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Optimal trajectory and insertion accuracy of sacral alar iliac screws

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A B S T R A C T

Objective: The aim of this study was to analyse the optimal trajectories for sacral alar iliac screws (SAISs) in a Japanese patient population and the clinical assessment of insertion accuracies.

Methods: The ideal trajectories of SAISs, starting from 2 mm medial to the apex of the lateral sacral crest on the midline between S1 and S2 dorsal foramina, were measured in 80 consecutive spinal disease patients (40 males and 40 females; average age: 67.4 ± 8.1 years) using three-dimensional computed tomographic image software. Following these anatomic analyses, accuracies of 32 inserted SAISs in consecutive patients, who underwent long spinal posterior fusion, were investigated clinically.

Results: Lateral angulations of optimal SAIS trajectories in males (left: 37.9; right: 37.7) were significantly larger than those than in females (left: 32.8; right: 32.4). Caudal SAIS angulations for females (left: 33.4; right: 33.9) were significantly larger than those in males (left: 27.5; right: 28.0). The 32 SAISs (100 mm long and 9 mm in diameter) assessed clinically were accurately inserted on optimal trajectories.

Conclusion: The optimal trajectories of SAISs in a Japanese patient population are more lateral in males and more caudal in females. This study examines the clinical safety and accuracy of SAIS insertion on these optimal trajectories.

Introduction

For spine surgeons treating spinal deformity, spino-pelvic fixation remains a challenge despite numerous various instrumentation methods have been reported and developed.[1–3] Sacral alar iliac screw (SAIS) stated by Sponseller[4] is useful strong caudal anchor in long spinal posterior fusion to sacrum, and has many advantages as compared with conventional iliac screws.[4,5] In the original paper, starting point of SAIS is 1 mm inferior and 1 mm lateral to the S1 dorsal foramen, and trajectory is 40–50° angulation relative to the horizontal line and 20–30° caudal from straight lateral.[4,5] After that, previous reports have indicated various optimal entry points and trajectories of SAIS.[6–8] However few reports have indicated so far actual insertion accuracy in clinical practice, and ethnic difference of pelvic shape may affect the optimal trajectories of SAIS.

Our past research of the inserted 25 SAISs based on the method of the original paper for two years until 2012 in our hospital revealed low accuracy of 12% and particularly the 64% shorter screws than iliac narrowest point (Table 1). Based on this low accuracy, we investigated optimal entry point and trajectory of SAIS in a Japanese population using three-dimensional computed tomographic (3DCT) image software in this study. Furthermore, the trajectories of the consecutive inserted SAISs in clinical practice after the anatomic study were also evaluated.

Materials and methods

In the anatomic study, at first, 2 mm medial to apex of lateral sacral crest on midline between S1 and S2 dorsal foramen was chosen as the optimal entry point of SAIS using 3DCT image software (SYNAPSE VINCENT, Fuji Photo Film, Co. Ltd., Japan) based on the data of the inserted 25 SAISs until 2012 in our hospital (Fig. 1). The ideal trajectories of SAIS which started from this point with sufficient length and diameter were measured in consecutive 80 spinal disease patients (male: 40; female: 40; average age: 67.4 ± 8.1) who admitted to our hospital from April, 2012 for 6 months using 3DCT image software by an observer blinded to the

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Table 1
Accuracies of insertion of 25 SAISs from 2011–2012.

Number of SAIS	Out of total of 25
Medial breach of ilium	3 (12%)
Lateral breach of ilium	4 (16%)
Cut out of sacrum	20 (80%)
Shorter than iliac narrowest point	16 (64%)
Optimal insertion	3 (12%)

SAIS: sacral alar iliac screw.
This assessment of 25 SAISs inserted for two years prior to 2012, based on the methods and findings of the original papers,[4,5] reveals a low optimal insertion accuracy of 12% and, notably, 64% of the screws being shorter than the iliac narrowest point.

study (Fig. 2). The measurements in the transverse plane along SAIS trajectory were lateral trajectory angulation, maximal SAIS length and maximal intrailiac length (Fig. 3A). Caudal angulation was measured in the sagittal plane along SAIS trajectory (Fig. 3B). Iliac width at the narrowest point was measured in the coronal plane vertical to SAIS trajectory (Fig. 3C).

In the clinical study, secondly, 32 inserted SAISs in consecutive 16 spinal deformity patients (male: 6; female: 10; average age: 72.5 ± 9.6) underwent long spinal corrective posterior fusion to sacrum and pelvis (mean fusion levels: 8.4 ± 1.8) who admitted to our hospital from April, 2013 for 10 months based on the optimal trajectory obtained from results of the above anatomic study were investigated. Screw trajectory angulation, maximal screw length, intrailiac screw length, screw diameter and presence/absence of screw breach at sacrum and/or ilium were measured and investigated also using postoperative 3DCT image software (Fig. 4). Presence/absence of L5-S1 union and SAIS loosening of the all 16 patients were investigated on CT images at one year after surgeries.

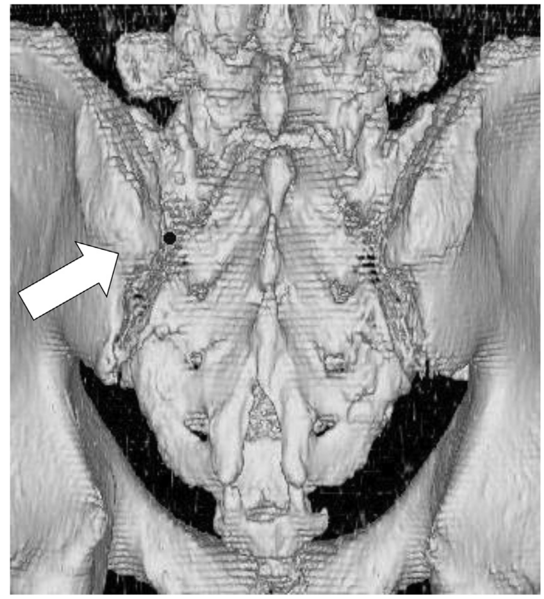

Fig. 1. Entry point of SAIS on 3DCT image. 2 mm medial to apex of lateral sacral crest on midline between S1 and S2 dorsal foramen (white arrow) was chosen as the optimal entry point of SAIS using 3DCT image software.

Values were expressed as mean ± standard deviation (SD). The mean values of trajectory angles, lengths and diameters of SAIS were analyzed using Student's *t*-test between left and right pelvis, and between male and female. A p value less than 0.05 was considered to be statistically significant.

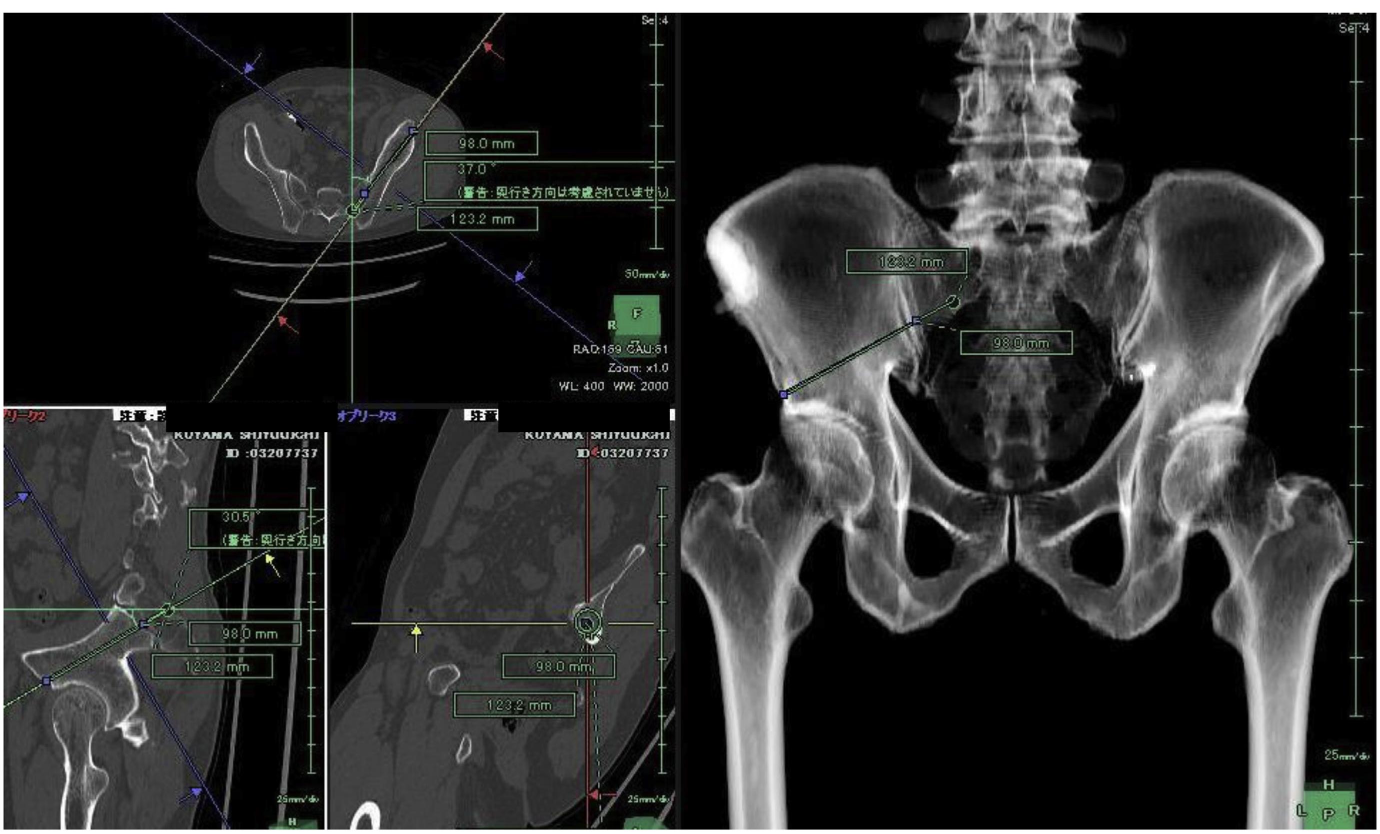

Fig. 2. The data of patient (male, 65 years) on 3DCT image software. Transverse, sagittal and coronal plane images on left side; 3D image on right side.

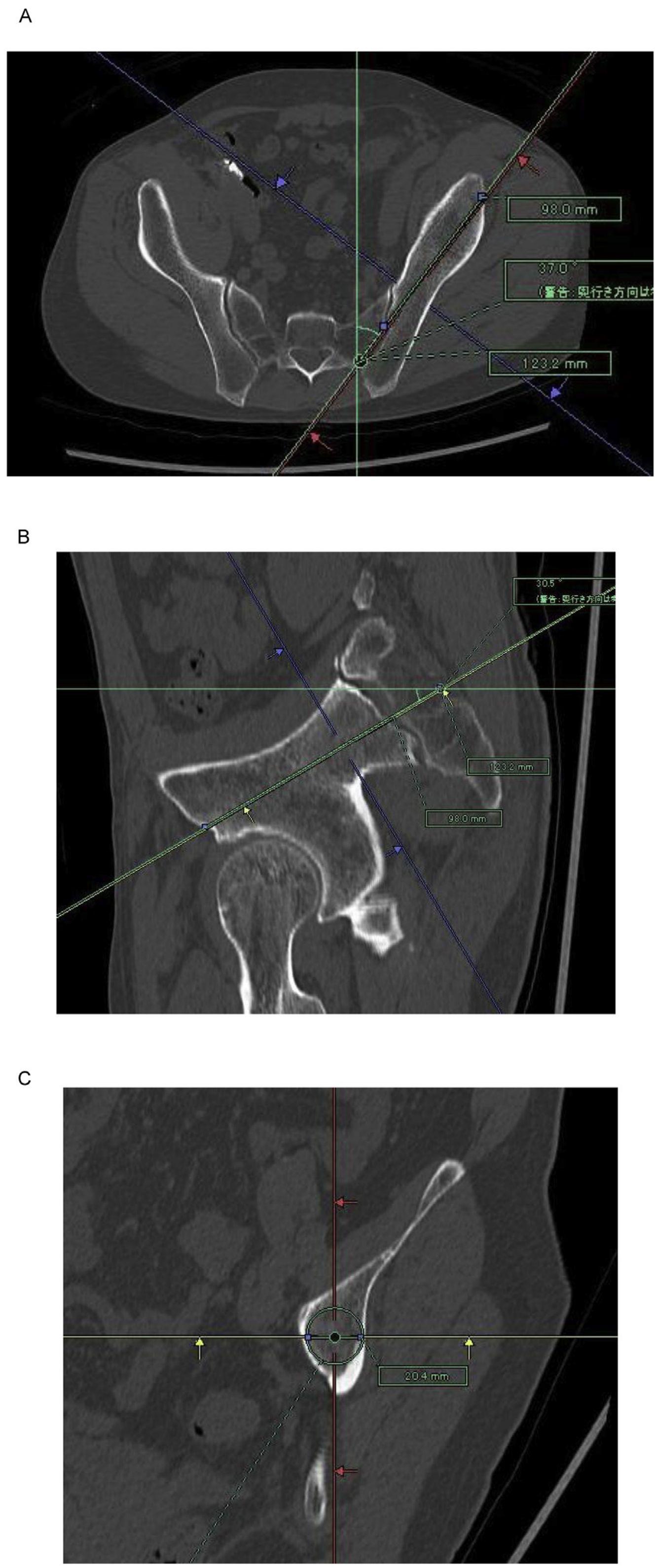

Fig. 3. Measurements of transverse, sagittal and coronal plane images along SAIS trajectory. Lateral angulation, maximal length and intrailiac length in transverse plane along SAIS trajectory (A). Caudal angulation in sagittal plane along SAIS trajectory (B). Iliac width at narrowest point in coronal plane vertical to SAIS trajectory (C).

The study protocol was approved by the Human Ethics Review Committee of our institution and a signed consent form was obtained from each subject.

Results

In the anatomic study, the mean values and SD for the angulations, lengths and diameters of optimal SAIS trajectories are reported in Table 2. In the transverse plane, the lateral angulation of male (Left: 37.9 ± 7.0; Right: 37.7 ± 7.5) was significantly larger than female (Left: 32.8 ± 7.6; Right: 32.4 ± 7.1) ($p = 0.04$), and the maximal and intrailiac length of male (Left: 121.5 ± 10.3; Right: 121.8 ± 10.1 and Left: 98.9 ± 8.7; Right: 98.6 ± 10.4, respectively) were also significantly larger than female (Left: 113.8 ± 9.6; Right: 112.7 ± 9.1 and Left: 91.6 ± 9.1; Right: 90.9 ± 9.3, respectively) ($p = 0.02$ and $p = 0.01$, respectively). In the sagittal plane, the caudal angulation of female (Left: 33.4 ± 6.4; Right: 33.9 ± 6.6) was significantly larger than male (Left: 27.5 ± 6.8; Right: 28.0 ± 7.2) ($p = 0.03$). In the coronal plane vertical to screw trajectory, the iliac width at narrowest point of male (Left: 18.1 ± 3.4; Right: 18.5 ± 3.7) were also significantly larger than female (Left: 15.9 ± 2.8; Right: 16.0 ± 3.1) ($p = 0.04$). The all measurements showed no difference between left and right pelvis.

In the clinical study, Table 3 shows 32 inserted SAISs using only one shot AP fluoroscopic image in consecutive 16 cases in consideration of the results of the present anatomic study mentioned above. The all 32 inserted SAISs had 100 mm lengths and 9 mm diameters on the optimal trajectory and there was no screw breaching at iliac wall. The mean angles of the trajectories were laterally 39.2 ± 4.4 and caudally 27.3 ± 2.8° in male, and laterally 34.5 ± 3.4 and caudally 32.7 ± 4.3° in female approximately similar to the results of the present anatomic study. The all 32 screws showed partial cut out at sacrum and 25 of the 32 SAISs were inserted through lateral edge of sacroiliac joint (Fig. 5). At one year after the surgeries, the all 16 patients achieved L5-S1 union and 5 of the 32 SAISs showed loosening on CT images.

Discussion

Numerous studies have reported that long spinal fusion to sacrum without supplemental sacroiliac instrumentation tends to fail with implant failure or non-union.[9–11] To avoid these failures and to achieve successful spino-sacral or spino-pelvic fixation, several supplemental sacroiliac instrumentation methods of Galveston technique, S2 screws, alar screws, and iliac screws have been reported.[12–15] However, these traditional techniques have some disadvantages including surgical difficulty, complex bending, complex connector, insufficient fixation strength, implant prominence, and/or soft tissue damage.[3,16] Spino-pelvic instrumentation using SAIS was supposed to be alternative, low-profile, and effective technique compensating these disadvantages.[4,5]

Various optimal entry points and trajectories of SAIS have been previously investigated in anatomic studies using cadavers or CT images.[5–8] Actually, however, acceptable range of SAIS trajectory seems to be very narrow in the clinical practice. Although, for this narrow acceptable range, several reports recommended using navigation system, computer-assisted method, or AP and lateral view fluoroscopy to insert SAIS on optimal trajectory,[17,18] these methods require additional education for users, complexity, high costs and large radiation exposure. To our knowledge, no previous study has quantified accuracy of SAIS inserted on optimal trajectory in clinical practice. Table 4 shows summary of previous published SAISs parameters in anatomic studies. The optimal entry point and

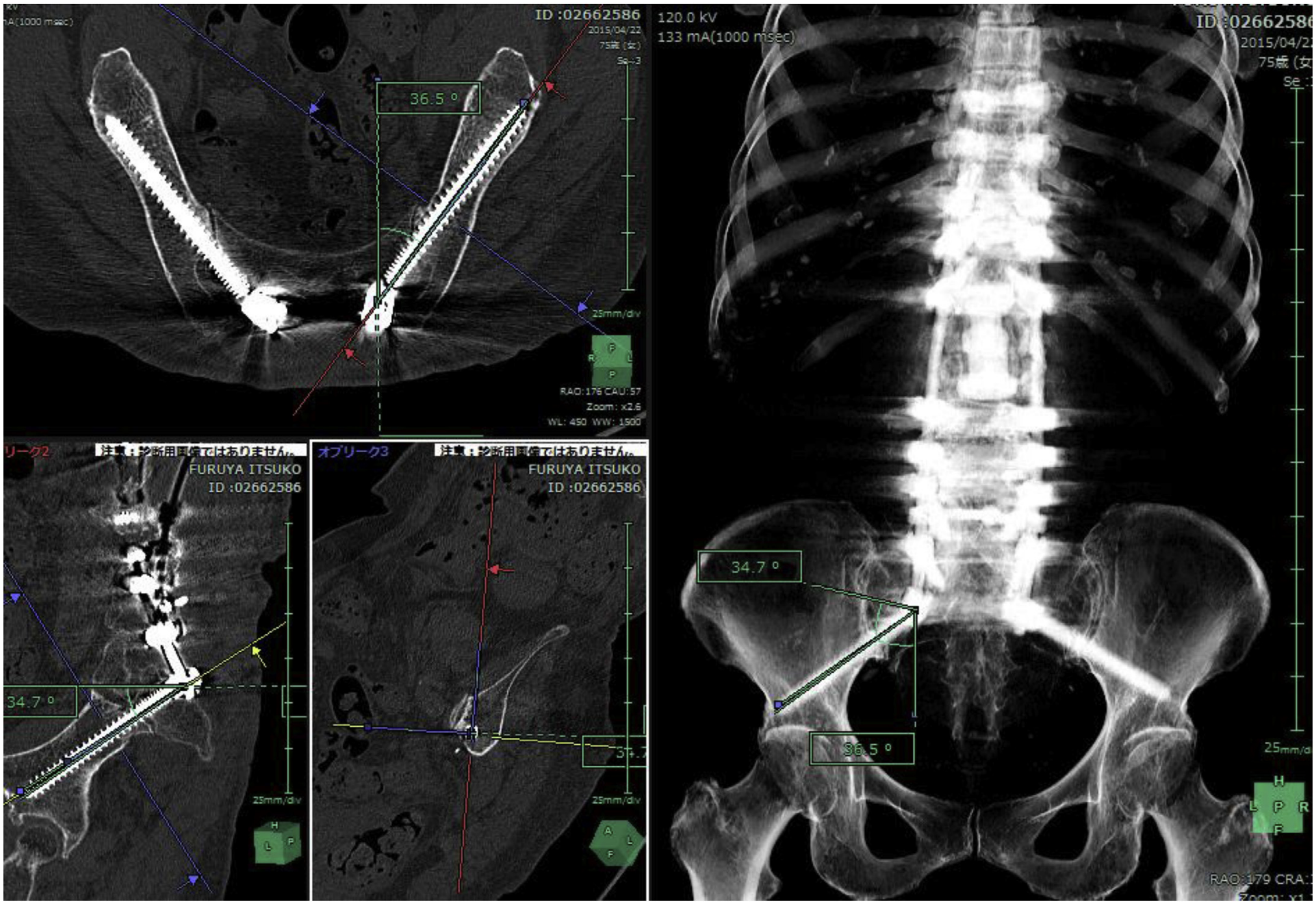

Fig. 4. Clinical investigation of inserted SAIS accuracy using 3DCT image software (female, 74 years). Lateral angulation: 36.5°; Caudal angulation: 34.7°; Maximal screw length: 100 mm; Intrailiac screw length: 71.8 mm; Screw diameter: 9 mm.

Table 2
Parameters of optimal SAIS trajectories.

Parameters	Left		p	Right		p
	Male (n = 40)	Female (n = 40)		Male (n = 40)	Female (n = 40)	
In the transverse plane						
Lateral angulation (°)	37.9 ± 7.0	32.8 ± 7.6	0.04	37.7 ± 7.5	32.4 ± 7.1	0.04
Maximal length (mm)	121.5 ± 10.3	113.8 ± 9.6	0.02	121.8 ± 10.1	112.7 ± 9.1	0.02
Intrailiac length (mm)	98.9 ± 8.7	91.6 ± 9.1	0.01	98.6 ± 10.4	90.9 ± 9.3	0.02
In the sagittal plane						
Caudal angulation (°)	27.5 ± 6.8	33.4 ± 6.4	0.03	28.0 ± 7.2	33.9 ± 6.6	0.04
In the coronal plane						
Iliac narrowest width (mm)	18.1 ± 3.4	15.9 ± 2.8	0.04	18.5 ± 3.7	16.0 ± 3.1	0.03

SAIS: sacral alar iliac screw.
All values are mean ± standard deviation. Analyzed with Student's *t*-test. $p < 0.05$ is considered significant.

Table 3
Accuracies and parameters of 32 inserted SAISs in 16 consecutive clinical cases.

Parameters	Left		Right	
	Male (n = 6)	Female (n = 10)	Male (n = 6)	Female (n = 10)
Lateral angulation (°)	39.2 ± 4.4	34.5 ± 3.4	37.8 ± 4.1	34.0 ± 3.2
Caudal angulation (°)	27.3 ± 2.8	32.7 ± 4.3	28.1 ± 3.5	34.3 ± 2.9
Full screw length (mm)	100	100	100	100
Intrailiac screw length (mm)	72.8 ± 2.9	71.5 ± 3.6	70.4 ± 3.1	73.3 ± 2.4
Screw diameter (mm)	9	9	9	9
Medial breach of ilium (no.)	0	0	0	0
Lateral breach of ilium (no.)	0	0	0	0

All angles and lengths are mean ± standard deviation.
These SAISs trajectories of the clinical cases are comparable to the results of the present anatomic study.

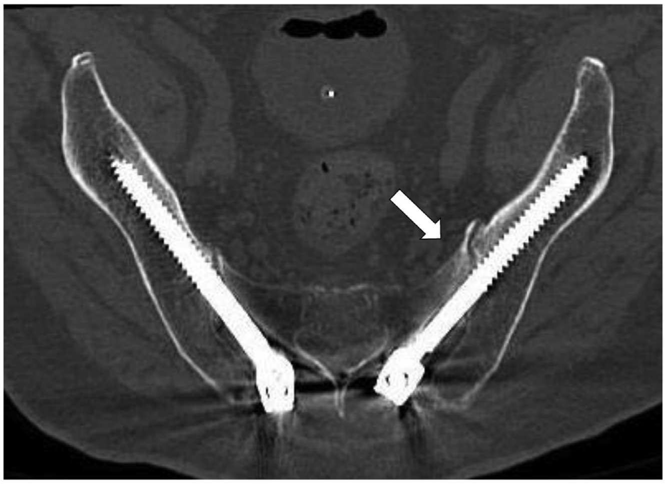

Fig. 5. The data of patient (female, 69 years) in clinical practice. The left SAIS was inserted through lateral edge of sacroiliac joint (white arrow).

Table 4
Summary of previously published SAIS parameters.

Author	Present study		Zhu (2013)		Chang (2009)		O'Brien (2009)	
Population	Japanese		Chinese		American		American	
Age (years)	58–81		20–60		12–18		Cadaveric	
Methods	CT		CT		CT		Instrumentation	
Male/Female (no.)	40	40	30	30	13	7	5	5
Lateral angulation (°)	37.9	32.8	36.5	35.7	39.4	38.0	51.2	39.2
Caudal angulation (°)	27.5	33.4	29.2	34.5	36.7	41.6	32.6	36.8
Maximal length (mm)	98.9	91.6	95.1	93.7	69.5	73.1	71.2	71.6
Intrailiac length (mm)	121.5	113.8	121.3	114.8	105.9	106.9	76.0	76.0
Iliac narrowest width (mm)	18.1	15.9	17.0	14.8	12.2	12.8	–	–

trajectory of SAIS obtained from the present anatomic study are useful with wide tolerance range because the diameters are larger than previous reports, and the maximal and intrailiac lengths are approximately equivalent to the previous reports.

Our present clinical results of the 32 inserted SAISs (Table 3) also show usefulness of inserting technique of SAIS based on the optimal trajectory obtained from our anatomic study. Furthermore, the results of the all 32 SAISs with 100 mm lengths and 9 mm diameters using only one shot fluoroscopic image show usefulness with regard to radiation exposure. O′ Brien reported that 60% of S2 iliac screw violated the articular cartilage in the cadaveric study.[5] 25 of the 32 SAISs were inserted through lateral edge of sacroiliac joint in the present clinical study. This result shows that the optimal trajectory of SAIS obtained from our anatomic study is likely to be clinically minimally invasive to sacroiliac joint cartilage.

In previous anatomic studies using CT images, Chang reported no significant difference of SAIS trajectory angulation between genders in American population,[6] and Zhu concluded that the trajectory angulation was significantly more caudal in female than male in Chinese population[8] (Table 4). These results likely show ethnic difference of pelvic shape and/or size. On the other hand, the optimal trajectory of SAIS in a Japanese population showed significantly more frontal and more caudal in female than male in the present study. These results are considered due to female pelvic shape compatible with delivery.

There are several limitations to our study. The all 32 inserted SAISs in the clinical study showed partial cut out at sacrum, and biomechanical strength was not taken into investigation. However, these SAISs seem to have sufficient biomechanical strength because very thick iliac cortex at sacroiliac joint contributes sufficient fixation strength compared with very thin sacral lateral cortex on CT images. The L5-S1 union-rate of the present clinical study also seems to show sufficient fixation strength of these SAISs on the optimal trajectories obtained from our anatomic study.

We revealed that the optimal trajectories of SAIS in a Japanese population started from 2 mm medial to apex of lateral sacral crest on midline between S1 and S2 dorsal foramen were toward to more lateral in male and more caudal in female in the present anatomic study using 3DCT image software.

The optimal entry point and trajectory of SAIS obtained from the present study are useful with wide tolerance range because the diameters are larger than previous reports, and the maximal and intrailiac lengths are approximately equivalent to the previous reports.

The all 32 SAISs with 100 mm lengths and 9 mm diameters were easily and safely inserted in the clinical practice in consideration of the optimal trajectories obtained from the results of the present anatomic study.

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Conflict of interest

None declared.

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