure 4 - Illustration of the measurement of the S2AL screw trajectory. A) Axial view; B) Sagittal view

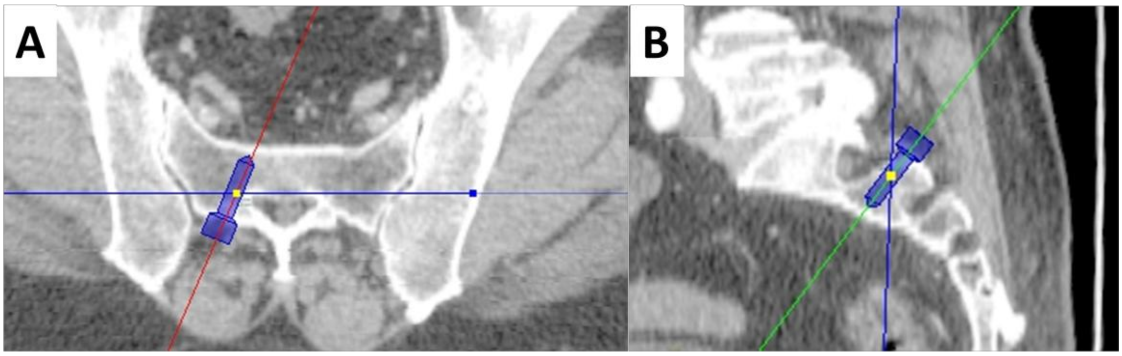

Figure 5 - Illustration of the measurement of the S2AM screw trajectory. A) Axial view; B) Sagittal view

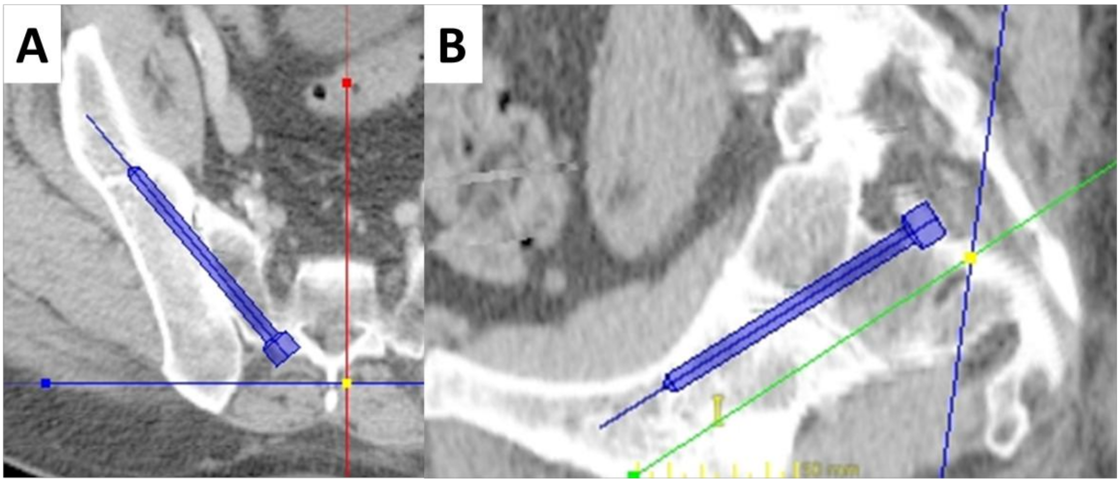

Figure 6 - Illustration of the measurement of the S2AI screw trajectory. A) Axial view; B) Sagittal view

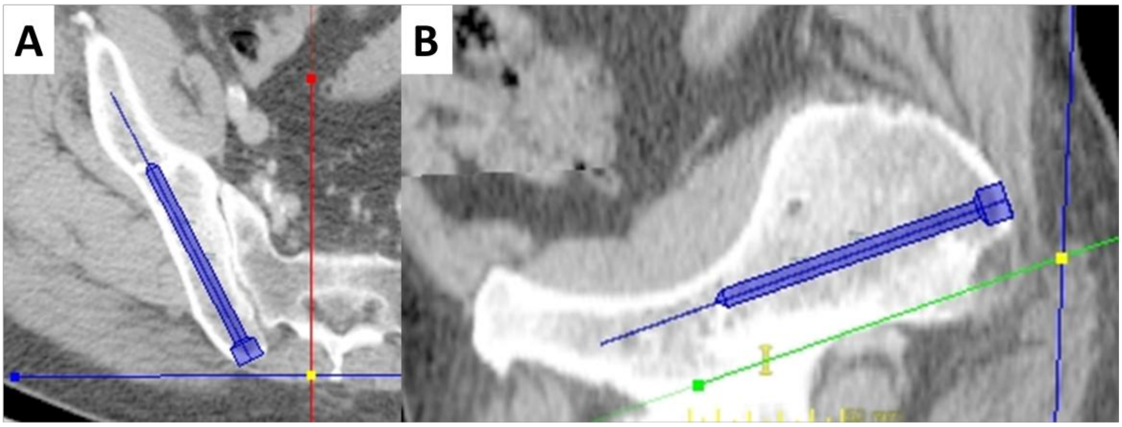

Figure 7 - Illustration of the measurement of the Iliac screw trajectory. A) Axial view; B) Sagittal view

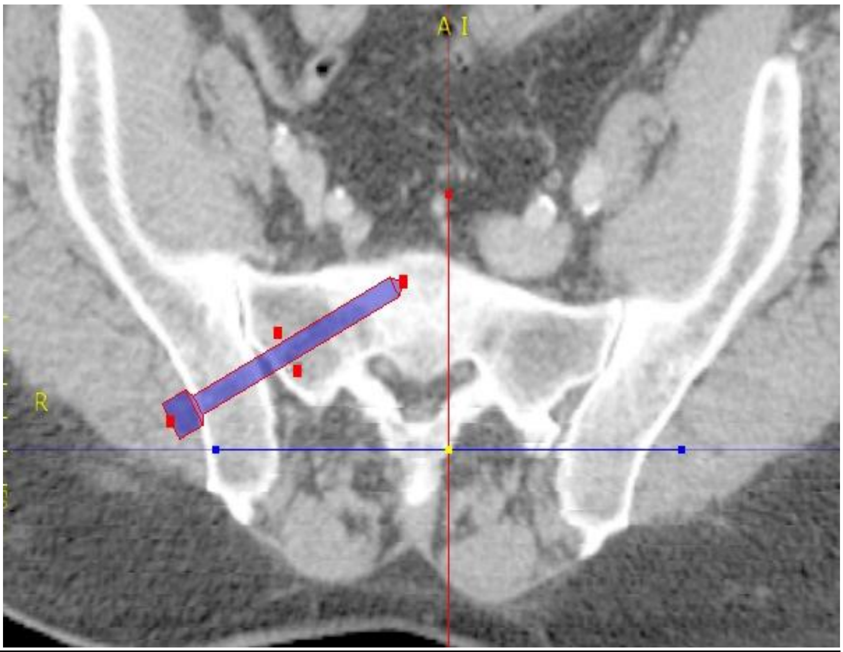

Figure 8 - Illustration of the measurement of the Sacroiliac screw trajectory.

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