Correlation of sagittal configuration of the sacrum and pelvic incidence evaluated by computed tomography measurements

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Abstract

Objective To measure the sagittal configurations of the sacrum using computed tomography (CT), and to investigate the correlation between the sagittal configuration of the sacrum and pelvic incidence.

Methods The computed topographies of complete pelvic imaging between 2006 and 2018 was retrospectively studied. Measurements of pelvic and sacral morphological parameters were performed on the midsagittal plane of the 2D reconstruction images of computed tomography. Pelvic incidence (PI) (STA) were measured as previously described, and sacral table angle, sacral incidence (SI), sacral segmental vertebral angle (SSVA), sacral segmental kyphosis (SSK), central angle (SCA), arc length (SAL) as well as arc radius (SAR) were introduced to describe the segmental morphology of sacrum. Pearson Correlation Coefficient and Stepwise Regression Analysis were used to determine the relationship between PI and sacral morphological parameters.

Results A total of 304 subjects were finally included in this study. The average age of the patients were 46.22 ± 15.92 years, and the average PI was 45.24±8.68°. Most of the sacral morphological parameters were not different as affected by gender or age. The morphological parameters of S1: S1I, SSVA1 and STA were finally confirmed to be closely correlated with PI, while no significant correlation between sacral curvature (SCA) and PI was identified, and morphological parameters of other sacral segments were not correlated to PI either.

Conclusion The morphological parameters of S1 are more closely correlated with PI, and the sacral incidence of S1 might serve as a useful tool for the calculation of PI.

Introduction

The measurements of sagittal balance have become an important consideration for many spinal disorders such as lumbar disc herniation and spondylolisthesis[1]. Pelvic incidence (PI) is one of the most studied radiologic measurements which was initially introduced by Duval-Beaupère[2]. As a position-independent parameter that quantifies the sagittal angle between the perpendicular axis of the sacral endplate and a line from the center of the sacral endplate to the femoral head axis, the unique value of PI represents pelvic morphology for every individual[3]. An association between PI and spondylolisthesis has been in numerous studies, and PI has been found to be increased in adults with low-grade isthmic spondylolisthesis and correlated with the severity of slippage[4].

Similarly, morphological characteristics of the sacrum have also been studied within the context of spinopelvic pathologies, and various studies indicate that the sagittal configuration of the sacrum might be an important factor related to spondylolisthesis[5]. Sacral table angle (STA) has been found to be related with the occurrence rate of spondylolysis. Besides the measurement of STA, two methods have also been reported in the literature to measure sacral kyphosis, using either the Cobb angle method or the Ferguson technique[6]. A more curved sacrum has been associated with degenerative and developmental

spondylolisthesis as well as lumbar disc herniation[7, 8]. Although a large number of studies reported the radiographic measurements of the sacral morphology, difficulties still exists regarding the limited visibility of sacrum on X-rays[9]. Different methods have described the measurement of sacral kyphosis, however, there is still no consensus on a standard method, since all the existing techniques have their own limitations[6].

Since both PI and the sacral morphology correlate with spondylolisthesis, how these two measurements relate to each other stated to gain interest recently. Abola et al reported that PI is associated with a highly angulated and curved sacrum through an anatomical comparative study of cadaveric specimens[10], however, no further studies supports this finding, and there has been no radiologic study about the impact of sacral morphology on pelvic incidence yet.

The purpose of this study was therefore to measure the sagittal configurations of the sacrum using computed tomography (CT), trying to establish a set of standard method for the measurement of sacral morphology, and also to investigate the correlation between the sagittal configuration of the sacrum and pelvic incidence.

Material And Methods

Study Population

The computed topographies of complete pelvic imaging between 2006 and 2018 was retrospectively studied from the database of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine. This study has been approved by the institutional review board of Shanghai Ninth People's Hospital, and written informed consents were obtained from the all patients. Inclusion criteria were as follows: (1) age between 20 and 80 years old; (2) complete pelvic imaging including the whole sacrum; (3) no pelvic or femoral fracture; (4) no surgical history of the spine, pelvis, or hip joints. Exclusion criteria include: (1) anatomical anomalies of the sacrum. (2) history of any disease that may affect bone growth. (3) severe osteoporosis or arthritis. A total of 304 subjects were finally enrolled in this study. The CT scans were performed using Siemens SOMATOM Definition Flash 128 scanners (Somatom Definition FLASH, Siemens Healthcare, Forchheim, Germany) with a mean voxel size of 0.98×0.98×1.00 mm. Imaging data were exported as DICOM (Digital Imaging and Communications in Medicine) files for further analysis.

Radiographic Measurements

Measurements of pelvic and sacral morphological parameters were performed on the midsagittal plane of the 2D reconstruction images of computed tomography (Fig.1, Table 1). Hip axis was determined on the midsagittal plane based on a 3D pelvic surface using Mimics software (Fig.1) (Materialise, Leuven, Belgium). We measured the pelvic incidence (PI) and sacral table angle (STA) as previously described[9], and also introduced several radiographic parameters to delineate sacral morphology, the definition of

which were listed in Table 2. A circle fitting method was developed based on the morphology of S1, S2, S3 to simulate the sacral curvature, and the central angle (SCA), arc length (SAL) as well as arc radius (SAR) of the simulated sacral arc were calculated. A positive central angle was defined if the arc central sat in front of the sacrum. The intraobserver and interobserver reliabilities of the measurements were determined using the intraclass correlation coefficient (ICC). The segmental morphology and curvature of sacrum were measured as sacral segmental vertebral angle (SSVA) and sacral segmental kyphosis (SSK) respectively, and a positive SSVA was defined if vertex of the angle sat in front of the sacrum. The measurements of the sacral parameters were demonstrated in Fig. 2.

Statistics Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 22 (Armonk, NY: IBM Corp). All data were expressed as mean ± standard deviation (SD). Kolmogorov-Smirnov test was employed to determine whether the parameters were normally distributed in the male and female cohorts. Variance discrepancy analysis was used to compare the difference among three or more groups. Differences in parameters between groups were evaluated by the t-test. Pearson Correlation Coefficient and Stepwise Regression Analysis were used to determine the relationship between PI and sacral morphological parameters. Statistically significant Pearson correlation coefficient was considered strong if greater than 0.5, moderate if larger than 0.3, and weak if greater than 0.1[11]. Differences were considered significant when p was <0.05.

Results

A total of 304 subjects were finally included in this study. The average age of the patients were 46.22 ± 15.92 years, and the average PI was 45.24±8.68°. The demographic data of the patients was shown in Table 1.

Radiographic measurements of pelvic incidence and sacral morphology

Definition and abbreviations of the radiographic measurements were listed in Table 2. Besides commonly used PI and STA, we introduced sacral incidence (SI), sacral segmental vertebral angle (SSVA) and sacral segmental kyphosis (SSK) to describe the segmental morphology of sacrum, and SCA, SAL as well as SAR to describe the overall sacral kyphosis. Most of the parameters were not different as affected by gender or age as shown in Table 3. However, by a correlation analysis stratified by PI, almost all these sacral parameters were somewhat correlated with PI (Table 4). The strongest correlation was identified between PI and S_1I ($r=0.791$, $p<0.01$), and a multivariate regression analysis was performed to further confirm these correlations. As shown in Table 5, three parameters were finally confirmed to be closely correlated with PI: S_1I, $SSVA_1$ and STA. Since S_1I was most significantly correlated with PI, a linear regression equation between PI and S_1I using the scatter diagram (Fig 3A). Fig 3B-C demonstrated that calculation of PI using S_1I and the equation would serve as a much easier method than a direct measurement of PI in a dome shaped sacrum as suggested by Labelle et al[12]

Discussion

The pelvis plays an important role as a mediator of sagittal balance in humans, and the sacrum is the junction which transfers loads from the spine to the lower extremity[13]. The anatomical characteristics of the sacrum must allow for the maintenance of bipedal posture as well as dynamic movements with minimal energy expenditure[14]. A more curved sacrum is considered to be a distinctive feature of homo sapiens[15, 16], and sacral curvature is minimal in tailed mammals and human infants, but increases with age in humans until reaches its skeletal maturity[17]. As pelvic incidence has also been reported to develop and change in a similar manner during human growth, which is thought as a result of erect posture and linked with numerous spinopelvic pathologies[18, 19], thus it's natural to relate the sacral curvature to PI together. There has been many reports showing that global sacral kyphosis correlates closely with increasing lumbosacral translation, sacral horizontal angle, lumbar lordosis, and lumbar index[6]. However, because of deficiencies in the conventional radiographic examination, the sacrum, acetabulum and hips were not included on spine radiograph in patients with lumbar spine disorders, and the association between pelvic incidence and sacral morphology is largely unknown.

As a parameter of the sagittal spine profile, pelvic incidence describes the angulation of the sacrum in the pelvis in relation to the hip joints, and influences force transmission thus has been associated with spondylolisthesis. Abola et al. [10] measured 120 cadaveric samples and found that a more curved sacrum, decreased sacral-ala width, and a more linear SI joint were related to an increased pelvic incidence. However, we only found a weak correlation between sacrum curvature (SCA) and PI by the correlation coefficient analysis, and further regression analysis were not able to confirm the significance. Rather than the sacrum curvature, morphological parameters of S1: S_1I, $SSVA_1$ and STA were found to be significantly correlated to PI. Morphological parameters of other sacral segments were also included in this study, but none of them were correlated to PI either.

STA is an anatomical parameter describing S1 rather than the curve of the sacrum. Inoue et al.[20] identified STA as a key anatomical sacral parameter in patients with spondylolisthesis. Compared to the control group, Wang et al. [21] revealed a significant decrease in STA in patients with L5-S1 spondylolisthesis, and that the slip grade is related to the decrease in STA. Whitesides et al. [22] indicated that STA may play a more important role than PI in the etiology of spondylolisthesis. We confirmed that STA is negatively correlated with PI, which corroborate the previous findings and may serve as an explanation. For patients with high-grade spondylolisthesis, whose sacral endplate is always dome shaped, PI can be difficult to measure[12, 23]. The newly suggested parameter (S_1I) may have great potential in defining the shape of the sacrum as well as the sagittal balance of the spine and may serve as an indirect parameter for the prediction of PI. However, more work is needed to validate the reliability of this new method.

Previously, two methods have been reported in the literature to measure, one using the standard Cobb angle method and the other with the Ferguson technique. Because the anterior and posterior aspects of

the sacrum often appear eroded in spondylolisthesis, the Ferguson method has been thought more reliable than the Cobb method. Even so, manual tracing of standing lateral radiograph still have inherent error and flaws, and reconstructed computed tomography scans would have given more information[24]. In this study, we introduced a new circle fitting method based on the morphology of S1, S2, S3 to simulate the sacral curvature, and three parameters: SCA, SAL and SAR were used to describe the curvature of sacrum. Since SI joint involves primarily the first three sacral vertebra and does not involve the last two sacral vertebra which curve is highly variable, we did not include S4 or S5. ICC analysis confirmed that this method has satisfactory intraobserver and interobserver reliabilities.

Conclusion

In this study, we introduced a new circle fitting to measure the sacral curvature, and were not able to identify a significant correlation between sacral curvature and PI. The morphological parameters of S1 are more closely correlated with PI, and the sacral incidence of S1 might serve as a useful tool for the calculation of PI.

Abbreviations

CT: Computed tomography

DICOM: Digital Imaging and Communications in Medicine

ICC: intraclass correlation coefficient

PI: pelvic incidence

SAL: sacral arc length

SAR: sacral arc radius

SCA: sacral central angle

SD: standard deviation

SI: sacral incidence

SPSS: Statistical Package for the Social Sciences

SSK: sacral segmental kyphosis

SSVA: sacral segmental vertebral angle

STA: sacral table angle

Declarations

Ethics approval and consent to participate

This study has been approved by the institutional review board of Shanghai Ninth People's Hospital, and written informed consents were obtained from the all patients.

Consent for publication

All participants in this study have consent for publication.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

Not applicable.

Funding

Not applicable.

Authors' contributions

Chen, Tian, Zhou and Zhang analyzed and interpreted the patient data. Chen and Tian were major contributors in writing the manuscript. Zhao designed this study. All authors read and approved the final manuscript.

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We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

References

1. **Jackson RPJackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine (Phila Pa 1976). 1994 Jul 15;19(14):1611-8.**
2. **Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. European Spine Journal. 1998;7(2):99-103.**
3. **Jean L. Influence of age and sagittal balance of the spine on the value of the pelvic incidence. European spine journal : official publication of the European Spine Society, the European Spinal**

Deformity Society, and the European Section of the Cervical Spine Research Society. 2014;23(7):1583-.

4. Rajnics P, Templier A, Skalli W, Lavaste F, Illes T. The association of sagittal spinal and pelvic parameters in asymptomatic persons and patients with isthmic spondylolisthesis. J Spinal Disord Tech. 2002 Feb;15(1):24-30.
5. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine (Phila Pa 1976). 1994 Jul 15;19(14):1611-8.
6. Antoniades SB, Hammerberg KW, DeWald RL. Sagittal plane configuration of the sacrum in spondylolisthesis. Spine (Phila Pa 1976). 2000 May 1;25(9):1085-91.
7. Lazennec JY, Ramaré S, Arafati N, Laudet CG, Gorin M, Roger B, et al. Sagittal alignment in lumbosacral fusion: relations between radiological parameters and pain. European Spine Journal. 2000;9(1):47.
8. Wang Z, Parent S, Mac-Thiong JM, Petit Y, Labelle H. Influence of sacral morphology in developmental spondylolisthesis. Spine (Phila Pa 1976). 2008 Sep 15;33(20):2185-91.
9. Wang Z, Parent S, de Guise JA, Labelle H. A variability study of computerized sagittal sacral radiologic measures. Spine. 2010 Jan 1;35(1):71-5.
10. 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. 2018:1.
11. KeithMuller. Statistical Power Analysis for the Behavioral Sciences. Journal of the American Statistical Association. 1988;31(4):499-500.
12. Labelle H, Roussouly P, Berthonnaud E, Dimnet J, O'Brien M. The importance of spino-pelvic balance in L5-s1 developmental spondylolisthesis: a review of pertinent radiologic measurements. Spine. 2005;30(6 Suppl):S27.
13. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. European Spine Journal. 2011;20(5):609-18.
14. Gruss LT, Schmitt D. The evolution of the human pelvis: changing adaptations to bipedalism, obstetrics and thermoregulation. Philos Trans R Soc Lond B Biol Sci. 2015;370(1663):20140063.
15. Abitbol MM. Evolution of the sacrum in hominoids. American Journal of Physical Anthropology. 1987;74(1):65-81.
16. Abitbol MM. Sacral curvature and supine posture. American Journal of Physical Anthropology. 1989;80(3):379-89.
17. Abitbol MM. Evolution of the lumbosacral angle. American Journal of Physical Anthropology. 1987;72(3):361-72.
18. Marty C, Boisaubert B, Descamps H, Montigny JP, Hecquet J, Legaye J, et al. The sagittal anatomy of the sacrum among young adults, infants, and spondylolisthesis patients. European Spine Journal. 2002;11(2):119-25.

19. Mangione P, Gomez D, Senegas J. Study of the course of the incidence angle during growth. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 1997;6(3):163.
20. Inoue H, Ohmori K, Miyasaka K. Radiographic classification of L5 isthmic spondylolisthesis as adolescent or adult vertebral slip. Spine. 2002;27(8):831-8.
21. Wang Z, Parent S, Macthiong JM, Petit Y, Labelle H. Influence of sacral morphology in developmental spondylolisthesis. Spine. 2008;33(20):2185.
22. Jr WT, Horton WC, Hutton WC, Hodges L. Spondylolytic spondylolisthesis: a study of pelvic and lumbosacral parameters of possible etiologic effect in two genetically and geographically distinct groups with high occurrence. Spine. 2005;30(6 Suppl):S12.
23. Vialle R, Ilharreborde B, C, Guigui P. Intra and inter-observer reliability of determining degree of pelvic incidence in high-grade spondylolisthesis using a computer assisted method. European Spine Journal. 2006;15(10):1449-53.
24. Antoniades SB, Hammerberg KW, Dewald RL. Sagittal plane configuration of the sacrum in spondylolisthesis. Spine. 2000;25(9):1085-91.

Tables

Table 1: Characteristics of Study Population

No. of patients	304
Age	46.22±15.92
<30	66
30-60	169
>60	69
Gender	
Male	126
Female	178
Pelvic incidence (°)	45.24±8.68

Table 2. Definition and abbreviation of morphometric measurements

Table 3. Measurements of PI and sacral morphological parameters

Table 4. Measured parameters of 304 subjects stratified by pelvic incidence

	Abbreviation	Definition
Pelvic incidence	PI	Angle between the line perpendicular to the midpoint of the sacral endplate and the line connecting this point to the hip axis
Sacral table angle	STA	Angle between the line along the S1 endplate and the line along the posterior border of the S1 body
Sacral incidence	SI	Angle between the line perpendicular to the midpoint of the caudal endplate of each sacral vertebra and the line connecting this point to the hip axis
Sacral segmental vertebral angle	SSVA	Angle between the cranial and caudal endplates of the sacral vertebrae
Sacral segmental kyphosis	SSK	Angle between the lines connecting the midpoints of anterior and posterior intervertebral disc space (or the midpoint of the S1 sacral endplate)
Sacral central angle	SCA	The central angle of the simulated sacral arc formed by the circle fitting method
Sacral arc length	SAL	The arc length of the simulated sacral arc formed by the circle fitting method
Sacral arc radius	SAR	The radius of the simulated sacral arc formed by the circle fitting method

		Gender			Age			
		Males (n=126)	Females (n=178)	p values	<30 (n=66)	30-60 (n=169)	>60 (n=69)	p values
PI	45.24±8.68	44.12±8.036	46.03±9.047	0.059	43.50±6.89	45.74±8.49	45.66±10.43	>0.05†
STA	98.63±6.37	98.04±6.109	99.04±6.527	0.487	98.56±5.63	98.80±6.20	98.27±7.42	0.838
S_1I	75.59±9.73	74.01±9.929	76.71±9.448	0.017*	73.72±8.14	75.51±9.90	77.58±10.42	>0.05†
S_2I	91.20±8.92	91.91±9.342	90.7±8.6	0.243	88.35±8.29	91.41±8.81	93.41±9.17	0.004*
SSK1	2.56±8.35	1.022±8.57	3.645±8.04	0.007*	1.65±9.17	2.73±7.76	3.00±8.96	0.597
SSK2	13.33±6.95	13.26±7.295	13.38±6.716	0.881	13.66±6.07	13.24±7.05	13.25±7.54	0.909
SSK3	14.21±6.90	15.07±7.005	13.6±6.78	0.067	14.29±6.45	13.83±6.96	15.07±7.20	0.451
SSVA1	-13.95±7.34	-13.35±5.343	-14.37±8.46	0.232	-14.27±4.99	-13.80±5.33	-14.01±12.08	0.903
SSVA2	0.91±7.54	-0.09549±7.122	1.619±7.761	0.051	2.09±6.85	0.74±7.20	0.19±8.85	0.313
SSVA3	11.16±9.23	10.96±9.471	11.31±9.071	0.750	11.23±8.62	11.14±8.91	11.17±10.58	0.997
SSVA4	14.30±9.95	16.02±8.465	13.08±10.73	0.008*	14.47±9.10	13.84±9.89	15.26±10.89	0.600
SCA	34.07±20.07	34.81±23.46	33.56±17.32	0.593	34.44±20.27	33.67±20.65	34.73±18.64	0.921
SAL	76.78±6.43	79.79±6.162	74.65±5.746	0.000*	78.15±6.61	77.01±6.35	74.91±6.13	0.011*
SAR	45.24±8.68	197.6±172.4	200.1±267.8	0.926	172.19±111.26	210.11±265.71	197.88±232.69	0.533

***Difference was regarded as significant when p was <0.05.**

† Dunnett T3 test was employed for PI and S_2I due to unequal variances. Difference between each two groups was not significant.

PI	<35° (n=44)	35°- 45° (n=114)	>45° (n=146)	Correlation Coefficients(r)
STA	100.6±7.061	98.66±6.197	98±6.198	-0.186*
S_1I	65.8±6.901	70.49±6.532	82.53±7.233	0.791*
S_2I	86.64±8.13	88.96±8.112	94.32±8.679	0.428*
SSK1	-4.34± 6.709	0.0027±7.554	6.634±7.183	0.517*
SSK2	7.906±6.788	11.88±6.839	16.1±5.703	0.465*
SSK3	11.61±5.998	12.91±6.807	16.01±6.789	0.320*
SSVA1	-17.67±4.699	-14.45±5.215	-12.43±8.835	0.270*
SSVA2	-2.882±7.282	-1.077±6.53	3.601±7.419	0.371*
SSVA3	5.978±8.176	9.638±8.923	13.92±8.851	0.358*
SSVA4	13.57±9.713	14.34±9.298	14.48±10.55	0.084
SCA	27.13±21.31	29.81±18.80	39.50±19.31	0.281*
SAL	79.22±6.14	78.63±6.26	74.60±5.95	-0.347*
SAR	323.81±331.31	212.97±162.50	150.68±229.74	-0.285*

*Statistically significant correlation coefficient ($p<0.05$).

Table 5: Multivariate regression analysis of variables on pelvic incidence

	Unstandardized beta	Standardized beta	P values
S_1I	0.736	0.825	<0.001
SSVA1	0.341	0.288	<0.001
STA	-0.183	-0.134	<0.001

Figures

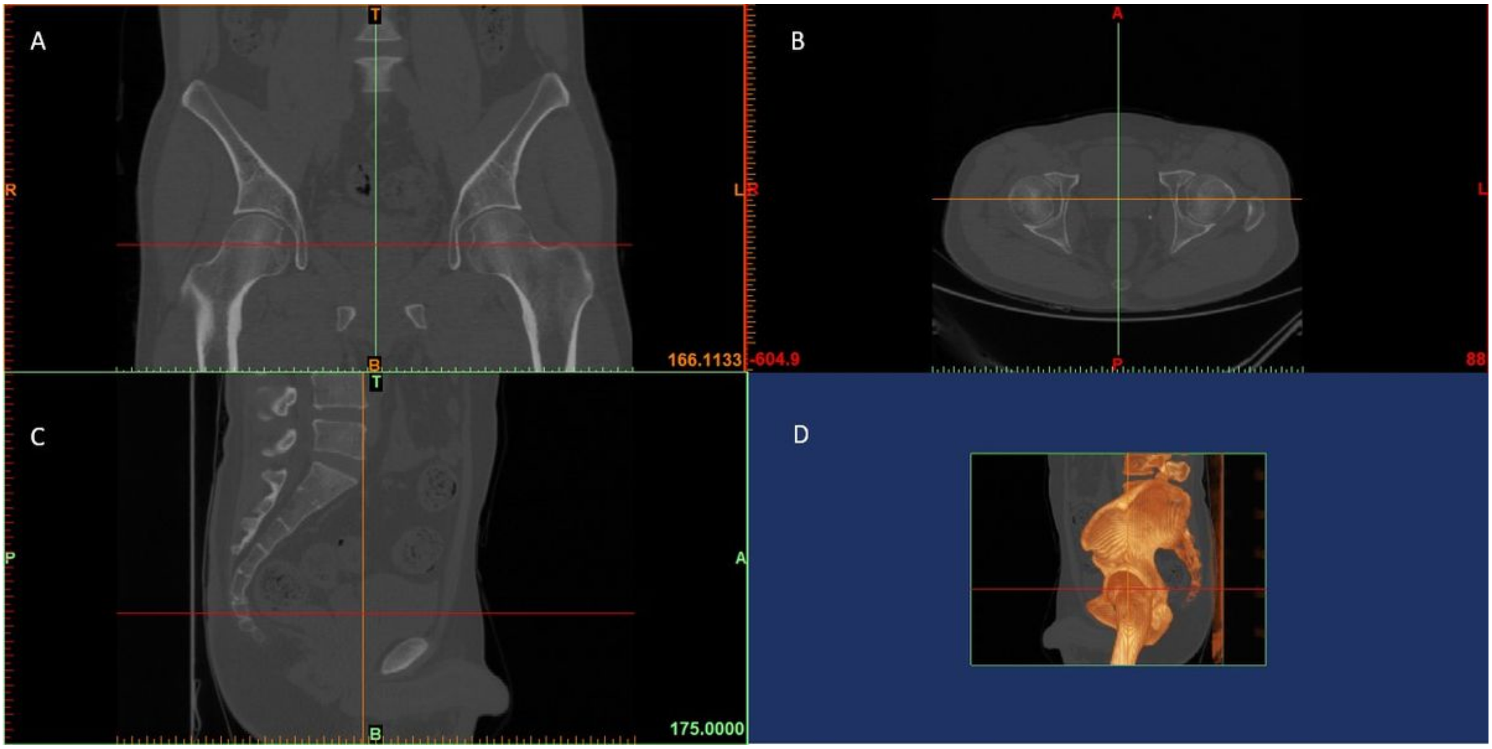

Figure 1

Determination of hip axis on reconstruction images of computed tomography. A. The hip axis on the coronal plane. B. The hip axis on the cross-sectional plane. C. The hip axis on the midsagittal plane. D. Determination of the center of the acetabular based on Volume rendering using Mimics software (Materialise, Leuven, Belgium).

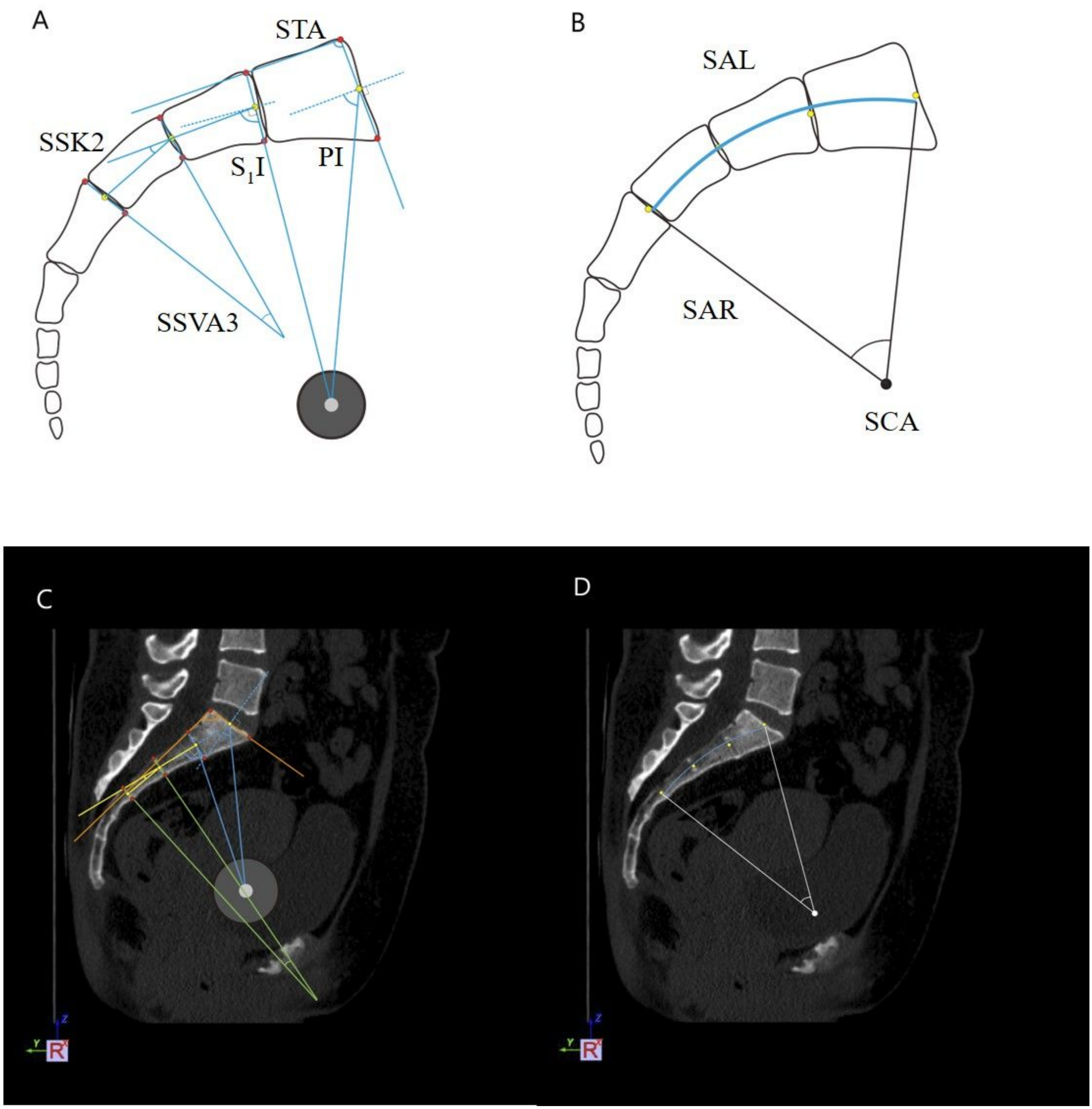

Figure 2

Measurement of pelvic and sacral parameters. A. Measurement of PI, STA, S1I, SSK2 and SSVA3. Since S2 and S3 are ventrally wedged, the value of SSK2 and SSVA3 are defined as positive. B. Measurement of SCA, SAL and SAR using the circle fitting method. Direction of the curvature is defined as positive in this schematic. C, D. Measurement of these above parameters on the CT images in the mid-sagittal plane.

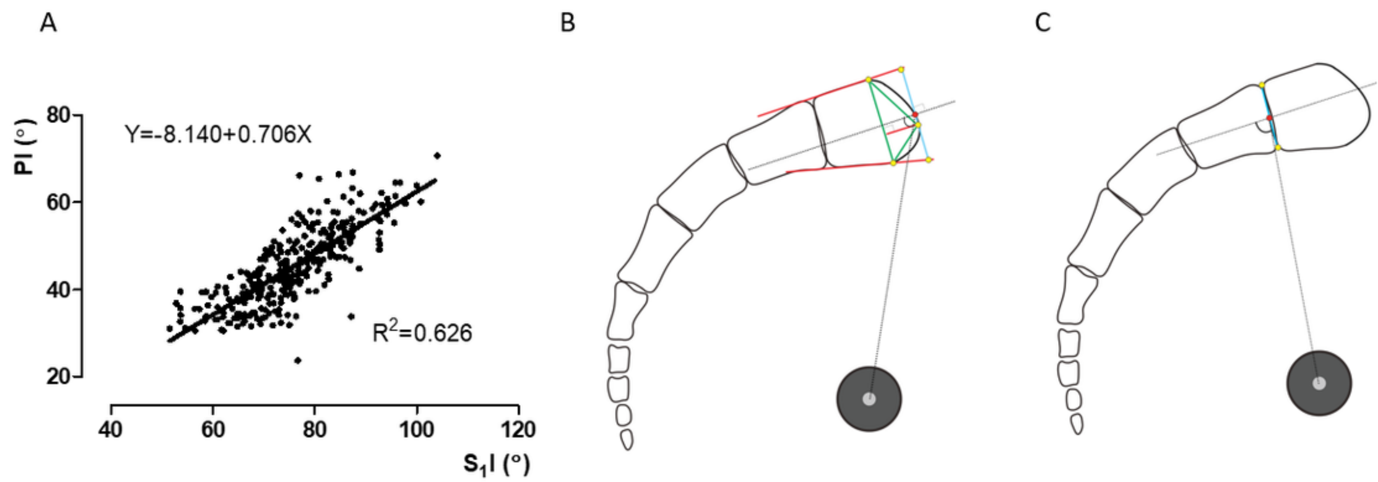

Figure 3

Measurement of PI in a dome shaped sacrum. A. The scatter diagram and linear regression equation between PI and S1I. B. The method to determine the original sacral endplate reported by Labelle et al for direct measurement of PI. C. measurement of the newly proposed parameter S2I. PI can be estimated according to the equation: PI = [0.706 × S2I] – 8.140°. *1: best fit line along the posterior border of sacrum. 2: best fit line along the anterior border of sacrum. 3: line joining posterior (g) and anterior (m) tangent points. 4: line is drawn parallel to line 3 and touches the most rostral part of the sacral endplate. g: point where line 1 loses contact with the posterior border of S1. m: point where line 2 loses contact with the anterior border of S1. n: contact point between line 4 and the dome shaped sacrum.