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Original Article

Determination of Anatomical Sacral Dysmorphism Criteria based on CT scan Findings for Iliosacral Screw Fixation in a Sample of Iranian Population without Pelvic Ring Fracture

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Abstract

Background: The pelvic ring, sacral fractures and sacroiliac dislocations are managed with different methods. The preferred treatment in sacral fractures or sacroiliac joint dislocations is iliosacral screw fixation. The upper sacral segment dysplasia increases the risk of perforation of the osseous cortex during Iliosacral fixation with a screw. The dysmorphic sacra have a narrow and angular osseous corridor.

Objectives: To date, no study has been conducted on the sacral dysmorphism and quantitative and qualitative criteria for fixation with iliosacral screw in sacral dysmorphism among the Iranian population.

Methods: We analyzed 100 CT scan and Outlet CT reformation forms of traumatic patients without pelvic trauma to determine 5 qualitative criteria of sacral dysmorphism (i.e., mammillary bodies, misshapen sacral foramen, upper sacral segment not recessed in the pelvis, residual disc between S1 and S2 vertebra and acute alar slope). Upper sacral surface area and angulation were determined based on the CT scan reformatted.

Results: Five qualitative criteria from the 3D pelvic CT outlet view and sixth characteristic (tongue-in-groove) from the axial pelvic CT section were obtained by an orthopedic surgeon. Coronal reconstruction was used to divide the patients into dysmorphic and non-dysmorphic groups by drawing a line along the axis of the osseous corridor from one side of iliosacral to its other side. The results showed that 37% of the patients were in the dysmorphic group and 63% in non-dysmorphic. Qualitative criteria were in the range 24% -71% in the dysmorphic group and 14%-34% in the non-dysmorphic group. The sacral dysmorphism score was calculated in all patients. The sacral dysmorphism score = (first sacral segment coronal angle) + 2(first sacral segment axial angle). The obtained mean angle in the dysmorphic and non-dysmorphic group was 84° and 72°, respectively. As the score increased, the safety of the osseous corridor decreased. The dysmorphic score ranged between 70 and 84 in one-third of the patients and none of them was less than 70°.

Conclusion: In this study, sacral dysmorphism was detected in 37% of the patients. Axial angulation and coronal angulation were the most important quantitative criteria for determining the sacral dysmorphism. Detecting sacral dysmorphism can be useful for preoperative planning of iliosacral screw placement.

Keywords: Sacral dysmorphism, Sacral CT-scan, Iliosacral fixation.

Introduction

The pelvic ring, sacral fractures and sacroiliac dislocations are managed with different methods. The use of a percutaneous sacroiliac screw is considered an efficient method for treating sacroiliac fractures and dislocations.[1-6] This technique is especially useful for patients with open pelvic fractures.[2] Several studies have introduced this technique as an appropriate clinical treatment.[2,7,8] Nevertheless, this method may damage the neurovascular system.[2,3,9] In this method, structures that are at risk of injury include sacral nerve roots that lie in the superior and inferior tunnel, anterior cortex, and spinal canal in the posterior region.[10,11] Although, screw installation increases the risk of cortex breakage and neurovascular damage in the narrow osseous corridor. If the screw installation is carefully selected, it can be safely used subcutaneously without risk.[2] Understanding variations in the three-dimensional anatomy of the sacrum is essential to prevent misplacement of an iliosacral screw.[7]

A safe bony corridor is located between the sacral alar and the first sacral neural tunnel for the insertion of a sacroiliac screw in the non-dysmorphic sacrum.[7,10] In order to pass a transsacral screw safely, it must traverse the ipsilateral and contralateral osseous corridors, which must be selected in sufficient size and complementary orientation to allow screw placement without a cortical breach.[7] A change in the trajectory of only 4° can result in cortical perforation and neurovascular damage. Upper sacral segment dysplasia refers to a sacral phenotype in which the size and orientation of the upper sacral segment do not allow safe passage of a transiliac, transsacral screw.[10] However, in sacral dysmorphism, the second segment of the sacrum has a safe zone for inserting an iliosacral screw.[7,10]

Routt et al., first described the qualitative characteristics of the upper sacral segment dysplasia.[13] The morphology of the osseous corridor in upper sacral segment dysplasia has five associated qualitative characteristics that are identifiable on an outlet radiograph including:1) mammillary bodies, 2) misshapen (noncircular) sacral foramen, 3) upper sacral segment not recessed in the pelvis, 4) residual disc between S1 and S2 vertebra, 5) acute alar slope and another one in the axial CT scan view was tongue-in groove.[7,9,10,12,13] Patients with the qualitative characteristics of upper sacral segment dysplasia have narrower and more angulated upper sacral segment.[14]

Objectives

The purpose of this study was to evaluate the qualitative and quantitative characteristics of sacral dysmorphism in a sample of the Iranian population and to determine the clinical criteria for predicting the presence of a safe bony corridor for fixation with screw in the upper segment of the sacrum.

Materials and Methods

We analyzed 100 patients referred to a first-level trauma center within a one-year period from 2017 to 2018. The patients without pelvic injury were subjected to a spiral spectral scanner with a GE light speed 64 slice CT scanner. Images were processed using Dicom software.

Inclusion criteria included age between 16-60 years, having undergone a CT scan for any reason, and having no pelvic injuries. On the other hand, exclusion criteria included lumbar scoliosis greater than 20°, spina bifida, history of previous pelvic trauma, vertebral fracture underlying fixation and radiographic contrast or implants obscuring the lumbosacral junction.

After selecting patients, demographic data including age and sex were collected. Each CT scan was formed from the vertebrae that were attached to the last ribs and the entire pelvis. Also, CT-reformation was developed along the axis of the sacrum to determine the qualitative and quantitative criteria. The conditions for outlet reconstruction were such that the lumbar spinous processes aligned with symphysis pubis and the superior cortex of the pubis were aligned with the second sacral vertebra body. As a result, we did not have a horizontal and vertical rotation.

The tongue-in-groove criteria on axial CT scan view and the qualitative criteria were determined based on outlet reformatted CT scan (Figure-1). Also, quantitative criteria including S1 and S2 cross-sectional area and axial and coronal angulation were measured. The results showed that the sacral dysmorphism score was twice the first sacral segment axial angle plus the first sacral segment coronal angle. Score= (first sacral segment coronal angle) + 2 (first sacral segment axial angle).[7]

Coronal angulation was measured as the angle subtended by a line drawn perpendicular to the axis of the osseous corridor and a line connecting the top of the iliac crests. Axial angulation was measured as the angle subtended by a line drawn perpendicular to the axis of the osseous corridor and a line connecting the posterior iliac spines (Figure-2). Also, quantitative criteria including S1 and S2 cross-sectional area and axial and coronal angulation were measured. The results showed that the sacral dysmorphism score was twice the first sacral segment axial angle plus the first sacral segment coronal angle. Score= (first sacral segment coronal angle) + 2 (first sacral segment axial angle).[7]

Coronal angulation was measured as the angle subtended by a line drawn perpendicular to the axis of the osseous corridor and a line connecting the top of the iliac crests. Axial angulation was measured as the angle subtended by a line drawn perpendicular to the axis of the osseous corridor and a line connecting the posterior iliac spines (Figure-2). The cross-sectional area of the corridor was the least of three measurements of a best-fit oval on contiguous slices perpendicular to the axis of the sacral osseous corridor on axial reformats.[7] The patients were divided into two groups (i.e., sacral dysmorphism and non-dysmorphism) by drawing a line in the coronal CT scan reformation along the axis of the osseous corridor from one side of iliosacral to its other side (Figure-3). In the dysmorphic phenotype, insertion of a long screw was not possible in the first sacral segment but was possible in the second segment.[7]

All tests and reviews were performed by one person. All analyses were performed using Prism 8.0.1 software considering a significance level of $p < 0.05$.

Table-1. Qualitative and quantitative criteria

Qualitative Characteristics
Upper sacral segment not recessed in pelvis
Mammillary bodies
Misshapen sacral foramen
Residual disc
Acute alar slope
Tongue in groove
Quantitative characteristics
Coronal angulation
Axial angulation sacral dysmorphism score
S1, S2 surface area

Figure-1. A) CT-SCAN reformat out-let view B) Tongue in groove in Axial CT-SCAN

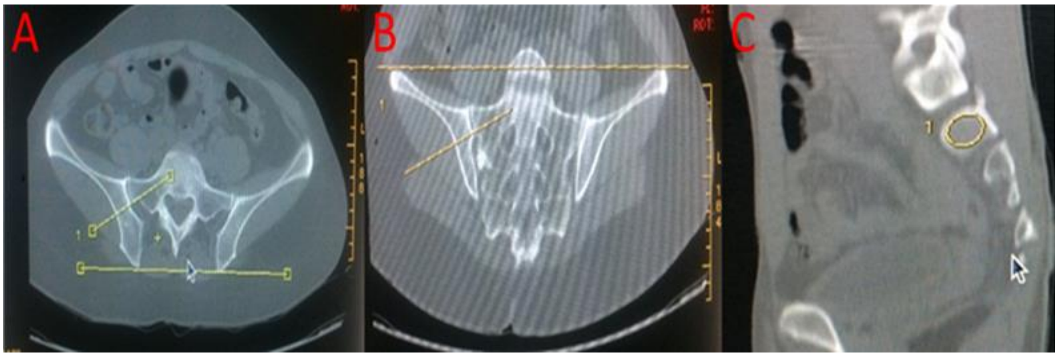

Figure-2. A) Axial angulation B) Coronal angulation C) S2 Surface area

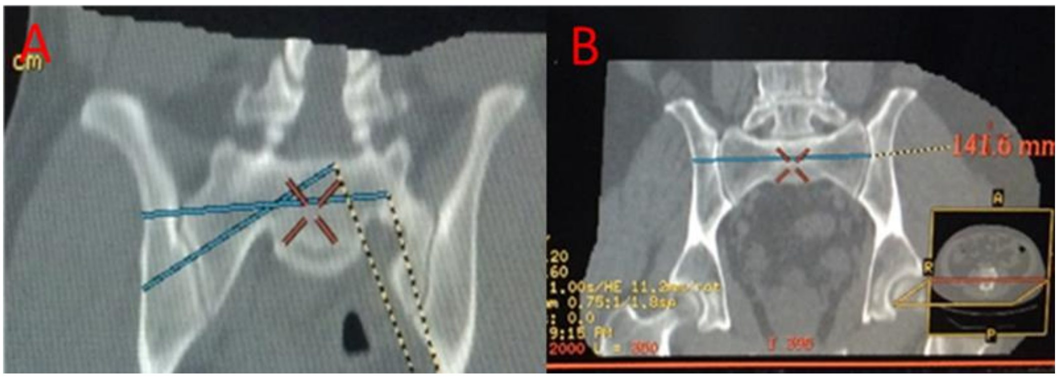

Figure-3. A) Dysmorphic upper sacral segment B) Non- dysmorphic upper sacral segment.

Results

We analyzed 100 pelvic CT scans of patients without a pelvic injury. About 37% of the patients were female and 63% male. The average age of the patients was 41.5 ± 12 years (ranging between 16-60 years). CT scan indications were flank, abdominal and back pain, hematoma, hematuria and trauma, and other abdominal CT scan indications.

Qualitative criteria were achieved with the use of reconstruction and reformatted axial sections of the pelvic CT scan. Quantitative criteria including the axial and coronal angles were determined using coronal and axial reformatted CT scan sections, and the sacral dysmorphism score was calculated twice the first sacral segment axial angle plus the first sacral segment coronal angle. Score = (first sacral segment coronal angle) + 2(first sacral segment axial angle). The patients were divided into two groups: sacral dysmorphism and non-dysmorphism, and then were compared in terms of gender and qualitative and quantitative criteria. No significant difference was observed between men and women in terms of dysmorphism using the analysis of the data by Fisher's exact test (Figure-4).

The qualitative criteria of the two groups of dysmorphism and non-dysmorphism were compared using the chi-square (χ^2) test, which showed a significant difference between them. In comparison, there was no significant difference in the tongue-in-groove group. The prevalence of dysmorphism qualitative criteria in the sacral dysmorphism and non-dysmorphism groups were in the range of 24-71% and 14%-34%, respectively (Table-2) (Figure-5).

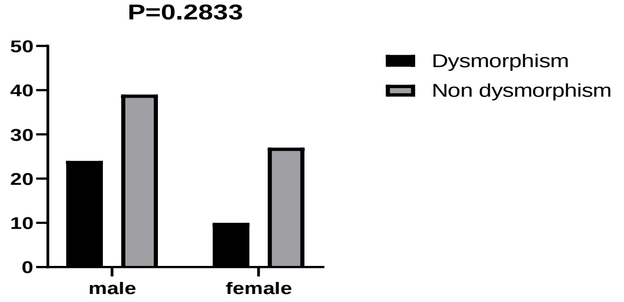

Figure-4. Differences between men and women in terms of dysmorphism using the analysis of the data by Fisher's exact test

Table-2. Comparison of the qualitative criteria of dysmorphism and non-dysmorphism groups using the chi-square (χ^2) test

Test	Chi-square
Chi-square, df	15.96, 5
P value	0.0070
P value summary	**
One- or two-sided	NA
Statistically significant (P < 0.05)?	Yes

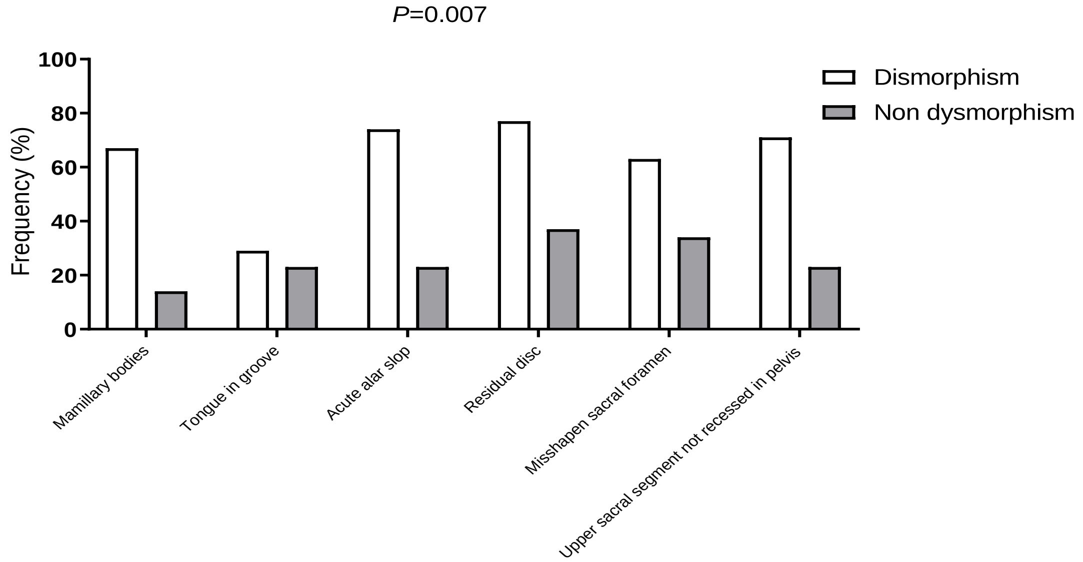

Figure-5. Prevalence of dysmorphism qualitative criteria in the sacral dysmorphism and non-dysmorphism groups

S1 and S2 vertebral cross-sections area were analyzed in both dysmorphic and non-dysmorphic groups using a one-way ANOVA test. In this analysis, the cross-section area of the S1 vertebra was more than S2 in both groups. Also, the S1 cross-section area in the dysmorphic group was less than non-dysmorphic group, and the difference in the S2 cross-section area of dysmorphic with non-dysmorphic was not significant (Table-3) (Figure-6).

Table-3. Comparison of S1 and S2 vertebral cross-sections area. (1=S1, 2=S2, d: dysmorphism, n: non dysmorphism)

comparisons test	Mean Diff.	95% CI of diff.	Significant?	Summary	Adjusted P Value
1d vs. 2d	103.8	53.31 to 154.3	Yes	****	<0.0001
1d vs. 1n	-65.84	-110.0 to -21.67	Yes	***	0.0009
2d vs. 2n	42.94	-1.228 to 87.12	No	Ns	0.0601
1n vs. 2n	212.6	175.8 to 249.4	Yes	****	<0.0001

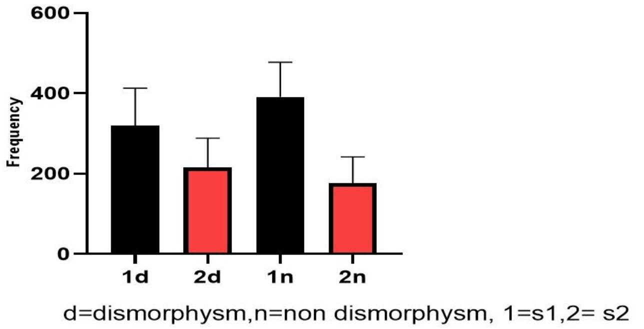

Figure-6. Comparison of S1 and S2 vertebral cross-sections area.

Sacral dysmorphism score was compared using unpaired t-test in two groups. The differences between them were significant (p <0.0001) (Figure-7).

The means of non- dysmorphism group and dysmorphism were 71.9 and 84.7, respectively, and the data distribution was normal (Figure-8).

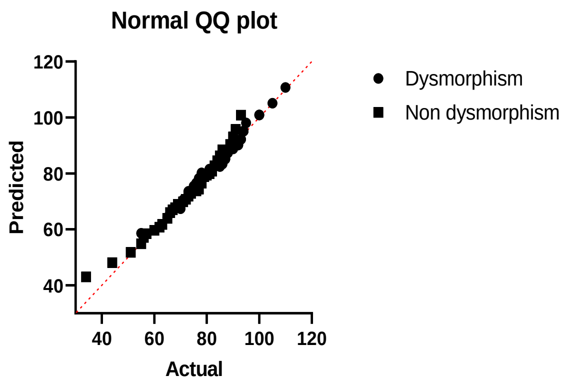

Figure-7. Normal QQ plot, normal distribution between non-dysmorphism and dysmorphism group

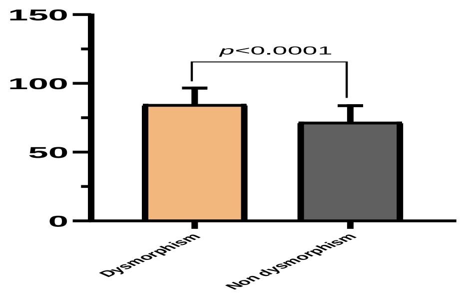

Figure-8. Sacral dysmorphism score compared using unpaired t-test in two groups

Discussion

Although knowledge about the sacral dysmorphism has increased, sufficient studies have not been performed on the determination of the criteria and its correlation with screw fixation in sacral dysmorphism. To the best our knowledge, there have been no studies on this topic in the Iranian population. The aim of this study was to determine the prevalence of quantitative and qualitative criteria and to determine the relationship between the sacral dysmorphism score and the rate of sacral dysmorphism.

This study showed that:

1) Sacral qualitative criteria for sacral dysmorphism based on outlet reformatted CT scan in sacral dysmorphism were more prevalent than the non-dysmorphic (except tongue-in-groove).

2) S1 cross-section area was greater than S2 in both groups. However, in sacral dysmorphism, S1 cross-section area was less than non-dysmorphic sacrum.

3) The sacral dysmorphism score was used to predict the relative risk of damage to the cortex during the screw fixation.

Routt et al., first described the qualitative characteristics of the upper sacral segment dysplasia.[7,13] There were six criteria for this purpose, which 5 of them were based on outlet-view radiograph and one (tongue-in-groove) was based on an axial CT scan. Previous studies have reported that patients with all of these characteristics have a narrower and angled osseous corridor in the first sacral segment compared with those who exhibit none of these characteristics.[7,12,14,15] Using these criteria to adjust operative planning, surgeons can achieve percutaneous fixation of pelvic fractures with low rates of neurovascular injury, ranging from 0% to 1%.[16,17]

We studied a large group of patients without pelvic injuries in a cohort study. In our study, the prevalence of qualitative criteria in the sacral dysmorphism and non-dysmorphic groups was in the range of 24-71% and 14-34%, respectively. The prevalence of sacral dysmorphism in this study was similar to those in prior studies.[7,10,12,16] We defined sacral dysmorphism as the inability to pass the transsacral screw in the first sacral vertebra but the ability to place it in the second segment safely. This method have been also used in previous studies.[7,12,16] By using this dividing method, we found a 37% sacral dysmorphism prevalence, which was lower than those reported by other studies.[7,14,18] This difference may be due to the role of ethnicity. More studies are needed on various breeds to prove this claim.

The axial and coronal angles of the sacral osseous corridor are the most important criteria to determine the first sacral vertebral variation. Gardner et al., have already reported higher coronal and axial angles in sacral dysmorphism.[14] In addition, Kaiser et al., reported a relationship between axial and coronal angles and calculated the sacral dysmorphism score based on the summation of the first sacral segment coronal angulation and twice the first sacral segment axial angulation.[7] Based on this finding, we calculated the sacral dysmorphism score in our patients and compared it between two groups. In the present study, a mean of sacral dysmorphism score in the dysmorphic group was obtained to be 84, which is more than the value reported by Kaiser et al.,[7] In the present study, the first vertebral surface area in both groups were more than the second vertebral surface area, which is consistent with the findings of the previous studies.[7] However, the first sacral vertebral surface area in the sacral dysmorphism was less than that of the non-dysmorphism patients, which has not been reported previously.

In the current study, we did not find any qualitative criteria as determination of sacral dysmorphism. Although, the frequency of qualitative criteria in sacral dysmorphism increased alone or together. However, we did not find the definitive link that could define the sacral dysmorphism based on them. Among these criteria, tongue-in-groove, which is determined by axial CT, was much less associated with sacral dysmorphism. Although the sacrum cross-section area in sacral dysmorphism was less than that of non-dysmorphism, and the variation in sacrum based on that was not categorical. However, the screw fixation problems increased with a decrease in the cross-sectional area.

In the present study, quantitative criteria including the axial and coronal angles and sacral dysmorphism score were useful in determining the variations in the sacral osseous corridor. The first sacral segment coronal angle plus twice the first segment axial angle was defined as the sacral dysmorphism score. The higher sacral dysmorphism score the less likely there is to be a safe transsacral corridor.[7] Score = (first sacral segment coronal angle) + 2 (first sacral segment axial angle). In our study, a high sacral dysmorphism score was correlated with increasing complications of screw fixation in the sacral osseous corridor. In scores above 84, there were many possible complications. Therefore, in a score higher than 84, we recommend surgeons to place the sacroiliac screw in the second sacral segment. In scores between 70 and 84, screw fixation must be carefully conducted to prevent complications.

Conclusions

Sacral dysmorphism is a morphological characteristic that increases the complications of iliosacral screw placement and causes damage to the neurovascular system. The sacral dysmorphism score is obtained from the twice first sacral segment axial angle plus first sacral segment coronal angle using a CT scan reformats along the plane of the sacrum. A high sacral dysmorphism score correlates with anatomy that precludes the safe placement of a transsacral screw.

The five qualitative criteria of sacral dysmorphism determined by CT outlet view (i.e., mammillary bodies, misshapen sacral foramen, upper sacral segment not recessed in the pelvis, residual disc between S1 and S2 vertebra and acute alar slope), increased the probability of the upper sacral segment dysmorphism. Regarding these criteria, the surgeon should pay special attention to preoperative planning of iliosacral screw placement. Therefore, we recommend reconstructing CT scan before iliosacral screw fixation. Also, the sacral dysmorphism score should be measured preoperatively to be used to estimate the presence of an unsafe corridor for placement of iliosacral screws.

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Authors' Contribution

All authors pass the four criteria for authorship contribution based on the International Committee of Medical Journal Editors (ICMJE) recommendations.

Conflict of Interests

The authors declared no potential conflict of interests with respect to the research, authorship, and/or publication.

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