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RADIOMORPHOMETRIC EVALUATION OF SACRAL DYSMORPHISM: PREVALENCE AND MORPHOLOGICAL CHARACTERISTICS AMONG PATIENTS AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET, KENYA

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Preface

Sacral dysmorphism is a critical anatomical variation with significant implications for pelvic trauma management and surgical fixation techniques. Its complex morphology affects osseous fixation pathways (OFPs), posing challenges in iliosacral screw placement and increasing the risk of iatrogenic injury. This study explores the prevalence, classification, and surgical relevance of sacral dysmorphism, providing insights into optimizing preoperative planning and improving patient outcomes.

This research was made possible through the support of Moi University, my colleagues, and the radiology and orthopaedic teams at MTRH. Their guidance, collaboration, and access to essential clinical data were invaluable in shaping this work.

I extend my deepest gratitude to my mentors, peers, and all those who contributed to this study in various capacities. Their insights and encouragement have played a crucial role in its completion.

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ABSTRACT

Background: Sacral dysmorphism is a condition in which the sacrum is malformed or abnormally shaped. Qualitative features of sacral dysmorphism include the presence of mammillary bodies, a non-circular and amorphous first sacral foramen, residual discs in sacral vertebrae, an acute alar slope and a tongue-in groove morphology. Quantitative methods to assess different aspects of the dysmorphic sacrum, include the sacral dysmorphism score, safe zone cross-sectional area, and critical sacroiliac (SI) angle. These approaches, help assess sacral dysmorphism. The high prevalence of sacral dysmorphism in the global population, estimated at 30-40%, presents a significant surgical problem such as increased intraoperative vascular and neurological injury warranting further investigation. Previous research on this condition has primarily been conducted outside Kenya, leaving a gap in understanding of the prevalence and impact of sacral dysmorphism in this region. Identification of a dysmorphic sacrum is crucial for a successful surgical outcome.
Objectives: To examine the prevalence and characteristics of sacral dysmorphism among patients presenting at the Computerized Tomography (CT) scan unit within the radiology department of Moi Teaching and Referral Hospital.
Methods: A cross-sectional study was conducted at Moi Teaching and Referral Hospital's radiology unit in Eldoret, Kenya, with a sample size of 372 scans, sampled in a systematic random manner. The study took place between July 2023 and December 2023. It involved reviewing the images in 3D and different planes and recording the age, gender, presence of mammillary bodies, shape of the S1-S2 neural foramina, presence of an acute alar slope, and existence of the tongue-in-groove sign on a data collection sheet. The sacral dysmorphism score, safe zone cross-sectional area, and critical sacroiliac angle were measured. Collected data was analysed and described using descriptive statistics, including means, standard deviations, frequencies, and percentages of the study sample.
Results: A total of 372 CT scans were analysed, comprising 158 males and 214 females. The overall prevalence of sacral dysmorphism was 44.1%, with individual dysmorphic features ranging from 9.7% to 75.2%. The most common dysmorphic feature was non-fused sacral segments (75.2%), while irregular sacral foramina were the least prevalent (9.7%). In the study population, 44.1% exhibited a sacral dysmorphism score exceeding 70. The mean safe zone cross-sectional area was 401.4 ± 80.3 mm². When evaluating the critical sacral iliac angle, 93.9% of dysmorphic sacra were found to safely accommodate SI screws. Statistically significant gender differences in sacral dysmorphism were observed, with females more frequently exhibiting residual discs and tongue-in-groove morphology, while males had a larger safe zone cross-sectional area..
Conclusion: Sacral dysmorphism is highly prevalent in our population, with the most common dysmorphic feature being non-fused sacral segments. Some dysmorphic features are more prevalent when compared to other populations. A majority of the dysmorphic sacra can safely accommodate sacroiliac screws when assessed with the critical sacroiliac angle
Recommendation: Orthopaedic surgeons and radiologists should consider sacral dysmorphism when evaluating and treating the pelvis. The sacral dysmorphism score and critical SI angle can be requested and reported when a CT pelvis is performed to aid in the preoperative planning of dysmorphic sacra. More studies should be conducted on sacral dysmorphism in our population to further contextualize the findings of this study.

INTRODUCTION

The vertebral column is a crucial component of the axial skeleton, providing structural support, mobility, and protection for the spinal cord. It consists of 33 vertebrae, categorized into cervical, thoracic, lumbar, sacral, and coccygeal regions (Singh, 2014). Among these, the sacrum plays a vital role in pelvic stability and weight transmission, articulating with the lumbar spine superiorly, the iliac bones laterally, and the coccyx inferiorly (Nastoulis et al., 2019). Structurally, the sacrum is a triangular bone composed of five fused vertebrae, with its base formed by the first sacral vertebra (S1) and its apex tapering to the coccyx. It encloses the sacral canal, which transmits the cauda equina and sacral nerves, and has foramina that facilitate neurovascular passage (Hinrichsen, 2008). Sexual dimorphism in sacral morphology is well documented, with females typically having a shorter and wider sacrum to accommodate childbirth (Singh, 2014).

Sacral dysmorphism refers to anatomical variations in sacral shape and structure, ranging from minor deviations to significant malformations (Pal, 2006). These variations alter the morphology of the sacral foramina, alar slope, and sacroiliac joint articulation, complicating clinical evaluation and surgical management (Kaiser et al., 2014). Routt et al. (1996) identified key dysmorphic features, including mammillary bodies, non-circular sacral foramina, residual S1-S2 disc spaces, acute alar slopes, and tongue-in-groove sacroiliac articulations (Radley et al., 2020; Weigelt et al., 2018). Compared to a normal sacrum, a dysmorphic sacrum often has an altered osseous structure that restricts safe screw placement, increasing the risk of neurovascular injury (Conflitti et al., 2010).

Studies indicate that sacral dysmorphism affects between 40% and 70% of various populations, with prevalence influenced by genetic, developmental, and ethnic factors (Weigelt et al., 2018). Imaging techniques, particularly 3D CT reconstructions, play a crucial role in identifying dysmorphic features, allowing for both qualitative and quantitative assessment (Conflitti et al., 2010). Alshaalan et al. (2024) found that dysmorphic sacra exhibit a significantly smaller osseous fixation pathway (OFP), reducing the available bone corridor for safe iliosacral screw placement by up to 33.4%.

Sacral dysmorphism poses significant challenges in pelvic trauma surgery, particularly in iliosacral and transsacral screw fixation, where altered sacral anatomy limits safe screw placement (Routt et al., 1996). While intraoperative navigation systems have been proposed to enhance accuracy, their high cost and limited availability remain barriers (Alshaalan et al., 2024). Given the high prevalence of sacral dysmorphism, its surgical implications, and the limited regional data on its characteristics, this study aims to assess the frequency and morphological variations of sacral dysmorphism in patients at Moi Teaching and Referral Hospital. A better understanding of these anatomical variations will aid in improving preoperative planning and surgical outcomes in our population

Methods:

Study Design
The research was a cross-sectional study that involved reviewing abdominopelvic CT scans taken between July 2023 and December 2023 at Moi Teaching and Referral Hospital radiology unit.

Study Area.
The research was conducted at the radiology department of Moi Teaching and Referral Hospital (MTRH). Using a 64 Slice Phillips Scanner.

Study Population
The study focused on CT scans, specifically abdominopelvic scans that capture the complete sacrum. These scans were obtained from the CT scan repository, Picture Archiving and Communication System (PACS).

Study Period: 1st July 2023 to 31st December 2023.

Sampling Technique: Systematic random sampling (K value: N/n =1800/372 = 4th scan

3.4 Eligibility Criteria:

3.4.1 Inclusion Criteria

- CT scans of patients who were at least 18 years old
- CT images that showed the entire pelvis.

3.4.2 Exclusion Criteria

- CT images with severe lumbosacral fractures distorting the images.
- CT images with severe sacral osteoporosis, sacral tumors or sacral infections.
- CT images with lumbar scoliosis greater than 20 degrees
- CT images with spina bifida distorting the sacrum.

3.5 Sample Size

The study aimed to determine the prevalence of sacral dysmorphism among patients at Moi Teaching and Referral Hospital. Previous global research has estimated that 30% to 41% of individuals exhibit sacral dysmorphism (Nastoulis et al., 2019; Radley et al., 2020; Conflitti et al., 2010). To calculate the sample size, the researcher utilized the prevalence figure of 41% reported by Nastoulis et al. (2019). The sample size was determined using the formula for calculating a single population proportion provided by Fisher et al. (1998), assuming a similar proportion in our context:

$$n = \left[\frac{Z_{1-\alpha/2}}{d}\right]^2 . P(1-P)$$

Where,

n= minimum sample size required

$Z^2_{1-\alpha/2}$= The typical usual distribution's critical value at the α -level of significance (α=0.05, $Z_{1-\alpha/2}$=1.96).

p = Prevalence of 41%, based on the study by Nastoulis et al. (2019)

d =Margin of error (d=0.05)

Substituting for the above values, the minimum sample for the study was 372.

3.6 Sampling Technique

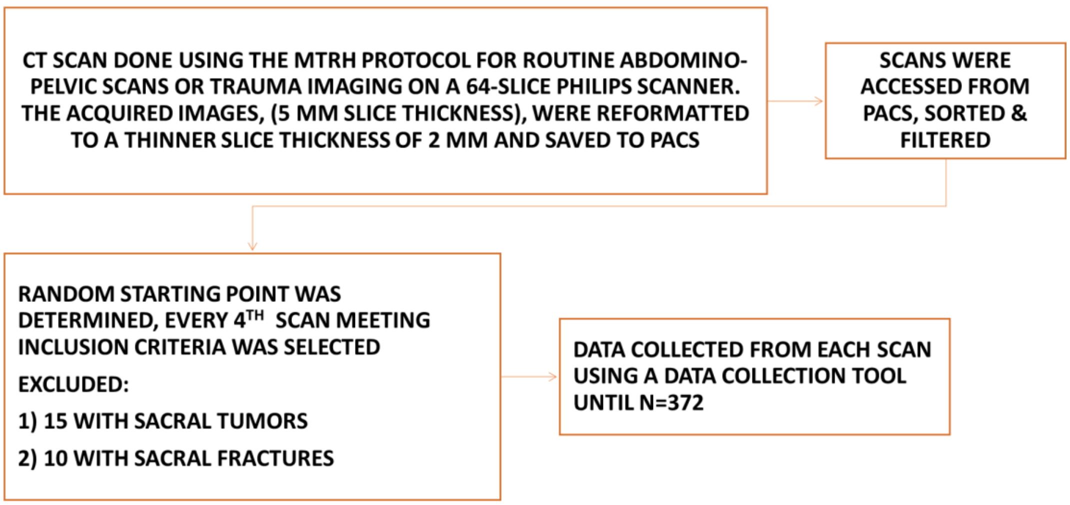
This study utilised systematic random sampling to ensure an equal probability of selecting every member of the study population. At least 10 CT scans showing the sacral region are performed daily at MTRH. These scans are saved in the Picture Archiving and Communication System (PACS), a cloud-based platform that facilitates the transfer, storage, and efficient organization of radiology data. It was estimated that a total of 1800 CT scans would be conducted over the 6-month study period.

In the systematic sampling method, a random starting point was determined, followed by the selection of every Kth patient until the desired sample size of 372 was reached.

The value of K was calculated using the formula K = N/n, where N represents the population size of unique patients over 6 months and n represents the desired sample size. K = 1800/372, which equalled approximately 4.84.

Every fourth CT scan meeting the inclusion criteria was included to ensure a representative sample. Each week, a structured review process was implemented to examine all abdominopelvic scans from that week, with aid from the radiology unit information technology (IT) personnel. The scans were sorted by PACS according to their completion dates and times. From this organized data set, every fourth scan that met the inclusion criteria was chosen for the sample. With an average of 70 scans performed weekly, selecting every fourth scan resulted in the recruitment of approximately 17 scans per week, or about 3 scans per day.

The below study procedure schema was used:



3.7 Data Collection Tools and Methods

The study commenced by selecting a normal pelvic scan, free of dysmorphism, and examining it across various planes. This standard scan was placed on a device on the worktable to serve as a reference for comparison.

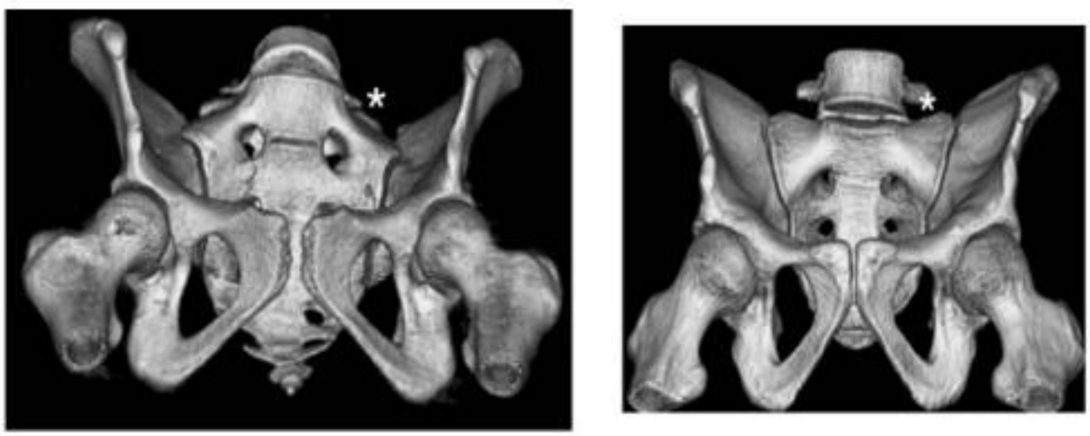
For each patient included in the study, relevant details such as age and gender were recorded on a data collection sheet. Tomography examinations generated both 2D images (sagittal, coronal, axial) and 3D reconstructions of the bony pelvis at the workstation.

These images were used to:

- Evaluate the presence of specific qualitative features of sacral dysmorphism, including:
- Acute alar slope
- Mamillary bodies
- Non-fused sacral disc segments
- Tongue-in-groove morphology
- Irregular sacral foramina
- Calculate the sacral dysmorphism score
- Measure the safe zone cross-sectional area
- Measure the critical SI angle

The alar slope was assessed in 3D reconstructed images, the outlet view, and the sagittal view, and was classified as either acute or non-acute in each view. The findings were recorded accordingly. Mammillary bodies were evaluated in both 3D reconstructed images and the outlet view and recorded as either present or absent.

Figure 16: demonstrating a sample of 3D images that were created. Source Researcher



To assess neural foramina, the pelvic scan was rotated to create a pelvic outlet reconstruction. Horizontal rotation was corrected by aligning the lumbar spinous processes with the symphysis pubis, while vertical rotation was adjusted to align the superior pubic cortex with the second sacral segment body. The shape of the sacral foramina was recorded as either regular or irregular.

Sagittal reformatted images were used to evaluate residual S1 and S2 discs, with sections passing through the central sacral vertical line (CSVL). The findings were recorded accordingly.

Figure 17: Demonstrating sagittal sections that were created showing residual discs, Source: Researcher

Tongue-in-groove morphology was assessed using coronal reformatted images, inclined along the vertical axes of the S1 and S2 vertebrae. Findings of the presence or absence of this morphology were recorded.

Figure 18: Demonstrating coronal sections that were created to demonstrate the tongue-in-groove sign, Source: Researcher

Sacral dysmorphism score

To standardize and ensure reproducibility, scans were reformatted into true coronal and axial planes (Morshed et al., 2015). This involved using cross-hair tools to align the sagittal axis with the posterior border of the sacrum and positioning axial reformats along the upper-end plate of the S2 vertebrae so as to measure axial and coronal angulation (Morshed et al., 2015).

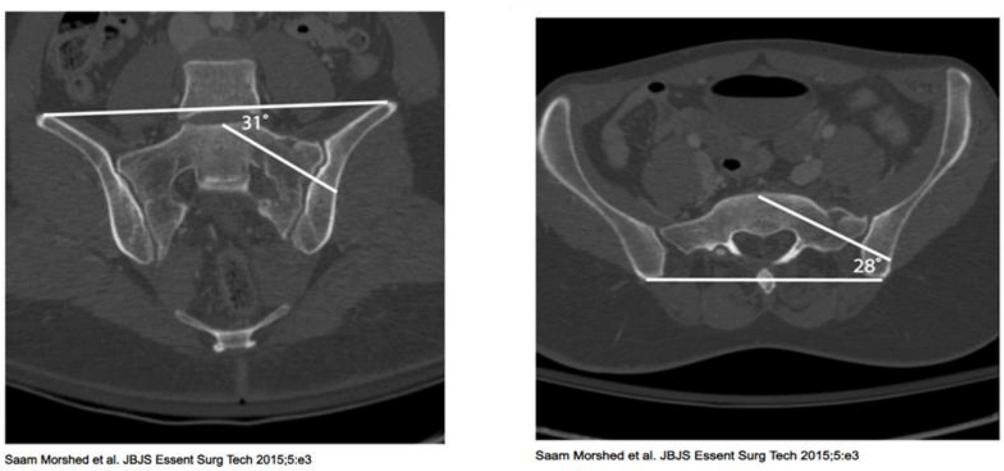
The score was calculated as follows:

The sacral dysmorphism score = (first sacral segment coronal angle) + 2(first sacral segment axial angle)

Coronal angulation was measured by the angle formed by a line drawn along the axis of the osseous corridor to the midpoint of CSVL and a line connecting the top of the iliac crests. Axial angulation was measured as the angle formed by a line drawn on the axis of the osseous corridor passing through CSVL and a line connecting the posterior iliac spines. Sacral dymorphism score was then calculated

The outcome variable is sacral dysmorphism, which was defined as a dysmorphic score of more than 70 on quantitative analysis.

Figure 19: Showing Coronal angulation and Axial Angulation. Kaiser et al (2014)



The Safe Zone Cross Sectional Area

Measurement of the cross-sectional area was done from sagittal cut images that were obtained at the medial border of 1st sacral foramina to obtain sagittal cut imaging of the S1 and S2 sacral osseous corridor for standardization using cross hair tools.
Measurement of the cross sectional area was done by inscribing a circumference on the margins.

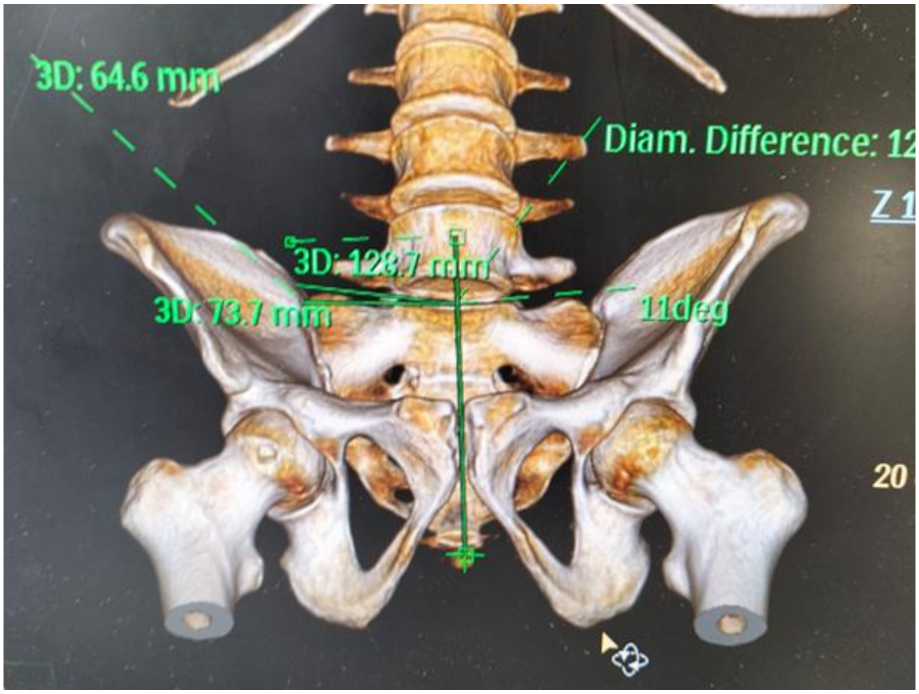
Figure 20: Demonstrating measurement of cross-sectional area Source: Researcher

Critical SI Angle

To get critical SI angle, pelvic outlet view was created. Neutral horizontal rotation was corrected by aligning lumbar spinous processes with the symphysis pubis.
Vertical rotation was adjusted to align the superior cortex of the pubis with the body of S2. CSVL line was drawn, to identify midpoint of S1 superior endplate. A horizontal line was drawn over the superior end plate of S1 touching the midpoint.

Another line was drawn from the tip of the SI joint, to the midpoint of S1 superior endplate. Angle was then measured

Figure 21: Demonstrating measurement of critical SI angle. Source: Researcher



Evaluations and data collection was conducted by the researcher and a trained radiographer. In cases of disagreement, a radiologist was consulted. Findings were recorded as either present or absent.

3.8 Data Management

Data collected on the collection chart was entered into Microsoft excel, for cleaning and storage. The data was later exported into a STATA version 16 for analysis

The data was described using descriptive statistics, including means, standard deviations, frequencies, and percentages of the study sample.

The appropriate test was chosen based on the measurement level, distribution of the data and the sample size with a p-value threshold of 0.05

3.9 Ethical Consideration

Before commencing, the study underwent an ethical review by the MTRH/Moi University Institutional Research and Ethics Committee (IREC), which granted approval under study number FAN:0004508. Additionally, the study received authorization from the National Commission for Science, Technology, and Innovation (NACOSTI) under license number NACOSTI/P/23/28531, as well as approval from MTRH management. Data security was ensured through the use of identification methods and password-protected databases.

3.10 Study Limitations

One notable limitation of the study was the interobserver variability in the evaluation and interpretation of the images. However, this concern was addressed by implementing standardized procedures for the scans, carefully reformatting them in both the axial and coronal planes, and rigorously comparing them to established standard normal scans (Morshed et al., 2015). Additionally, the research assistant was provided with comprehensive training, and experienced radiologists were consulted to offer expert guidance, further minimizing the variability risk.

Another limitation that impacted the study was the frequent malfunctioning of CT scan equipment, coupled with a shortage of essential supplies, such as contrast agents. To address this challenge proactively, the study was designed with an extended duration of six months, ensuring ample time for procuring necessary materials and facilitating the timely repair of any equipment malfunctions.

4.0 FINDINGS

4.1 INTRODUCTION

The findings are based on 372 abdominopelvic CT scans taken between July 2023 and December 2023 at Moi Teaching and Referral Hospital radiology unit of patients aged 18 years and above

4.2 DEMOGRAPHICS CHARACTERISTICS

Among the 372 examined CT scans, the predominant gender represented was female, constituting 57.7%, while males accounted for the remaining 42.3%. The mean age observed was 50.2 years, with an age range from 18 to 96 years.

Table 1: Demographic Characteristics

	Total N=372
Age(years)	
Mean (SD)	50.2 (17.5)
Range	18 – 96
Sex	
Male	158 (42.5%)
Female	214 (57.5%)

4.3 PREVALENCE OF SACRAL DYSMORPHISM

An analysis of sacral dysmorphism in 372 scans revealed that 164 individuals, comprising 44.1% of the total, had a score exceeding 70, indicating the presence of sacral dysmorphism. In contrast, 208 individuals, accounting for 55.9% of the total, showed no signs of sacral dysmorphism. The overall prevalence of sacral dysmorphism was confirmed to be 44.1%, with a 95% confidence interval ranging from 39.1% to 49.2%. Among the 372 scans, the prevalence of sacral dysmorphic features varied widely, ranging from 9.7% to 75.2%. The most prevalent feature was non-fused sacral segments present in 75.2% of the study population, while the least common feature was the irregular sacral foramina present in 9.7% of the population

Table 2: Prevalence of dysmorphism

	Total N=372
Sacral Dysmorphism	
Absent	208 (55.9%)
Present	164 (44.1%)

4.4 FEATURES OF SACRAL DYSMORPHISM AND SAFE ZONE CROSS-SECTIONAL AREA

The study examined 372 scans to assess the features of sacral dysmorphism and the safe zone cross-sectional area. It was found that in the outlet view, the alar slope was predominantly non-acute in 82.8% of participants, with only 17.2% showing an acute slope. Similarly, in the lateral view, a non-acute alar slope was present in 82.5% of the participants, while 17.5% had an acute slope. Regarding the presence of mamillary bodies, the majority of scans (81.5%) lacked these structures, with only 18.5% displaying them.

When evaluating the sacral disc segments, 75.2% of the scans had non-fused segments, while 24.8% exhibited fused segments. The tongue in groove morphology was absent in 78.5% of the scans, being present in 21.5%. The sacral foramina were regular in 90.3% of the scans, and irregular foramina were noted in 9.7%.

The safe zone cross-sectional area, which was an important metric in this study, had a mean value of 401.4 mm^2 with a standard deviation of 83.6 mm^2, and it ranged from 317.8 mm^2 to 485 mm^2 across the participants.

Table 3: Features of sacral dysmorphism and safe zone cross-sectional area

	Total N=372
Alar slope(outlet view)	
Non-acute	308 (82.8%)
Acute	64 (17.2%)
Alar slope (lateral view)	
Non-acute	307 (82.5%)
Acute	65 (17.5%)
Mamillary bodies	
Absent	303 (81.5%)
Present	69 (18.5%)
Sacral disc segments	
Non-fused	279 (75.2%)
Fused	93 (24.8%)
Tongue in groove morphology	
Absent	292 (78.5%)
Present	80 (21.5%)
Sacral foramina	
Regular	336 (90.3%)
Irregular	36 (9.7%)
Safe zone cross-sectional area (mm2)	
Mean (SD)	401.4 (83.6)
Range	306.5–695.3

The study examined sacral dysmorphism and clinical features by sex among 158 male and 214 female participants, totalling 372 individuals. The presence of sacral dysmorphism did not significantly differ between sexes, with 43.9% of males and 56.1% of females exhibiting this characteristic, while 41.3% of males and 58.7% of females did not ($p = 0.669$).

In the outlet view, the alar slope was non-acute in 44.5% of males and 55.5% of females, while an acute slope was observed in 32.8% of males and 67.2% of females, approaching statistical significance ($p = 0.062$). The lateral view revealed a statistically significant difference, with 44.5% of males and 55.5% of females showing a non-acute slope, while an acute slope was present in 32.8% of males and 67.2% of females ($p = 0.049$).

Regarding the mamillary bodies, 44.2% of males and 55.8% of females lacked these structures, while 34.8% of males and 65.2% of females had them ($p = 0.117$). Sacral disc segments were non-fused in 43.9% of males and 56.1% of females, whereas fusion was noted in 15.8% of males and 84.2% of females, a statistically significant difference ($p = 0.006$).

The tongue-in-groove morphology was absent in 45.5% of males and 54.5% of females, while it was present in 31.3% of males and 68.8% of females, showing statistical significance ($p = 0.015$).

Regular sacral foramina were found in 43.5% of males and 56.5% of females, whereas irregular foramina were seen in 33.3% of males and 66.7% of females, though this was not statistically significant ($p = 0.251$).

The mean safe zone cross-sectional area was 415.0 mm^2 in males and 391.0 mm^2 in females, with a statistically significant difference ($p = 0.006$). The range for males was from 334.7 mm^2 to 695.3 mm^2, while for females it was from 306.5 mm^2 to 575.5 mm^2.

The critical sacroiliac (SI) angle showed no significant difference between sexes, with males having a mean of 11.2 degrees (range 7.2 to 15.6) and females having a mean of 10.9 degrees (range 7.5 to 16.6) ($p = 0.149$).

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Table 4: Sacral Dysmorphism and Clinical Features by Sex

	Male N=158	**Female** N=214	**p-value**
Sacral Dysmorphism			0.669 [c]
Absent	86 (41.3%)	122 (58.7%)	
Present	72 (43.9%)	92 (56.1%)	
Alar slope(outlet view)			0.062 [c]
Non-acute	137 (44.5%)	171 (55.5%)	
Acute	21 (32.8%)	43 (67.2%)	
Alar slope (lateral view)			**0.049** [c]
Non-acute	137 (44.5%)	171 (55.5%)	
Acute	21 (32.8%)	43 (67.2%)	
Mamillary bodies			0.117 [c]
Absent	134 (44.2%)	169 (55.8%)	
Present	24 (34.8%)	45 (65.2%)	
Sacral disc segments			**0.006** [c]
Non-fused	155(43.9%)	198(56.1%)	
Fused	3 (15..8%)	16 (84.2%)	
Tongue in groove morphology			**0.015** [c]
Absent	133 (45.5%)	159 (54.5%)	
Present	25 (31.3%)	55 (68.8%)	
Sacral foramina			0.251 [c]
Regular	146 (43.5%)	190 (56.5%)	
Irregular	12 (33.3%)	24 (66.7%)	
Safe zone cross-sectional area (mm2)			
Mean (SD)	415.0 (80.3)	391.0 (84.8)	**0.006** [t]
Range	334.7 – 695.3	306.5 – 575.5	

4.5 PROPORTION OF DYSMORPHIC SACRA THAT CAN SAFELY ACCOMMODATE SI SCREWS

Table 5: Proportion of dysmorphic sacra that can safely accommodate SI screws

	Dysmorphic sacra		
	Absent	**Present**	**Total**
	N=208	**N=164**	**N=372**
Safely accommodate SI Screws			
No	9 (4.3%)	10 (6.1%)	19 (5.1%)
Yes	199 (95.7%)	154 (**93.9%**)	353 (94.9%)

Proportion of dysmorphic sacra that can safely accommodate SI screws is 93.9% (96% CI: 89 – 96.7).

CHAPTER FIVE: DISCUSION

5.1 Prevalence of sacral dysmorphism among patients evaluated at the CT Scan Unit of the radiology department of Moi Teaching and Referral Hospital.

In the examination of 372 scans, the sacral dysmorphism score was analyzed, revealing that 164 individuals, accounting for 44.1% of the total sample, exhibited this condition. The prevalence of sacral dysmorphism was confirmed at 44.1%, with a 95% confidence interval ranging from 39.1% to 49.2%. This finding closely mirrors the results of a study conducted in San Francisco, California, USA, which reported a 41% prevalence of sacral dysmorphism with dysmorphic features ranging from 28% to 53% (Kaiser et al., 2014). Additionally, findings from another study conducted in the same country indicated prevalence rates ranging from 30% to 40% among adult patient groups, thus reinforcing the validity of our study's results (Conflitti et al., 2010). This similarity highlights the consistency of our findings with existing literature, emphasizing the prevalence of sacral dysmorphism within our study population.

Table 6: Prevalence of sacral dysmorphism within our study population.

STUDY	COUNTRY	PREVALENCE
Present Study	Eldoret, Kenya	44.1% (9.7-75%)
Kaiser et al., (2014)	San Francisco, USA	41% (28-53%)
Manafi et al., (2020)	Iran	37% (24-71%)
Weiglet et al., (2018)	Switzerland	5-70%

5.2 Features of sacral dysmorphism and description of the sacral dysmorphism score and the safe zone cross-sectional area.

5.2.1 Mammillary Bodies

This study reveals the presence of mammillary bodies in 69 out of 372 participants, constituting 18.5% of the study population. A noteworthy observation is that females exhibited a higher prevalence, accounting for 57.7% (214 individuals), whereas males comprised 42.3% (158 individuals). These findings were similar to a study conducted in Pittsburgh, USA, examining 48 scans, reported the presence of mammillary bodies in only 9 out of 48 cases, equating to a prevalence of 18.75% (Radley et al., 2020). Conversely, Weigelt et al. (2018) in Switzerland found a prevalence of mammillary bodies in 67 out of 242 cases, constituting 27.7%. In Nairobi, Kenya, Valentine (2022) reported a prevalence of mammillary bodies in 77 out of 303 cases, representing approximately 25.4% of the total, with 43 cases among females (14.2% of the total) and 34 cases among males (11.2% of the total). Similarly, a study conducted in Turkey revealed the presence of mammillary bodies or mammillary processes in 209 out of 1737 cases, constituting approximately 12% (Kilinc et al., 2021). These variations in prevalence rates across different studies and regions suggest the potential influence of various factors. Possible explanations for these discrepancies could include ethnic differences, which need further evaluation through more comprehensive and targeted studies within the African population. Additionally, the potential role of interobserver variability should be considered, as differences in interpretation and assessment criteria among researchers could contribute to the observed variations in prevalence rates

Table 7: Mammillary Bodies

Study	Location	Prevalence (%)
Present study	Kenya	18.50
Radley et al., (2020)	Pittsburgh, USA	18.75
Weiglet et al., (2018)	Switzerland	27.70
Kilinc et al., (2021)	Turkey	12.00

5.2.2 Tongue in-groove morphology

In this study, we observed a prevalence of tongue-in-groove morphology at 21.5% among the study population. This rate is significantly higher than the findings of a similar study by Kilinc et al. in Turkey, which reported a prevalence of only 10.25%. Additionally, the results were compartably similar to a study conducted in Iran, where a prevalence of 20% was noted in the scans (Manafi et al, 2020). These differences in prevalence rates could be attributed to several factors. One possible reason is the variation in genetic backgrounds and ethnicities among the populations studied, which may influence anatomical features. Interobserver variability also comes to play and experience of the observers, could also play a role.

Table 8: Prevalence of sacral dysmorphism within our study population.

STUDY	PREVALENCE (%)
Present Study	21.5
Kilinc et al., (2021)– Turkey	10.25
Manafi et al., (2020) - Iran	20.0

5.2.3 Acute alar slope

In the present study, a prevalence of 17.5% was observed for acute alar slope among the study population. This rate is notably higher than the findings reported in other studies. Kilinc et al. (2020) in Turkey reported a prevalence of 10.48%, and Radley et al. (2020) in Pittsburgh, USA, found a prevalence of 12.5%. The higher prevalence observed in our study suggests potential regional or population-specific differences

Table 9: Acute alar slope

Study	Prevalence (%)
Present Study	17.5
Kilinc et al., (2021) – Turkey	10.48
Radley et al., (2020) – USA	12.5

5.2.4 Residual sacral disk space

In this investigation, we examined the prevalence of residual disk space, revealing a comparable rate of 75.2%. This finding closely mirrors the results reported by Radley (2020) in Pittsburgh, USA, where a prevalence of 70.8% was documented, as well as by Weigelt et al. (2018) in Switzerland, who reported a similar prevalence of 70%. However, it is worth noting that our observed prevalence was notably higher than that reported by Kilinc et al. (2021) in Turkey, where a prevalence of 50.6% was documented. This consistency across multiple studies underscores the strength of my findings and emphasizes the potential universality of residual disk space prevalence among diverse populations.

Table 10: Residual sacral disk space

STUDY	PREVALENCE(%)
Present Study	75.2
Radley et al., (2020) – USA	70.8
Weiglet et al., (2018) – USA	70
Kilinc et al., (2021) -Turkey	50.6

5.2.6 Non-cylindrical neural foramina

Investigation into the prevalence of irregular sacral foramina yielded a result of 9.7%. This finding aligns closely with the prevalence rate of 9.67% reported by Kilinc et al. (2020) in their study conducted within the Turkish population. While geographically distinct, both studies suggest a similar occurrence of this anatomical variation. Interestingly, Radley et al. (2020) documented a slightly higher prevalence of 12.5% in Pittsburgh, USA.

Table 11:Non-cylindrical neural foramina

Study	Location	Prevalence (%)
Present Study	Eldoret, Kenya	9.7
Kilinc et al., (2020)	Turkey	9.67
Radley et al., (2020)	Pittsburgh, USA	12.5

5.2.7 The cross-sectional area of the safe zone:
Our analysis revealed a mean safe zone cross-sectional area of 401.4 mm². This value falls within a similar range to those reported in previous studies. Kaiser et al. (2020) documented a mean area of 417.4 mm² in the United States, with a standard deviation of 81.1 mm² (Kaiser et al., 2020). Similarly, a study conducted in Germany by Mendel et al. (2013) reported a mean cross-sectional area of 392 mm² with a standard deviation of 114 mm² (Mendel et al., 2013).

Table 12: The cross-sectional area of the safe zone

Study	Location	Mean Cross-Sectional Area (mm^2)
Present Study		401.4
Kaiser et al., (2020)	USA	417.4 +/- 81.1
Mendel et al.,(2013)	Germany	392+/-114.3

5.2.8 Sacral dysmorphic score
Our study revealed that 44.1% of the total population (n=164) exhibited scores exceeding 70. This finding aligns with the prevalence rates reported in previous research. Kaiser et al. (2014) documented a prevalence of 41% in the USA, while Minafi et al. (2020) reported a prevalence of 37% in their study. These results and those of Kaiser et al. (2014) suggest a similar prevalence of high scores within the respective populations.

Table 13: Sacral dysmorphic score

STUDY	PREVALENCE (%)
Present Study	44.1
Kaiser et al., (2014)-USA	41
Manafi et al., (2020)-IRAN	37

5.2.9 Proportion of dysmorphic sacra that can safely accommodate SI screws using Critical SI angle

This study aimed to determine the safety of SI screw placement in sacra exhibiting dysmorphic morphology. The results demonstrated a high success rate, with 93.9% of dysmorphic sacra (96% CI: 89% - 96.7%) deemed suitable for safe screw accommodation. Notably, no comparable studies was identified that specifically evaluated the use of the critical SI angle in the context of sacral dysmorphism. This gap in current research underscores the need for further investigations to explore the potential utility of this measurement in guiding safe SI screw placement in patients with dysmorphic sacra.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study aimed to investigate the prevalence and characteristics of sacral dysmorphism within the MTRH patient population. The findings revealed a significant prevalence of sacral dysmorphism, with the most frequently observed dysmorphic feature being unfused sacral segments and non-cylindrical neural foramina as the less prevalent feature. Intriguingly, the prevalence of certain dysmorphic features varied from those documented in other populations, indicating potential anatomical diversity among different ethnic groups.

In comparing sacral dysmorphism features by gender, statistically significant differences (p-value < 0.05) were observed in non-fused sacral disc segments, tongue-in-groove morphology, and the mean safe zone cross-sectional area. The tongue-in-groove morphology and non-fused upper sacral disc segments were more prevalent in females compared to males. Conversely, males had a larger mean safe zone cross-sectional area than females. This information is relevant surgically when prescribing sacroiliac screws for our patient population, in that females can accommodate smaller screws compare to males.

Additionally, a significant discovery of this study is that a majority of dysmorphic sacra exhibited the capacity to safely accommodate sacroiliac screws, as determined by the critical sacroiliac angle assessment. This noteworthy revelation suggests that the presence of dysmorphism may not necessarily preclude the utilization of sacroiliac screws in a substantial proportion of patients.

The presence of sacral dysmorphism may require some important modifications in surgical techniques due to its unique morphology, and surgical complications may be encountered with conventional methods.

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