3-Dimensional Morphometric Analysis of the Sacrum

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Introduction

- Sacral morphology exhibits significant demographic variability that influences both normal function and response to injury.
- Transsacral fixation devices depend on the integrity and dimensions of the sacrum for their effectiveness.
- The efficacy of these devices hinges on the "S1 Bony Corridor," a critical anatomical pathway constrained by structures such as the auricular surface, S1 foraminal dimensions, and the overall length of the sacrum.

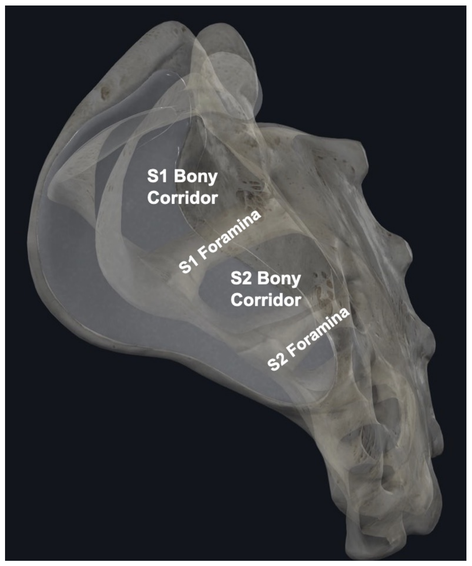

Fig. 1 S1 and S2 Bony Corridor seen through a lateral view of the sacrum

- Sacral dysmorphism includes morphometric variations such as L5/S1 sacralization, the tongue-in-groove phenomenon, and the presence of mammillary bodies.
- These variations complicate standard approaches to fixation by altering typical anatomical landmarks and biomechanical properties.
- Existing literature uses CT scans or cadaveric bone studies to determine these measurements, which are limited in precision and access within the sacral canal to establish dimensions of the “S1 Bony Corridor.”

Hypothesis

- A detailed 3D morphometric analysis of the sacrum will reveal critical anatomical features and biomechanical properties that can significantly improve the accuracy and effectiveness of sacral fixation devices

Methods and Results

This study utilized high-resolution computed tomography (CT) datasets, analyzed using the 3D Slicer software to conduct a 3D analysis of the sacrum's internal osteology and biomechanical properties. The 3D Slicer segmentation editor was manually employed to delineate the division between sacral and pelvic structures to determine the metrics of the auricular surface. For the measurement approach, specific anatomical landmarks were identified that were seen to be critical for assessing sacral morphology and the “Bony Corridor” accurately. Screening for sacral dysmorphism characteristics was a focal point of this analysis. Specific attention was given to identifying L5/S1 sacralization, tongue-in-groove phenomenon through CT imaging, and the presence of mammillary processes. All measurements and segmentations were conducted using 3D Slicer, facilitating the creation of accurate 3D printed models of the sacrum. This method allowed for a better understanding of sacral architecture and provided a reliable basis for evaluating potential complications in sacral fixation procedures.

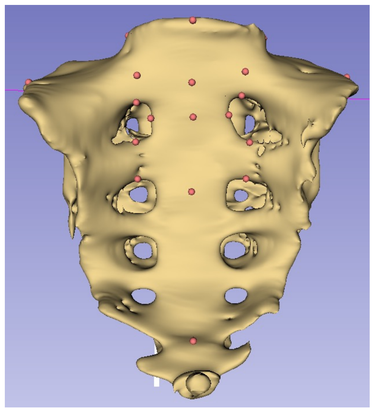

Fig. 2 Demo of Landmark Points - Anterior

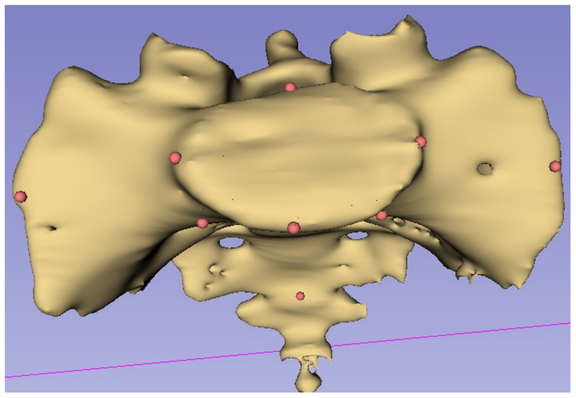

Fig. 3 Demo of Landmark Points - Superior

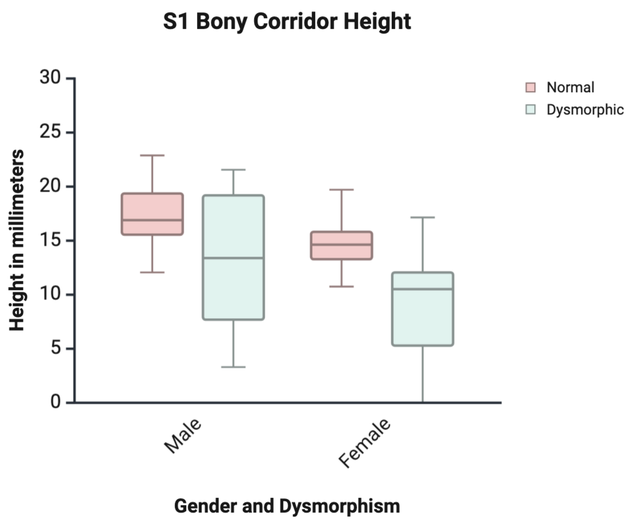

Fig. 4 S1 Bony Corridor Height based on Gender and Dysmorphism

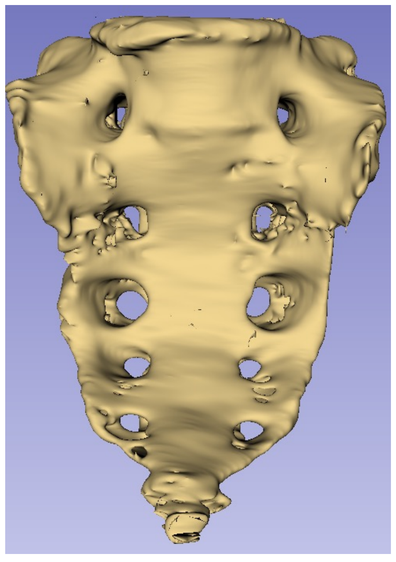

Fig. 5 Segmented Illustration of Lumbosacral Fusion

Category	Length	S1 Vertebra Width	S1 Vertebra Length	S1 Corridor Height Ant. Left	S1 Corridor Height Ant. Right
Normal	119.73	34.56	53.88	15.96	16.34
Dysmorphic	117.13	32.70	51.18	11.04	11.13
All	118.49	33.67	52.59	13.61	13.85
Male Normal	119.55	35.77	55.97	17.18	17.72
Female Normal	119.94	33.13	51.42	14.53	14.71

Category	S1FLRA	S1FLLA	S1-S2 Left	S1-S2 Right	Curved Length	BC Width Right	BC Width Left
Normal	13.38	13.89	13.57	13.71	119.08	16.15	16.27
Dysmorphic	13.00	12.93	14.06	14.26	124.25	15.15	14.42
All	13.20	13.44	13.80	13.97	121.55	15.67	15.38
Male Normal	14.13	14.61	13.87	14.00	123.85	17.07	17.10
Female Normal	12.49	13.04	13.21	13.38	113.43	15.07	15.30

Conclusion

Of the 46 patients studied in this research, 22 were identified as having sacral dysmorphism, which accounts for approximately 47.8% of the total sample. The demographic breakdown included 24 males and 22 females, with 13 males and 11 females categorized as having normal sacral morphology. Notably, 10 data sets exhibited lumbar-sacral fusion, 7 displayed mammillary processes, and 5 presented with the tongue-in-groove phenomenon. Trends in the data suggest that dysmorphic features are not exclusively associated with any single demographic group but are rather distributed across different age and gender categories. This variability underscores the complexity of sacral anatomy and the challenges it presents in clinical practice.

Future Directions

This preliminary study sets the groundwork for ongoing research aimed at expanding our understanding of sacral morphology. Future efforts will focus on enlarging the dataset to include a broader demographic spectrum, which will enhance the statistical power and generalizability of the findings. The insights gained from this study are intended to allow for tailored surgical approaches that accommodate the specific morphological characteristics observed.

References

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