
**“ DEFINING SAFE CORRIDORS FOR ILIO-SACRAL
AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN
POPULATION- A CROSS SECTIONAL PRELIMINARY
COMPUTERIZED TOMOGRAPHY SCAN BASED
ANTHROPOMETRIC STUDY ”**

BY
REG NO. BL0120009

Dissertation

*Submitted to the
KAHER, Belagavi, Karnataka
In partial fulfillment
of the requirements for the degree of*

MASTER OF SURGERY
In
ORTHOPAEDICS

**DEPARTMENT OF ORTHOPAEDICS
JAWAHARLAL NEHRU MEDICAL COLLEGE,
KAHER, BELAGAVI – 590010
KARNATAKA.**

JUNE/JULY 2023

KLE ACADEMY OF HIGHER EDUCATION AND RESEARCH,
BELAGAVI, KARNATAKA

**Endorsement by the HOD/ Principal/
Head of the Institute**

This is to certify that the dissertation entitled " DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION- A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHROPOMETRIC STUDY " is a bonafide research work done by REG NO. BL0120009.



Dr. Ravi S. Jatti M.S Orthopaedics
Professor & Head
Department Of Orthopaedics
KAHER,
Jawaharlal Nehru Medical College
Belagavi, 590010

Date: 2 | 1 | 2023
Place: Belagavi



Dr. N.S. Mahantashetti M.D, Paediatrics
Principal **PRINCIPAL**
J.N. Medical College,
BELAGAVI-590 010
Department Of Paediatrics
KAHER,
Jawaharlal Nehru Medical College
Belagavi, 590010

Date: 2 | 1 | 2023
Place: Belagavi

UNDERTAKING

I, (REG NO. BL0120009), hereby declare that the information and the data mentioned in my dissertation entitled, “**Defining Safe Corridors For Ilio-Sacral And Trans-Sacral Screw Placement In Indian Population- A Cross Sectional Preliminary Computerized Tomography Scan Based Anthropometric Study**” belongs to me and is original. I am aware of the definition of plagiarism as detailed below :

- An act or instance of using or closely imitating the language and thoughts of another author without authorization and the representation of that author’s work as one’s own, as by not crediting the original author.
- A piece of writing or other work reflecting such unauthorized use or imitation.
- The deliberate or reckless representation of author’s words, thoughts or ideas as one’s own without attribution in connection with submission of academic work, whether graded or otherwise.

I hereby declare that the dissertation prepared by me is original one and does not involve plagiarism anywhere. In case at a later stage, it is found that I have indulge in plagiarism, then I am solely responsible for the same and the institution is at liberty to take any disciplinary action against me including cancellation of dissertation or any other penalties imposed by the university.

Date: 2/1/2023

Place: Belagavi



REG NO. BL0120009

ANTI-PLAGIARISM CERTIFICATE



JAWAHARLAL NEHRU MEDICAL COLLEGE

(Recognized by Medical Council of India, New Delhi)



Accredited 'A+' Grade by NAAC (3rd Cycle)

Placed in Category 'A' by MHRD (GoI)

Nehru Nagar, Belagavi- 590 010, Karnataka, INDIA

0831 - 2471350



0831 - 2470759



www.inmc.edu

principal@inmc.edu

Ref No: MDC/PG/

Date: 16-12-2022.

ACCEPTANCE LETTER

The softcopy of thesis entitled: "DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION- A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHROPOMETRIC STUDY" has been submitted for Anti-Plagiarism check through Turnitin software. The scan has been carried out and the scanned output reveals a match percentage of 05% which is within the acceptable limits of 10% as per the guidelines given by UGC.

Guide.



Dr. (Mrs.) N.S. Mahantashetti.
Chairperson-Antiplagiarism Committee &
Principal,
J. N. Medical College, Belagavi.

To,
Reg. No. BL0120009,
Postgraduate Student,
2020-21 Batch,
Department of Orthopaedics,
J. N. Medical College, Belagavi.

ETHICAL CLEARANCE LETTER



K.L.E. ACADEMY OF HIGHER EDUCATION AND RESEARCH
(Deemed – to- be- University)

Accredited 'A' Grade by NAAC (2nd Cycle)

Placed in Category 'A' by MHRD (GoI)

JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)

Website: <http://www.jnmc.edu>

E-Mail : dome@jnmc.edu

Phone: (+ 91-(0)831 Office : 2472550

Principal: 2471701

Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 34

Date: 25/01/2021

To

REG NO. BL0120009

PG student in Orthopaedics,
J. N. Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **“DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION – A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHROPOMETRIC STUDY”**, is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Smita Sonoli)
Member Secretary

JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Harsha Hegde)
Chairman,

JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

ABSTRACT

TITLE: “DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION- A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHROPOMETRIC STUDY”

INTRODUCTION:

The use of nonsurgical treatment for unstable pelvic ring injuries has been attributed to lower outcome. Apart from the high initial mortality (4.8-50 percent), individuals who survive the acute phase may experience significant morbidity due to chronic pain, deformity, sexual dysfunction, and other factors. Sacroiliac joint disruption and sacral fractures, or a combination of the two, are examples of posterior pelvic ring injuries. Complications such as implant prominence and skin necrosis have been reported with posterior fixation options such as sacral plating and lumbo-pelvic fixation. Screw fixation is increasingly being used to treat unstable posterior pelvic injuries, owing to a greater understanding of radiological sacral anatomy and the widespread availability of intra-operative fluoroscopy. Their popularity has increased, but they have drawbacks such as a high learning curve and the risk of neurovascular injury. Since the bone corridors available for safe screw insertion in the sacrum are narrow, the screw threads may breach the cortex and cause damage to the surrounding structures. In some circumstances, a dysmorphic sacrum makes sacroiliac screw insertion difficult or impossible. As a result, identifying the sacrum's corridors prior to surgery will aid in avoiding complications. Accurate reduction of the sacroiliac joint or sacral fractures (open or closed reduction), pre-operative detection of aberrant sacral anatomy, and good recognition of bony landmarks on intra-operative

fluoroscopic imaging are all prerequisites for safe ilio-sacral screw placement. Inlet view, outlet view, and true lateral view of the pelvis are the usual fluoroscopic views used to introduce screws. The importance and reliance of suitable and safe corridors for inserting the ilio-sacral or trans-sacral screws comes into play only after this has been established. As a result, the study's goals include describing the safe corridor for ilio-sacral and trans-sacral screw insertion in Indian pelvises, as well as comparing the screw size and applicability in male and female pelvises.

AIMS AND OBJECTIVES:

Primary Objective :

The objective of this study include the measurement of the safe corridor and trajectory for ilio-sacral and trans-sacral screw placement in Indian pelvises.

Secondary Objective :

To compare the measurements and applicability of screws between male and female pelvises.

MATERIALS AND METHODS :

Study Design:

A hospital based one year Cross-Sectional Study. The study will be conducted from January 2021 to December 2021.

Source of data obtained from the patient of age more than 18 years of either gender undergoing 3D-CT Scan of abdomen with pelvis or pelvis with bilateral hip CT for orthopaedic purpose (like pelvic trauma , pelvic dysmorphism, pelvis with

bilateral hip ,etc) or non orthopaedic purpose (like patients undergoing CT abdomen with pelvis advised by any other department who otherwise are having no bony pelvic complaints, that is having normal pelvic bones.) at out patient department and in patient department of KLE Dr.Prabhakar Kore Hospital, Belagavi, over a period of one year.

Methodology:

In this study, 76 pelvic 3D CT scans (38- Male cases ; 38- Female cases) from patients admitted to KLE super-speciality hospital in Belgaum, Karnataka, India were analyzed prospectively after getting ethical clearance. Sagittal sections were used to evaluate vertical height at the level of constriction of S1 and S2, whereas axial sections were used to quantify antero-posterior constriction width. In axial and sagittal sections, we established that bone boundaries were not breached. We checked the application of the 6.5mm screw whenever there was a violation in the bone limit.

RESULTS :

Males had significantly larger vertical height and antero-posterior width of S1 and S2 constriction. When a safe corridor of 2mm was kept on all over sides, 84.21 percent male and 47.37 percent female pelvises were amenable to S1 trans-sacral and S1 ilio-sacral screw fixation with 7.3mm screw while 10.53 percent male and 26.32 percent female pelvises were susceptible to 6.5mm screw fixation. Even a 6.5mm screw could not be properly put in S1 in 5.26 percent of male and 26.32 percent of female pelvises. When the S2 segment was studied, 68.42 percent male and 31.58 percent female pelvises were receptive with a 7.3mm screw, whereas 10.53 percent male and 23.68 percent female pelvises were amenable with a 6.5mm screw when a safe corridor of 2mm was maintained on all sides. Even a 6.5mm screw could not be

put securely in S2 by 21.05 percent of male pelvises and 44.74 percent of female pelvises. Sacral dysmorphism was seen in 31.58 percent of males and 18.42 percent of females.

CONCLUSION :

Before embarking on ilio-sacral and trans-sacral screw fixation in the Indian population, a personalized approach is required, and each patient's CT scan must be investigated thoroughly.

KEYWORDS :

Sacrum ; Safe Corridor ; S1 Corridor ; S2 Corridor ; Ilio-Sacral Screw ; Trans-Sacral Screw

LIST OF ABBREVIATIONS

EMS	EMERGENCY MEDICAL SERVICES
APC	ANTERO- POSTERIOR COMPRESSION
LC	LATERAL COMPRESSION
VS	VERTICAL SHEAR
CM	COMBINED MECHANISM
CT SCAN	COMPUTED TOMOGRAPHY SCAN
SI	SACRO-ILIAC
GCS	GLASGOW COMA SCALE
ISS	INJURY SEVERITY SCORE
EPBR	EXTRA PERITONEAL BLADDER RUPTURE
IPBR	INTRA PERITONEAL BLADDER RUPTURE
RUG	RETROGRADE URETHROGRAM
ORIF	OPEN REDUCTION INTERNAL FIXATION
V/S	VERSUS
ATLS	ADVANCE TRAUMA LIFE SUPPORT
ILLS	ILIO- LUMBAR LIGAMENTS
3D	THREE DIMENSIONAL
MRI	MAGNETIC RESONANCE IMAGING
DVT	DEEP VEIN THROMBOSIS

PSILs	POSTERIOR SACROILIAC LIGAMENTS
ST	SACROTUBEROUS LIGAMENT
SSp	SACROSPINOUS LIGAMENT
SD	STANDARD DEVIATION
MM	MILLIMETER
ISS	ILIO- SACRAL SCREW

INDEX

S. NO.	SECTIONS	PAGE NO.
1	INTRODUCTION	1-4
2	AIMS & OBJECTIVE	5
3	REVIEW OF LITERATURE	6-40
4	METHODOLOGY	41-50
5	RESULTS	51-64
6	DISCUSSION	65-69
7	CONCLUSION	70-71
8	SUMMARY	72-73
9	BIBLIOGRAPHY	74-76
10	ANNEXURES	
	ANNEXURE I - INFORMED CONSENT	77-79
	ANNEXURE II - PROFORMA	80-83
	ANNEXURE III - PHOTOGRAPHS	84-104
	ANNEXURE IV - MASTERCHART	105

LIST OF TABLES

TABLE NO.	NAME	PAGE NO.
3.1 (a,b,c)	CLASSIFICATION OF PELVIC RING FRACTURE	25-27
5.1	ANTERO – POSTERIOR WIDTH FROM CENTRE OF PROMONTORY IN AXIAL SECTION	2
5.2	ANTERO- POSTERIOR WIDTH FROM CONSTRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM (NARROWEST) IN AXIAL SECTION	53
5.3	ANTERO- POSTERIOR WIDTH FROM LATERAL TO SACRAL FORAMEN IN AXIAL SECTION	54
5.4	S1 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION	55
5.5	S1 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION	56
5.6	S2 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION	57
5.7	S2 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION	58
5.8	TRANS-SACRAL LENGTH	59
5.9	ILIO- SACRAL LENGTH	60
5.10	SACRAL DYSMORPHISM	61
5.11	SUMMARY OF VARIABLES MEASURED ON PELVIC 3D CT SCAN SECTIONS (AXIAL & SAGITTAL) IN THE PROSPECTIVE PATIENTS (N = 76), STRATIFIED BY GENDER	62
5.12	SUMMARY OF APPLICABILITY OF SCREWS IN PATIENTS	63

LIST OF GRAPHS

GRAPH NO.	NAME	PAGE NO.
4.1	GENDER DISTRIBUTION OF SAMPLE	50
5.1	ANTERO – POSTERIOR WIDTH FROM CENTRE OF PROMONTORY IN AXIAL SECTION	52
5.2	ANTERO- POSTERIOR WIDTH FROM CONSTRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM (NARROWEST) IN AXIAL SECTION	53
5.3	ANTERO- POSTERIOR WIDTH FROM LATERAL TO SACRAL FORAMEN IN AXIAL SECTION	54
5.4	S1 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION	55
5.5	S1 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION	56
5.6	S2 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION	57
5.7	S2 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION	58
5.8	TRANS-SACRAL LENGTH	59
5.9	ILIO- SACRAL LENGTH	60
5.10	SACRAL DYSMORPHISM	61

LIST OF FIGURES

FIGURE NO.	NAME	PAGE NO.
3.1	RETROGRADE URETHROGRAM	10
3.2	SUPRAPUBIC CATHETER	11
3.3 (a,b,c)	PLAIN RADIOGRAPH OF PELVIS	16
3.4	COMPUTED TOMOGRAPHY (2D & 3D IMAGES)	18
3.5	SCHEMATIC REPRESENTATION OF THE DIRECTION OF THE INCIDENT C-ARM X-RAY BEAM FOR A) INLET VIEW, B) AP VIEW, C) OUTLET VIEW	21
3.6 (A,B,C)	C-ARM PICTURES SHOWING INTRA-OP AP, INLET & OUTLET VIEWS	22
3.7	DENIS CLASSIFICATION (ZONE 1,2 & 3)	28
3.8	STRANGE VOGNSEN CLASSIFICATION	30
3.9	BONY LANDMARKS OF PELVIS	31
3.10	MAGNIFIED BONY MODEL OF SACRUM (A. ANTERIOR VIEW ; B. POSTERIOR VIEW)	31
3.11	SACRALIZATION OF L5	33
3.12 (a,b)	SCHEMATIC DRAWING SHOWING LIGAMENTOUS STRUCTURES OF THE PELVIS	34
3.13 (a,b)	SCHEMATIC DRAWING SHOWING NEUROVASCULAR STRUCTURES WITHIN THE PELVIS	36-37
4.1 (a,b)	SHOWING S1 AND S2 SACRAL SEGMENTS	43

4.2 (a,b,c)	a) MEASUREMENTS FROM CENTER OF PROMONTORY, b) NARROWEST MEASUREMENT (CONSTRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), c) MEASUREMENT LATERAL TO SACRAL FORAMEN	44
4.3.1 (a-i)	SAGITTAL CUTS AT THE LEVEL OF S1	45
4.3.2 (a-i)	SAGITTAL CUTS AT THE LEVEL OF S2	46
4.4 (a,b)	a) AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW, b) AXIAL SECTION SHOWING TRAJECTORY AND LENGT FOR TRANS-SACRAL SCREW	47
4.5	DIAGRAMMATIC REPRESENTATION OF TWO MM SAFE CORRIDOR	48

INTRODUCTION

Pelvic ring injuries are extremely complicated and challenging injuries for the orthopaedic trauma surgeon. Many controversies still exist as to the best method of treatment for particular fracture patterns. The treatment of pelvic ring injuries has evolved considerably resulting in improved outcomes for all patients especially in terms of mortality.¹ With the increasing age of the population and unfortunately the decreasing bone quality that accompanies aging, new fixation techniques are being evaluated and used in an effort to improve outcomes in the geriatric patient population.² Fixation constructs and methods of resuscitation of the trauma patient with a pelvic fracture continues to improve.

The foundation of pelvic fracture management continues to be based on the fundamental understanding of pelvic anatomy and pathophysiology. Treatment not only includes the orthopedic aspects of fracture fixation, but also effectively managing the hemorrhage and other associated injuries that accompany these potentially life-altering fractures. Although many stable fractures can be managed non-operatively, recent literature has questioned our understanding of the "stable" fracture and what can be effectively managed without surgery. Most unstable fractures continue to require surgical intervention to allow for the best functional outcome possible. As a result of improvements in automotive safety features as well as emergency medical services (EMS) response and transport times, multiple trauma patients who have pelvic ring injuries are surviving and presenting to trauma centers.³ This has also been aided by the increased use of binders in the field and in the emergency room upon arrival. Increased knowledge of pelvic ring injuries by emergency room physicians, trauma surgeons, and especially orthopedists is paramount for expeditious diagnosis,

management, and appropriate treatment to be rendered to the patient.³

The pelvis is divided into anterior and posterior parts, and injuries to these respective areas will dictate treatment. Generally, a single break in the ring does not lead to instability, whereas for unstable injuries there are always injuries to at least two areas of the pelvis. An account of the accident in which the patients sustained a pelvic ring fracture can help determine the mechanism of injury and help classify the pattern. The Young and Burgess classification categorizes fracture patterns based on such mechanisms into three anterior-posterior injuries (APCI, II, III), three lateral compression injuries (LC I, II, III, vertical shear (VS), and combined mechanism (CM). Most importantly, this classification can help the trauma surgeon to predict associated injuries.¹

Sacral fractures are common pelvic ring injuries that are under-diagnosed and often associated with neurologic compromise.² Although pelvis radiographs can be used to make a diagnosis, a pelvic CT scan is typically necessary for thorough delineation of the sacral fracture. Depending on the displacement of the fracture, the concomitant pelvic ring instability, and the level of patient activity required, the course of treatment may be conservative or surgical. As a result of high-energy trauma in young individuals and low-energy falls in the elderly, pelvic ring injuries occur at an incidence of 0.82 per 100,000 people with a bimodal distribution.³

Over time, there has been a better understanding of the biomechanics involved while treating severe pelvis ring fractures. Surgical techniques have improved and studies showed improved outcomes with a dorsal ring anatomical fixation. Addition of anterior fixation, either with ex-fix or symphyseal plating, has increased the biomechanical stability in cases of vertical instability. Early operative stabilization

allowing mobilization of the patient improved short-term patient outcomes. These successes with operative stabilization have led to development of newer devices and techniques, such as ilio-sacral screw fixation, lumbo-pelvic fixation, and internal pelvic fixators. Although anterior external fixators have advantages for temporary fixation and for definitive management of some complex anterior fracture patterns, plates for symphyseal injuries avoid the pin-tract complications seen with external fixators and improve the biomechanics and clinical outcome.¹

Pelvic fractures represent 2-8% of all traumatic fractures in the elderly occur from minor trauma or from skeletal insufficiency.⁽²⁾ The majority of fractures occurs in women (up to 80%) older than 80 years of age.⁽²⁾ Because of its intricate fracture patterns, anatomical variances, and nearby essential tissues, treating pelvic fractures is difficult.⁽³⁾ Types of posterior pelvic ring fractures include sacral fractures, disruption of the sacroiliac joint, and combinations of the two.⁽⁴⁾ Anatomical reduction with good fixation is crucial with these injuries since the posterior pelvic ring contributes 60–70% of the pelvis' stability.⁽⁵⁾ As a result, pelvic rim fractures must be customized to each patient's clinical picture, taking into account implant possibilities as well as operative approach and positioning options.

The classic method of open reduction and internal fixation by sacral bars or posterior plating had a risk of large dissection, iatrogenic nerve injury, infection, and blood loss.⁽⁶⁾ Due to its enhanced knowledge of radiological sacral anatomy and the accessibility of intra-operative fluoroscopy, sacroiliac (SI) screw fixation is a less invasive technique for treating unstable posterior pelvic ring injuries.⁽⁴⁾ SI screws are versatile and can be positioned in the prone, supine, or lateral position irrespective of soft tissue injury.⁽⁶⁾ However, because there are few bone corridors in the sacrum that

may accommodate screws, the threads of the screws could penetrate the cortex and harm the nearby tissues. In some cases, a dysmorphic sacrum makes screw insertion difficult.⁽⁷⁾ Therefore, identifying the sacrum's corridors before surgery will aid in avoiding complications. Imaging modalities such as fluoroscopy and computed tomography are used for assisting screw insertion.^(6,8) However, 3D-CT guided navigation system provides a more detailed imaging while preserving surgery minimally invasive.⁽⁹⁾

The anatomy of the "sacral safe corridor" for SI-screw placement has been the subject of several prior research to increase surgical precision and lower the possibility of intraoperative problems.⁽¹⁰⁻¹²⁾ However, little is known about the 3-dimensional structure of the sacrum and how it relates to a "safe corridor" for the insertion of SI-screws in South Indian patients. As a result, the study's goals include describing the CT-based 3-dimensional safe corridor for ilio-sacral and trans-sacral screw insertion in South Indian pelvis, as well as comparing the screw size and applicability in male and female pelvis.

OBJECTIVES

Primary Objective :

The objective of this research is to measure safe sacral corridor and trajectory for ilio-sacral & trans-sacral screw placement in Indian pelvises.

Secondary Objective :

To assess variations in screw sizes and applications between male and female pelvises.

REVIEW OF LITERATURE

In an attempt to establish factors that may predict mortality in patients presenting with pelvic ring injuries, various researchers have queried the National Trauma Database. Arroyo et al. reported that there were over 41,200 cases of pelvic trauma with an in-hospital mortality of 7% and 17% had one or more complications. Wang et al. reviewed the National Trauma Data Bank but limited their population to those pelvic trauma patients that were initially stable upon presentation. Over 30,000 pelvic fracture patients that were hemo-dynamically stable on arrival were reviewed and included in their analysis. The overall mortality was 2.7%. They found that mortality was increased twofold in the middle-aged patient but fourfold in the geriatric patients (>70 years) in the presence of a pelvic fracture compared to those trauma patients without pelvic injury. Those patients that had a higher severity of injury, GCS <8, or a GCS between 9 and 12, prolonged ventilation, increased blood administration, or advanced age experienced higher mortality. They felt that transport to a level 1 or 2 trauma center was in the best interest of the middle-aged and geriatric pelvic fracture trauma patient. Morshed et al. also confirmed that mortality was decreased in patients with unstable pelvic and severe acetabular fractures when care was provided at a level 1 trauma center. In a separate review of over 4,100 pelvic fractures in the National Trauma Databank, increasing age, shock at presentation, and Injury Severity Score (ISS) were important predictors of mortality after pelvic trauma. Cardiac events were more likely to occur in obese and older patients. Treatment algorithms have been created to reduce the severe pelvic injuries having high rate of morbidity and fatality and to improve functional outcomes. Unfortunately, however, many patients with multiple injuries who also have pelvic ring injuries die from head

injury, chest injury, or abdominal injury rather than pelvic ring fracture." Ongoing blood loss can be a significant contributor to mortality, especially in the unstable pelvic ring trauma." A multidisciplinary approach for the management for such patients, including involvement of the orthopedic traumatologist, has been shown to improve patient survival. We want to give orthopaedic specialists a better understanding of how pelvic ring injuries are currently managed and treated.^{1,33}

ASSESSMENT OF PELVIC RING INJURIES

MECHANISM OF INJURY

Although a fall from standing height can cause such injuries in many older people, high-energy traumas account for the bulk of pelvic ring injuries. Motorcycle accidents and motor vehicle pedestrian accidents are the most common mechanisms, although falls, motor vehicle collisions, equestrian accidents, and crush injuries also result in pelvic ring injuries. Because more patients in high-energy accidents survive to arrive at trauma centers, there is an increased incidence of pelvic ring injuries occurring from high-speed motor vehicle collisions. Despite advances in airbag technology and other state-of-the-art safety measures in modern motor vehicles, side impact continues to be a major risk factor for pelvic ring fracture mortality and morbidity, as does vehicle size mismatch. In addition, these patients present with associated bony, visceral, and soft tissue injuries. Elucidation of the mechanism of injury has led to the development of a classification scheme that has provided a better understanding of the associated injuries seen with pelvic ring injuries. The Young and Burgess classification (described in greater detail later) is based on the mechanism of injury, and specifically the direction of force applied to the pelvis during injury. These investigators described four groups of injuries: APC, LC, VS, and CM. Studies have

shown that the mechanism of pelvic injury can correlate with mortality. The overall mortality for APC injuries is approximately 20%, whereas for LC injuries mortality is about 7%.¹

INJURIES ASSOCIATED WITH PELVIC RING INJURIES

Many patients with pelvic ring injuries have multisystem injury. These patients will often have associated head, thoracic, and abdominal injuries, in addition to other extremity injuries. Previous studies have indicated that the most frequently encountered injuries associated with pelvic ring injuries in general are chest injuries (63%), long bone fractures (50%), head injury (40%), solid organ injury (40%), and spinal fracture (25%). Intestinal injuries are also encountered in up to 14% of patients with concomitant pelvic ring injuries. It is important to understand the mechanism of injury and the resultant pelvic injury pattern, which can help to elucidate associated injuries. Specifically, in patients with APC injuries there is an eightfold increased incidence in thoracic aorta injuries when compared to patients with blunt trauma without pelvic ring fracture. Compared to other injury types, APC III injuries have a higher rate of circulatory shock (67%) and more blood loss and transfusion needs. In addition, in patients who are hemodynamically unstable there is a higher incidence of acute respiratory distress syndrome (ARDS) (18.5%), Sepsis (59%), and death (37%). LC injuries tend to be associated with a high incidence of head injury (50%). The most severe, LC III, which can occur from a rollover mechanism is associated with a 20% risk of bowel injury, 40% incidence of concomitant lower extremity fracture, and 60% presence of a retroperitoneal hematoma. VS injuries have a high risk of hypovolemic shock (63%), mortality (25%), head injury (56.2%), lung injury (23%), and splenic injury (25%). Patients with pelvic ring fracture require a methodical, well-

structured multidisciplinary approach for managing many such injuries that are regularly seen.¹

GENITOURINARY TRACT INJURIES

Bladder and urethral injuries occur in 6% to 15% of pelvic ring injuries depending on the severity of the pelvic ring fracture. Male patients have a higher incidence of urethral injury compared to female patients. The female urethra is short and adjacent to the vagina, which protects it from injury by the pelvic ring fracture. In addition, the vagina has a remarkably low incidence of injury, ranging from 0% to 5%. The male urethra is divided into anterior and posterior portions, with the latter being more commonly injured from shearing forces rather than by direct laceration from bony fragments. In posterior urethral injuries, there is a 10% to 20% associated incidence of bladder rupture. Because of its location behind the symphysis pubis, the bladder can be injured easily: extra-peritoneal bladder rupture (EPBR) is common. In this type of injury, the urine may communicate with the pelvis. An intra-peritoneal bladder rupture (IPBR), which is often caused by compression on the distended bladder resulting in rupture of the dome, communicates with the peritoneal cavity but will not contaminate the pelvis. Bladder injuries occur in up to 10% of pelvic ring injuries, with approximately 60% EPBR, 30% IPBR, and 10% both. Because the amount of force required to rupture hollow structures, such as the bladder, is so high, the associated mortality has been reported anywhere from 22% to 34%. Most patients with urologic injury will have gross hematuria, although a small subset of patients may have only the finding of more than 30 to 50 red blood cells noted on a urinalysis, which is indicative of an injury. All these patients should have a cystogram. In the male patient, a dynamic retrograde urethrogram (RUG) is the best study to

evaluate for a urethral injury. A Foley catheter is inserted into the penile urethra and the balloon is inflated with 1 to 2 mL of saline, the next step is to administer 25 milliliters of a water-soluble contrast material. Antero-posterior view of the pelvis with both hip or a 30 - 45-degree oblique view is obtained under fluoroscopy, if possible, so that any leak posteriorly may be detected since the contrast may obscure an injury from being seen on an AP view. Lack of contrast in the bladder usually indicates a urethral disruption, although the bladder may still fill with contrast. After the RUG is performed, if the urethra is not injured, an attempt is made to pass catheter in bladder followed by plain pelvis xray or computed tomography is performed by instilling an additional 300 to 400 milli-liter of contrast in the bladder. Many centers prefer to use CT cystography to diagnose bladder ruptures.¹



FIGURE 3.1 RETROGRADE URETHROGRAM

Once a bladder or urethral injury has been diagnosed, consultation by the urologist is required. Clear communication between the orthopedic trauma service and the urologic service is recommended to ensure that urologic treatment does not prevent or hinder potential orthopedic interventions for the pelvic ring injury. IPBRs are treated with exploratory laparotomy and suture repair, and should be drained by

Foley or supra-pubic catheter placed well out of the way of sites of potential anterior incisions. If anterior fixation is required, it can be accomplished in the same setting, or an anterior external fixator can be placed if the patterns warrant it. An EPBR could be managed non-operatively by catheterization and antibiotic prophylaxis. When an open reduction and internal fixation of the anterior pelvis is required, both bladder repair surgery and ORIF of the anterior pelvic ring can be performed at the same surgical setting through the same incision.¹



FIGURE 3.2 SUPRAPUBIC CATHETER

If an extra-peritoneal bladder injury cannot be healed or is not advised, external fixation should be strongly considered as the final option because internal hardware may become contaminated with urine. Non-operative management of EPBRs has a reported complication rate of up to 26% versus 0% in operatively managed bladder ruptures. The treatment of urethral tears in male patients is controversial and ranges from endoscopic realignment to acute supra-pubic drainage followed by delayed reconstruction. Advocates of realignment procedures note decreased stricture rates from 14% to 45% versus almost 100% in delayed reconstructions. In either case, the bladder must be reliably drained to avoid complications from extravasation of urine in the face of internal anterior ring fixation.

OPEN PELVIC RING INJURIES AND GASTROINTESTINAL INJURIES

With significant trauma and high-energy injuries, pelvic ring fracture fragments can penetrate soft tissue, resulting in direct communication with the external environment resulting in an open fracture in less number of patients with pelvic injuries. In addition, bony fragments may cause direct damage when in contact with the visceral cavity. Furthermore, open fractures may occur from the tensile forces in APC-type injury in the midline. These open pelvic ring injuries are often contiguous with the vagina or rectum resulting in contamination. This can significantly increase the number of complications including osteomyelitis, deep pelvic infection, long-term disability, and mortality. Jones et al. reported on a classifications of open pelvic ring injury : class 1, 2, or 3. Class 1 fractures were open pelvic ring injuries in which the pelvic ring is stable. In class 2 fractures, the pelvic ring is rotationally or vertically unstable, and there is no rectal or perineal wound. In class 3 open pelvic ring injuries, the ring is rotationally or vertically unstable, and a rectal or perineal wound with potential for fecal contamination is present. Many of these class 3 patients developed sepsis, results in a 44% mortality rate. Clinical examination of patients who are having a pelvic ring fracture should include a careful genitourinary examination to ensure that no occult open fracture has been missed. A digital rectal examination and a vaginal examination should be performed in female patients. Anywhere along the iliac crest's extent or via the perineum, open wounds are possible. Open pelvic ring injuries with fecal contamination have high mortality of up to 50%, therefore, early recognition and appropriate therapeutic interventions are required. Injuries which damage the anal sphincter or the gastrointestinal tract may require diverting colostomy and emergent irrigation and debridement of the fracture . Any potential for fecal contamination of a fracture site or the open wound should be

addressed with fecal diversion and distal washout in an effort to prevent infection. The actual placement of the colostomy should be as high as feasible and as far as possible from any potential surgical approaches for pelvic ring fracture fixation. Ideally, to maximize outcome and minimize sepsis and death, within the first six to eight hours following injury, the diversion colostomy should be carried out. In cases in which fecal contamination is not a concern, open fractures can be treated with regular irrigation and debridement and handling of the soft tissues as indicated along with intravenous antibiotics. Similar to this, an open fracture that communicates with the vagina should be treated with multiple irrigations, debridement, packing, and eventually closing of the vaginal wound over a drain when it is clean.¹

PELVIC RING INJURIES : POSSIBLE CLINICAL FINDINGS

- Open wounds of the groin, buttock, or perineum
- Blood at the urethral meatus
- Blood in or around the rectum
- Pelvic , flank or perineal contusions, ecchymosis or abrasions
- Blood out of the vagina (rule out laceration vs. menses)
- Neurologic deficit involving the lumbosacral plexus
- Leg length inequality
- High – riding prostate (urethral injury)
- Abnormal pelvic motion on antero-posterior or lateral compression of the anterior iliac spines and iliac crests.
- External or internal rotation deformity of the hemipelvis
- Scrotal edema
- Pain on palpation of the posterior pelvis

IMAGING AND OTHER DIAGNOSTIC STUDIES FOR PELVIC RING INJURIES

Plain Radiography

Plain radiographs are still the mainstay of initial diagnostic imaging, although recent clinical trends favor CT scanning, sometimes in lieu of plain films. The most recent ATLS protocol (10th edition) still recommends an AP pelvis as part of the initial trauma radiographs: "An antero-posterior view of the pelvis should be obtained early for all patients with multiple injuries who have no hemodynamic abnormalities and for whom a source of bleeding has not been identified." However, many institutions have increased the use of immediate CT scan as the initial diagnostic examination. A review of imaging practices at two level 1 trauma centers revealed that 62% of trauma patients with severe pelvic ring fractures had both plain radiographs and CT scans, 28% had plain films only, 6.4% had CT images only, and 6.4% had no images. Interestingly, patients with plain images or no images were more severely injured. Some trauma surgeons have an integrated trauma CT protocol with complete imaging of the trauma patient (head, spine, chest, abdomen, and pelvis), The use of an early full-body CT scan was shown to have an association with increased survival. There are concerns with this protocol regarding radiation dose and intravenous contrast, which may limit its widespread acceptance and use. Dedicated films are often ordered once confirmatory evidence of a pelvic ring fracture exists. "Ghost" images- images (AP, inlet, and outlet) reconstructed from CT scans have also been used in increasing frequency, and the argument has been made that this obviates the need for true AP., inlet, and outlet films . Unlike acetabular Judet views, where there is a "dynamic" component because the position of the patient changes, for outlet and inlet views the beam changes, so ghost images may be satisfactory if the image

quality remains high. The advantage of such reconstructed images is that they allow for manipulation to correct rotation and angulation as opposed to plain radiographs, which may be malpositioned. Pekmezci et al,²⁰³ reviewed their retrospective database to evaluate these "ghost" or "virtual" images and compared them to conventional radiographs. They found that these recreated images were consistently better especially for the inlet and outlet. If plain films are obtained, attempts should be made to obtain the best images possible. The AP radiograph should not be rotated. The pubic symphysis should be midline and collinear with the sacral spinous processes, but with injury it is difficult to use as a guide. If the patient's torso is not rotated, the lumbar spinous processes being centered within the pedicles can be used and more reliable in pelvic ring injuries. However, one must be aware if a patient has a subtle lumbar scoliosis, because it may offset the pedicles due to the rotational deformity and thus be confused for an injury. Such properly aligned imaging will facilitate diagnosis especially in subtle posterior injuries. Any asymmetry either in the sacroiliac (SI) joint or sacral foramina can be indicative of pathology such as an sacro-iliac joint disruption or sacrum fracture, and underscores importance of a centered AP to allow for such side-to-side comparisons. Because the pelvis is a ring structure, when a fracture occurs, a minimum of two injuries will be present. If symphyseal diastasis or disrupted rami fractures are seen, one must seek out the added injuries, which is usually in the posterior pelvis. Recent studies shows, 97% of patients with pubic rami fracture were also having an injury to posterior pelvic ring, with a predominance of trans-forminal sacral fractures. Other subtle injuries can indicate underlying pathology. L5 transverse process fractures, called the "sentinel sign" for a VS injury, typically represent an avulsion fracture by the ilio-lumbar ligaments (ILLs). The AP pelvis view is done with the patient supine on the imaging

table. The beam is centered directly over the pelvis. All structures of the pelvic ring can be assessed for injury on this view. Although displacement is generally visible on this view, the inlet and outlet views help to identify the exact direction of the displacement as do orthogonal radiographs in other skeletal regions. It is crucial to recognize any oddities in the sacrum's appearance from the AP view.¹



a. AP view



b. Inlet View



c. Outlet View

FIGURE 3.3 (a,b,c) PLAIN RADIOGRAPH OF PELVIS

Any of the following findings indicate a dysmorphic sacrum :

- The upper sacrum being collinear with the iliac crest.
- Presence of mammillary processes in the alar region.
- Uppermost sacral foramen are larger, misshapen, and irregular.
- Residual disc space between the dysmorphic upper and second sacral segments.
- Alar slope is more acute on the lateral sacral view and thus is not collinear with the iliac cortical density.
- Tongue-in-groove SI articulation visible on the CT scan.
- An anterior cortical indentation is present in the dysmorphic sacral ala.

Such injuries can be further delineated by CT scans and reconstructions. In an attempt to aid in the evaluation of the dysmorphic sacrum, CT scans were evaluated to determine if quantitative measurements could be obtained to allow for preoperative planning. They reviewed 104 patients to evaluate for the upper segment sacral dysplasia and found sacral dysmorphism in 41% of the pelvises. They describe a sacral dysmorphism score that can be determined from a CT scan. The higher the score, the lower the likelihood of placing a safe trans-sacral screw. It has been recommended that SI screw insertion, especially trans-sacral, be performed at the S2 level in the dysmorphic pelvis. The inlet and outlet views are obtained by directing the x-ray beam caudally and cephalad respectively, to the radiographic plate and aid in the diagnosis and management of these injuries. Obtaining these views may require adjustments in the angle due to the patient's pelvic obliquity and sacral inclination. These angles, historically, were 45 degrees in either direction. A retrospective study using CT data defined the "ideal" angles for screening X-rays as 25 degrees for the inlet and 60 degrees for the outlet to profile the anterior sacrum and neural foramen, respectively. This was true irrespective of the patient's sex or the presence of sacral dysmorphism. The inlet view allows for assessment of an internal or external rotation of each hemi-pelvis in addition to movement at the SI joint. Impaction fractures of the sacral ala are best seen on this view. Because this is a straight view "into" the pelvis from upwards, any anterior or posterior displacement in the plane of the sacrum is also well visualized. The outlet view allows for evaluation of sacral fractures with respect to the foramina. Adequate outlet views are in the plane of the foramen, and are visualized as close to circular, as well as the SI joints. Most important, the relationship of each side of the symphysis to one another and the ischia to one another allows for detection of flexion or extension deformities in unstable pelvic ring

patterns. Although, these "oblique" images show displacement in a particular direction, it is important to note that the amount of translation is always a sum of the displacement vectors in two planes. Hence on an outlet view, any "vertical" displacement is still accompanied by anterior or posterior translation seen on the inlet view. Each view must be interpreted within the context of the other. Single-leg-stance radiographs, aka "flamingo" views, are dynamic views that aid in identifying occult instability. It is important to note that up to 5 mm of physiologic motion and translation at the symphysis occurs when obtaining these stress views in women, particularly if they have had children. The clinical setting in which to obtain these views is still unclear and their utilization ill-defined, but they are most useful in late cases where instability is suspected.¹

Computed Tomography

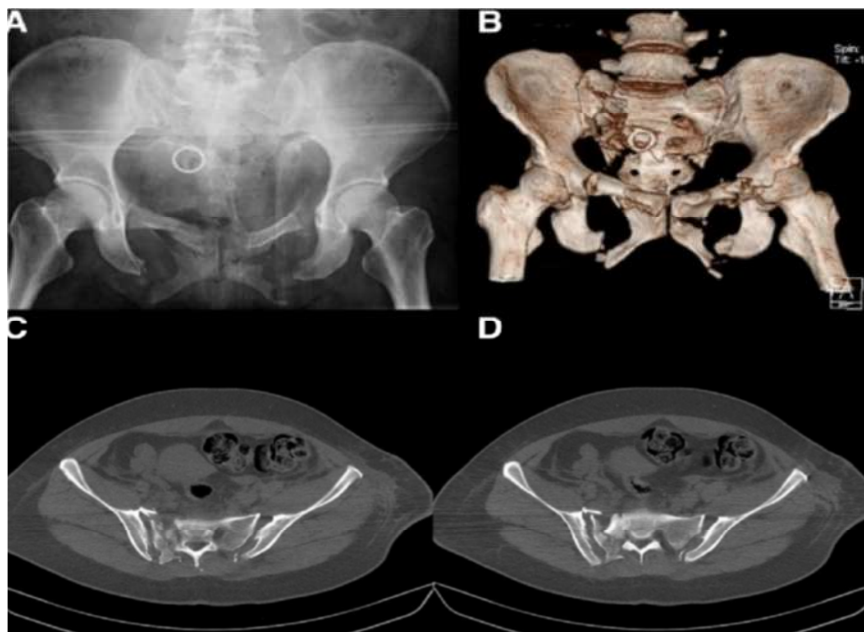


FIGURE 3.4 COMPUTED TOMOGRAPHY (2D & 3D IMAGES)

The CT scan has become crucial in the treatment of pelvic ring injuries and can help with injury grading. Many injuries may be subtle and not visualized clearly on plain radiography. In addition, radiographs done in the elderly may be difficult to interpret because of the osteopenia. Fractures can be difficult to visualize because of the decreased bone density which can further be obscured in the obese patient. The CT scan can aid in the recognition of many of these injuries that go undetected on plain radiographs. Axial cuts of the CT scan should be done in 2- to 3-mm increments. Larger axial slices may miss fractures in the axial plane and thus will not be seen on the reconstructed images. In addition, the quality of reconstructed images is improved with finer cuts. This is especially true for the three-dimensional (3D) reconstructions. The 3D and other reconstructed images can assist in determination of the surgical approach to be used. The sagittal sacral reconstructions are especially useful to evaluate for the presence of kyphosis, which may be indicative of a sacral fracture dislocations, U shape sacral fracture, or a spino-pelvic disassociation. In addition, multiple authors have advocated that preoperative planning for iliosacral screw fixation be performed off the CT scans. This has been shown to reduce operating room time and radiation. It has also recommended to be performed to ensure that the optimal screw pathway is feasible especially for iliosacral- trans-sacral screws. The techniques described are useful but a bit labor intensive. The orthopedic surgeon should review the CT scan thoroughly for potential extraluminal air as this may indicate an open fracture. In a study to evaluate the presence of extraluminal air densities on the CT scan in patients with pelvic ring injuries, less than 50% of radiology reports failed to mention the presence of air. The air should be followed for its source, which may indicate open fractures. In a study of 233 consecutive elderly (average age of 85 years) patients with blunt pelvic trauma, conventional radiographs

were compared to CT scans in evaluating the presence of a sacral fracture. Plain images showed a sacral fracture in only six patients. There was a false-negative rate of 21.7% as the CT scan showed sacral fractures in 56 patients which yielded a sensitivity of only 10.5%. They went further in recommending an MRI for the patient with blunt trauma that had poor mobilization if no pelvic fracture was seen on the CT scan. Nuchtern et al. felt that MRI of the pelvis in patients with osteoporosis would be beneficial in detecting a posterior pelvic fracture. They reviewed 60 patients that had anterior pelvic ring injuries in which all underwent clinical examination of the posterior pelvis, CT scan, and MRI. The MRI detected a posterior pelvic ring fracture in 48 patients (80%). The CT scan missed eight cases (17%). Clinical examination alone revealed the same rate of posterior pelvic ring injury as the CT scan. Conversely, a study looking at elderly patients that did have a low-energy pelvic fracture identified on advanced imaging showed that essentially the treatment was the same irrespective of the findings. They were all weight bearing as tolerated due to the nondisplaced nature of these injuries and felt that perhaps advanced imaging is not required. There was no displacement in any of the patients. Because the pelvis is a ring structure, one must always remember that a disruption in one location is accompanied by a second disruption somewhere in the pelvic ring.¹

Fluoroscopic Stress Examinations

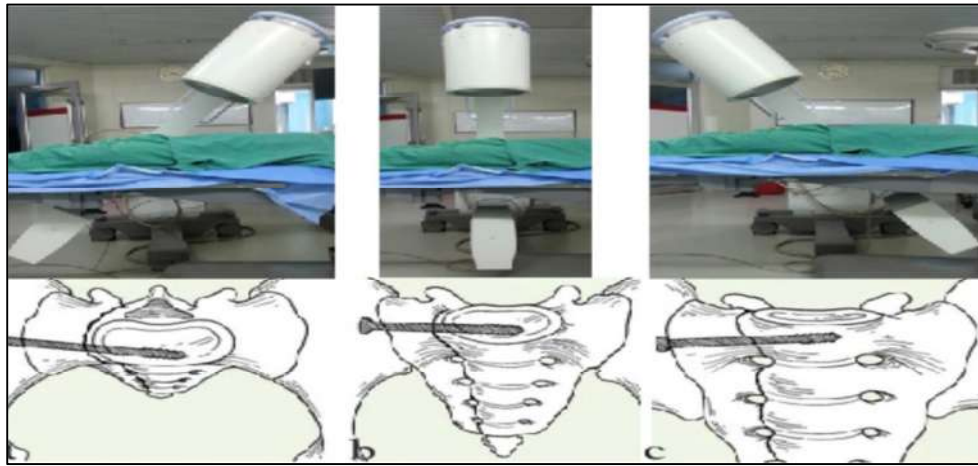
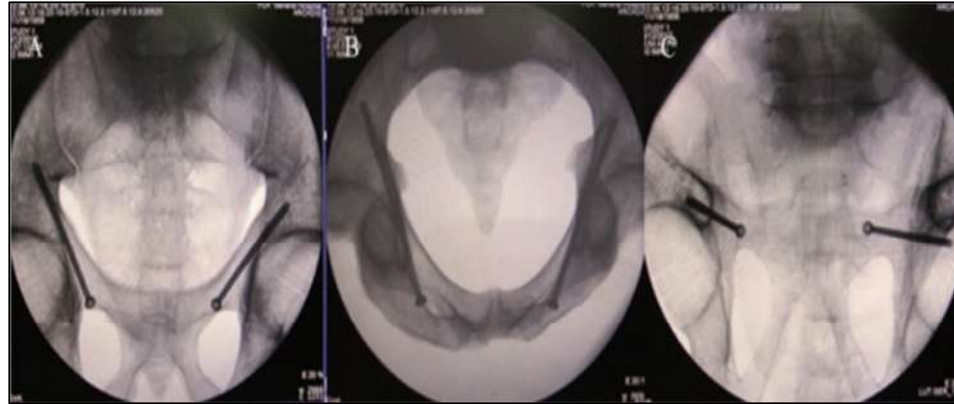


FIGURE 3.5 SCHEMATICAL REPRESENTATION OF THE INCIDENT'S DIRECTION USING THE C-ARM X-RAY BEAM A) INLET VIEW, B) AP VIEW, C) OUTLET VIEW

The static images of the AP, inlet, and outlet radiographs, as well as the CT scan at the point of presentation, do not always show the displacement that occurred at the time of impact. Recently, fluoroscopic stress views to assist in determining instability and the subsequent need for operative stabilization have been recommended. In a series of 68 patients undergoing fluoroscopy after an initial determination of stability, 34 were believed to have stable patterns (APC I or IC I), but 41% (14) were actually found to have sufficient instability on stress examination to warrant operative fixation. Examination under anesthesia may aid the clinician in determining the degree of instability of pelvic ring injuries and guide treatment. This is especially true for cases in which imaging was performed with a binder in place which has been shown to mask the true pelvic injury.¹



**FIGURE 3.6 (A,B, C) C-ARM PICTURES SHOWING INTRA-OP AP, INLET
& OUTLET VIEWS**

Magnetic Resonance Image

Although magnetic resonance image (MRI) has been useful in the management of certain ligamentous injuries, such as those in knee dislocations, its use in pelvic injuries is limited. CT scan imaging provides both fracture and ligamentous disruption information. There has been no clear benefit to the added use of MRI for acute treatment of pelvic ring injury. Recently, use of MRI in elderly patients with pelvic ring injuries has been suggested as a better imaging tool than CT but this remains controversial. However, in cases of lumbo-pelvic dissociation or sacral fractures with neurologic compromise, MRI is of benefit in determining the areas of neural canal compromise and nerve root compression. MR venography is also useful for the evaluation of deep vein thrombosis (DVT) in the pelvic veins.¹

CLASSIFICATION OF PELVIC RING INJURIES

➤ **TILE CLASSIFICATION**

TYPE A : PELVIC RING SATBLE

A1 : Fracture not involving the ring (i.e avulsion, iliac wing, or crest fractures)

A2 : Stable minimally displaced fractures of the pelvic ring

TYPE B : PELVIC RING ROTATIONALLY UNSTABLE , VERTICALLY STABLE

B1 : Open book

B2 : LC, ipsilateral

B3 : LC , contralateral , or bucket handle – type injury

TYPE C : PELVIC RING ROATIONALLY AND VERTICALLY UNSTABLE

C1 : Unilateral

C2 : Bilateral

C3 : Associated with acetabular fracture

➤ **YOUNG AND BURGESS CLASSIFICATION**

LC : ANTERIOR INJURY = RAMI FRACTURE

LC 1 : Sacral fracture on side of impact

LC 2 : Crescent fracture on side of impact

LC 3 : Type 1 or 2 injury on side of impact with contralateral open book injury

APC : ANTERIOR INJURY = SYMPHYSIS DIASTASIS / RAMI FRACTURES

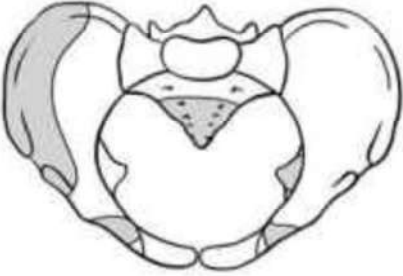



APC 1 : Minor opening of symphysis and SI joint anteriorly

APC 2 : Opening of anterior SI , intact posterior SI ligaments (PSILs)


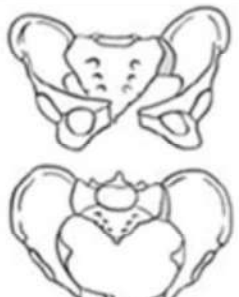
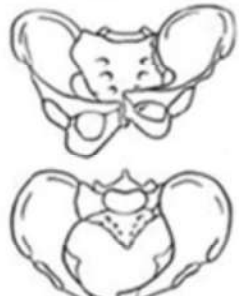
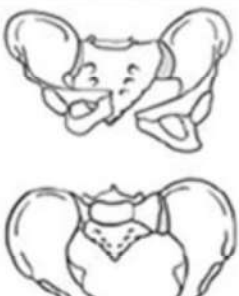
APC 3 : Complete disruption of SI joint

VS TYPE : Vertical displacement of hemipelvis with symphysis diastasis or rami fractures anteriorly, iliac wing, sacral fracture, or si dislocation posteriorly.


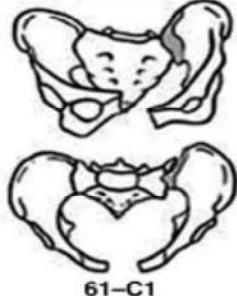
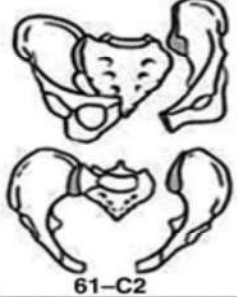
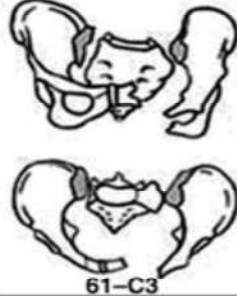
CM TYPE : Any combination of the above injuries

A type - Stable pelvic ring injuries		
		
AO / OTA	Tile	Young & Burgess
 61-A1	A1 Avulsion of the innominate bone	n/d
 61-A2	A2 Stable iliac wing fracture or stable, minimally displaced pelvic ring fracture	(LC I/APC I)
 61-A3	A3 Transverse sacrum or coccygeal fracture	n/d

a.)

B-type – partially stable pelvic injuries (rotationally unstable)		
		
AO/OTA	Tile	Young and Burgess
 61-B1	B1 "Open book" injury Anterior SI-ligament stretched	APC I Pubic diastasis <2.5 cm APC II Pubic diastasis ≥2.5 cm Anterior SI-ligament disrupted
 61-B2	B2 Lateral compression injury (B2-2: contralateral "bucket-handle" type)	LC I Posterior injury: sacral impaction LC II Posterior injury: Anterior sacral crush (LC IIA) or Iliac wing "crescent" injury (LC IIB)
 61-B3	B3 Bilateral B-type injuries	LC III Unilateral B1 with contralateral B2 type injuries ("windswept pelvis")

b.)

C-type – completely unstable pelvic ring injuries (rotationally and vertically unstable)		
		
AO/OTA	Tile	Young and Burgess
 61-C1	C1 Unilateral	<p>APC III Pubic diastasis ≥ 2.5 cm Anterior and posterior SI-ligament disruption</p> <p>VS (Vertical shear) APC III with vertical displacement of hemipelvis</p> <p>CM (Combined mechanical) Complex fractures with combined elements of APC, LC, and/or VS</p>
 61-C2	C2 Bilateral: One side B-type One side C-type	
 61-C3	C3 Bilateral C-type	

c.)

Table 3.1 (a,b & c) : Classification of Pelvic Ring Fracture

➤ **DENIS CLASSIFICATION**

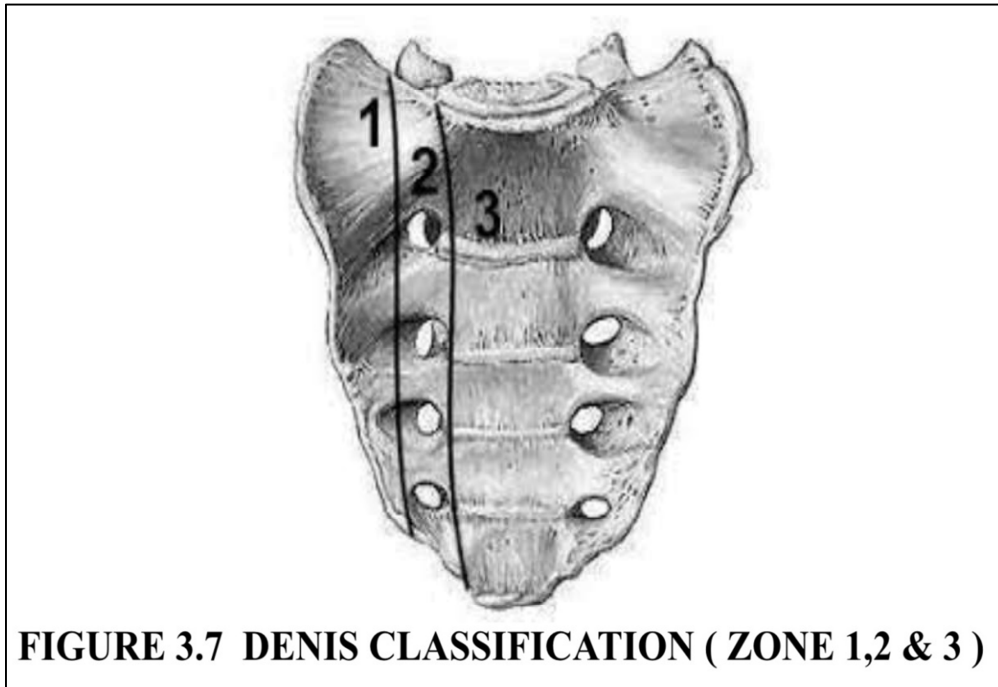


FIGURE 3.7 DENIS CLASSIFICATION (ZONE 1,2 & 3)

Sacral fractures are most commonly classified by the system described by Denis. Based on the orientation and location of the fracture line in relation to the sacral foramina, it classifies the fractures. Zone I fractures are those that happen vertically or obliquely just lateral to the sacral foramina. This is the most common pattern, comprising almost 50% of injuries. Because the fracture is lateral to the foramen, the rate of neurologic injury is low. When the fracture line enters the sacral foramina, it is classified as a zone II injury, and these account for about one-third of all sacral fractures. These fractures are accompanied by a neurologic deficit in about 30% of cases. The zone III injury is a much more heterogeneous group of fracture patterns compared to zone I or II injuries. The fracture lines can run horizontally, vertically, or obliquely; they remain generally medial to the sacral foramina and enter the spinal canal. In zone III fractures, the rates of injury to the nerve roots or the cauda equina can be as high as 60% due to extension into the spinal canal. Zone III

fractures are the least common of injuries with an incidence of 16%. Pelvic stability can be compromised with complete sacral fractures. Moed described the vertical midline "split" that is associated with unstable APC injuries of the pelvic ring. Horizontal fractures can be easily missed without fine-cut CT scans and sagittal reconstructions. These horizontal fractures often have little impact on pelvic stability, but depending on where they are in relation to the SI joints, they may have an impact on spinal stability. Although fractures below the level of the SI joints are stable lesions, they can harm the cauda equina and the spinal nerve roots. Fracture fragments may occlude the canal, resulting in injury to these structures usually at the S3 level and below.¹

➤ **MODIFIED ROY-CAMILLE (STRANGE-VOGENSEN) CLASSIFICATION**

A U- or H-shaped fracture pattern may develop from a horizontal fracture that occurs at the level of the SI joints and is typically accompanied by bilateral vertical trans-foraminal fracture lines. According to Denis, Roy-Camille, and Strange-Vogensen, these injuries are caused by acute hyper-flexion of the pelvis and lumbosacral junction, which causes lumbo-pelvic dissociation. This "disassociation" results in a loss of continuity between the pelvis and spine that can lead to a kyphotic deformity, impaction, and potential compromise of the sacral spinal canal. The kyphotic deformity is best seen on sagittal reconstruction images of a fine-cut CT scan of the pelvis. This is in contrast to zone I or II injuries. The lumbopelvic disassociation injury is highly unstable and is a result of either VS forces or rotational forces on the pelvis. If the fracture line in these injuries extends proximally and fractures the L5-S1 articulation, spinal stability may be impacted, or transforaminal fractures with comminution, fracture separation, and/or vertical instability, and may

also require triangular osteosynthesis and spinopelvic fixation, The Roy-Camille classification initially had three subtypes but was modified by Strange-Vognsen and Lebecht to include a fourth subtype. The type 1 patterns have kyphosis (anteriorly flexed) without translation. The type 2 patterns have kyphosis with posterior translation of the cephalad fragment. Type 3 fractures are completely translated injuries, most often with the cephalad fragment anterior to the caudal segment. The type 4 fracture has complete comminution without displacement of the cephalad fragment. In addition, these high-energy fractures have been classified into morphologic variations based on the fracture configurations: U, H, I, and Y patterns.¹

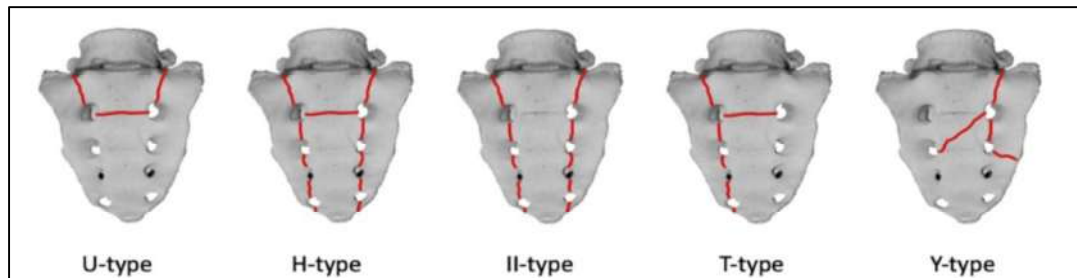


FIGURE 3.8 STRANGE VOGNSEN CLASSIFICATIONS

PATHOANATOMY AND APPLIED ANATOMY RELATING TO PELVIC RING INJURIES

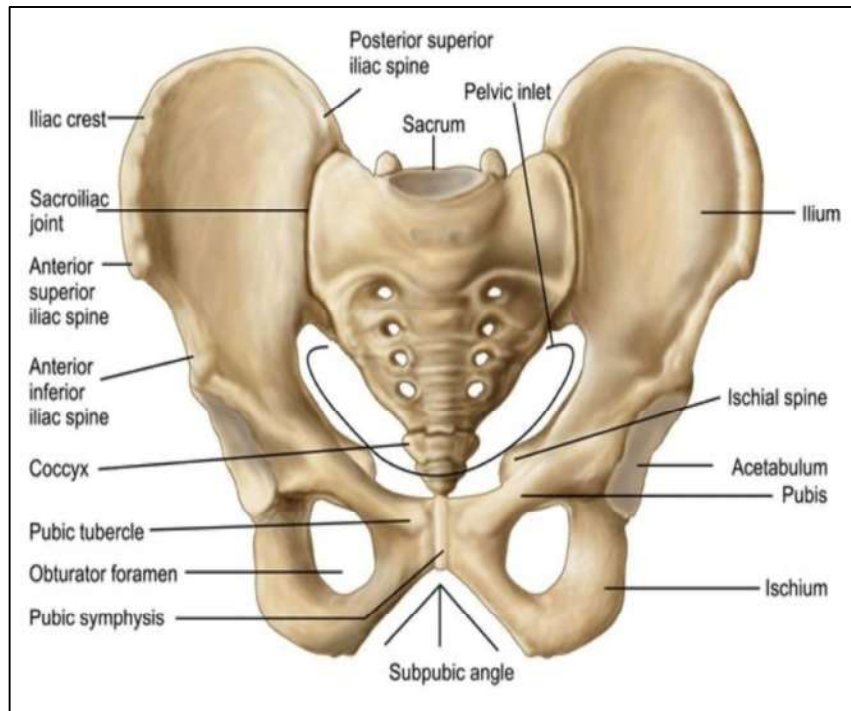


FIGURE 3.9 BONY LANDMARKS OF PELVIS

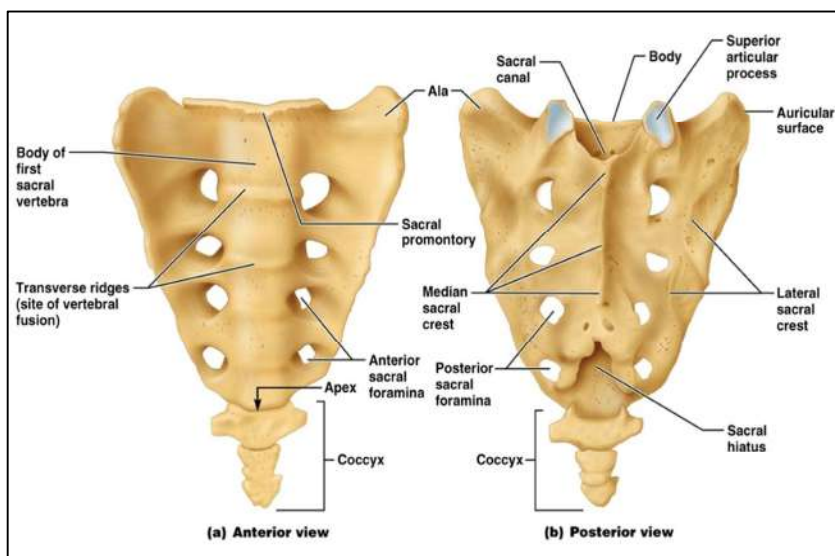


FIGURE 3.10 MAGNIFIED BONY MODEL OF SACRUM (A. ANTERIOR VIEW ; B. POSTERIOR VIEW)

Sacrum & each hemipelvis, also referred to as the innominate bones, make up the three bones that constitute the pelvis. Ilium, ischium, and pubis, three embryonic parts, come together to form the innominate bone. The triradiate cartilage, where the acetabulum grows, is where the fusion takes place. Forces can be transferred from the lower extremities up to the spine via the ilium thanks to the femoral head's joint with the acetabulum. Consequently, the ilium bone has two extraordinarily thick and sturdy columns. The first column, which runs from the ischial tuberosity to the SI joint, distributes force when a person is seated. The second column joins the SI joint to the dome of the acetabulum to transfer force when standing. The sciatic buttress, a section of bone that is incredibly dense, spans both columns. At the symphysis pubis, the two hemi-pelvises are connected anteriorly. The SI joints connect the sacrum, which develops from the fusing of five embryonic sacral vertebral bodies, posteriorly to each hemipelvis. Superiorly it articulates with the L5 vertebral body through the L5-S1 disc space and corresponding facet joints. The spino-pelvic junction is the term used to describe the bony structure that connects the spine to the lower extremities and is supported by ligaments. The S1 joints and their associated ligaments, which are located in the posterior portion of the pelvic ring, serve as the foundation for the stability of the pelvic ring and are a part of the spine (sacrum). Because it is formed through fusion of the five sacral bodies, the sacrum is prone to segmentation anomalies, which need to be evaluated as they can affect treatment options and strategies, when treating pelvic ring injuries. These segmentation malformations could be either complete or partial sacralization of L5 or lumbarization of S1.¹

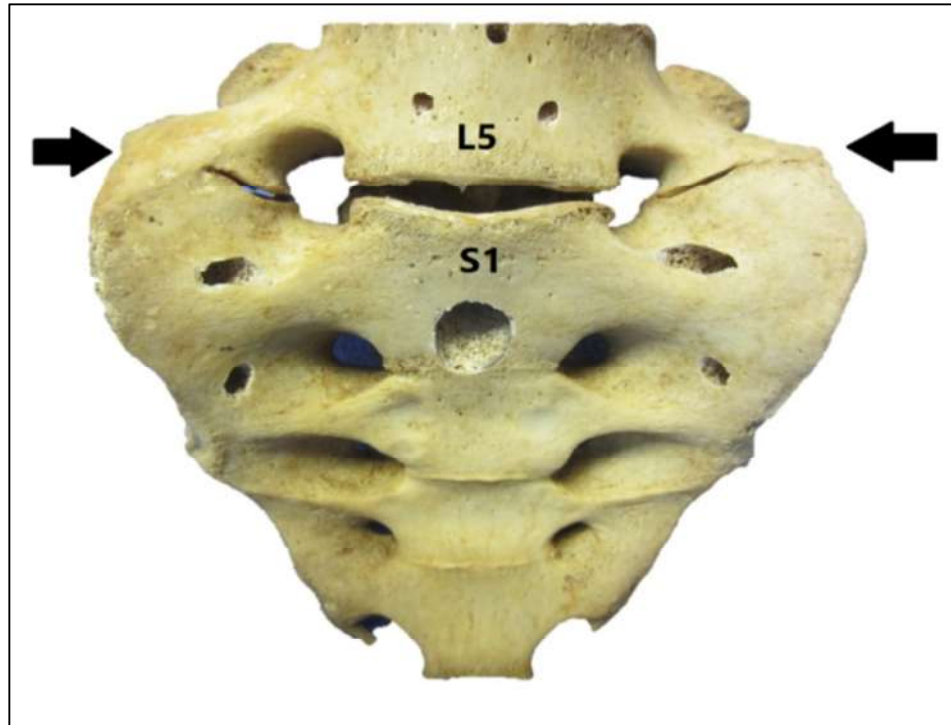


FIGURE 3.11 SACRALIZATION OF L5

The sacrum forms in such a way that the posterior aspect is convex and anterior concave, and there are varying degrees of kyphosis inherent in the curvature. Such anatomic and geometric subtleties need to be noted when sacral imaging and fixation are considered.¹

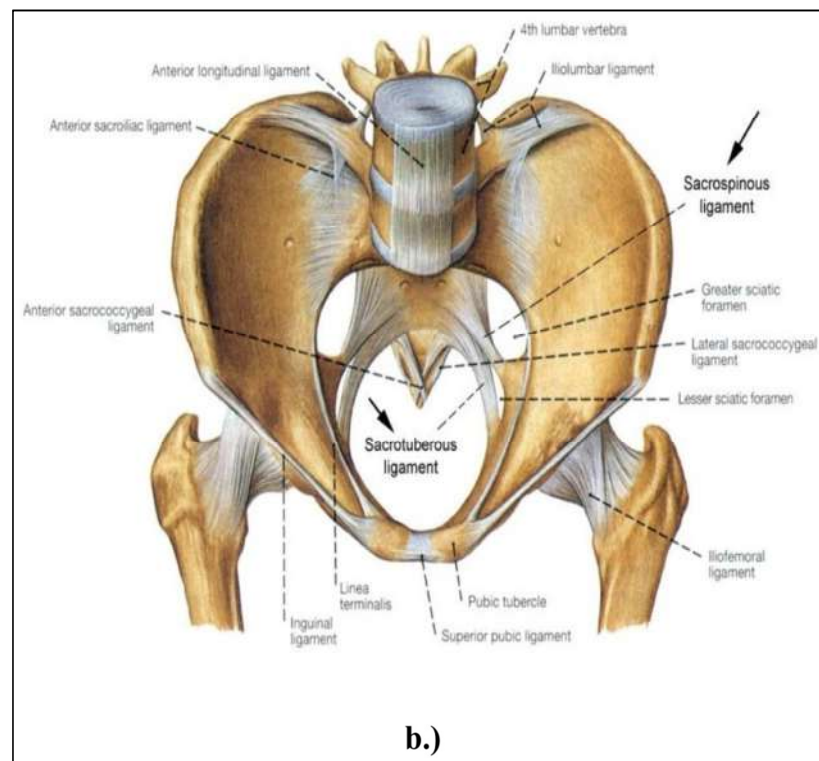
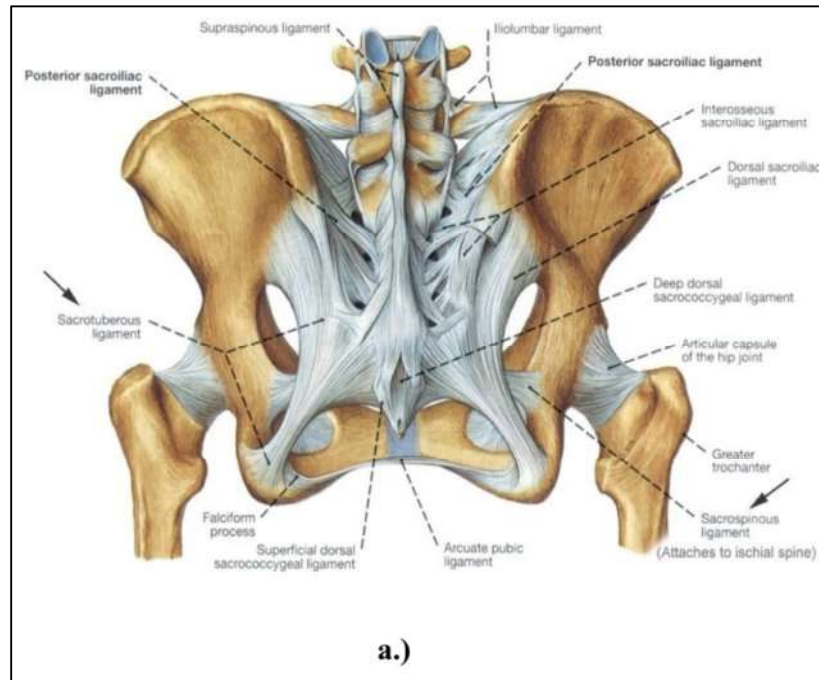


FIGURE 3.12 SCHEMATIC DRAWING SHOWING LIGAMENTOUS STRUCTURES OF THE PELVIS.

A.) POSTERIOR VIEW

B.) ANTERIOR VIEW

Strong ligaments hold the three bone structures together. Each of the bony structures' articulations—the bilateral S1 joints in back and the symphysis pubis in front—is by nature unstable. These sturdy supporting ligamentous structures keep the regular anatomic relationships in place. The SI joints are stabilised by the anterior, intra-articular, and PSILs. The posterior ring is further supported by the ST and SSp ligaments. The symphyseal ligaments, which keep the pubis together, contribute for only 15% of the stability of the total ring, whereas the posterior ring structures account for the bulk. For anterior stability, these ligaments are in charge. In order to develop effective treatment strategies, it is crucial to comprehend the structures that various pelvic ring injuries affect. The biomechanics of the pelvic ring are also important to understand to aid in treatment decisions. The stresses on the pelvic ring vary depending on the load, most notably whether it is a single-leg or bilateral-leg attitude, because the S1 joints and acetabula are off axis in regard to the axial skeleton. When a person is standing on both legs, the superior SI joint is compressed and the symphysis and inferior SI joints are both under tension. The symphysis really experiences compression and VS while in a single-leg stance, while the SI joint forces switch to compression internally and tension superiorly. The intact pelvis exhibits these stresses. There is a change in the directional forces when ligaments are injured. When the posterior ligamentous complex is intact but the symphysis is disturbed, compressional forces cause the symphysis to close, which is the justification for non-operative therapy of an APC I injury. It has been observed that mobilization causes the diastasis to gradually close. The symphysis continues to remain under tension when the anterior SI ligaments are damaged in addition to the symphyseal injury, which causes it to spread even more when you bear weight. Then, surgical intervention is required.¹

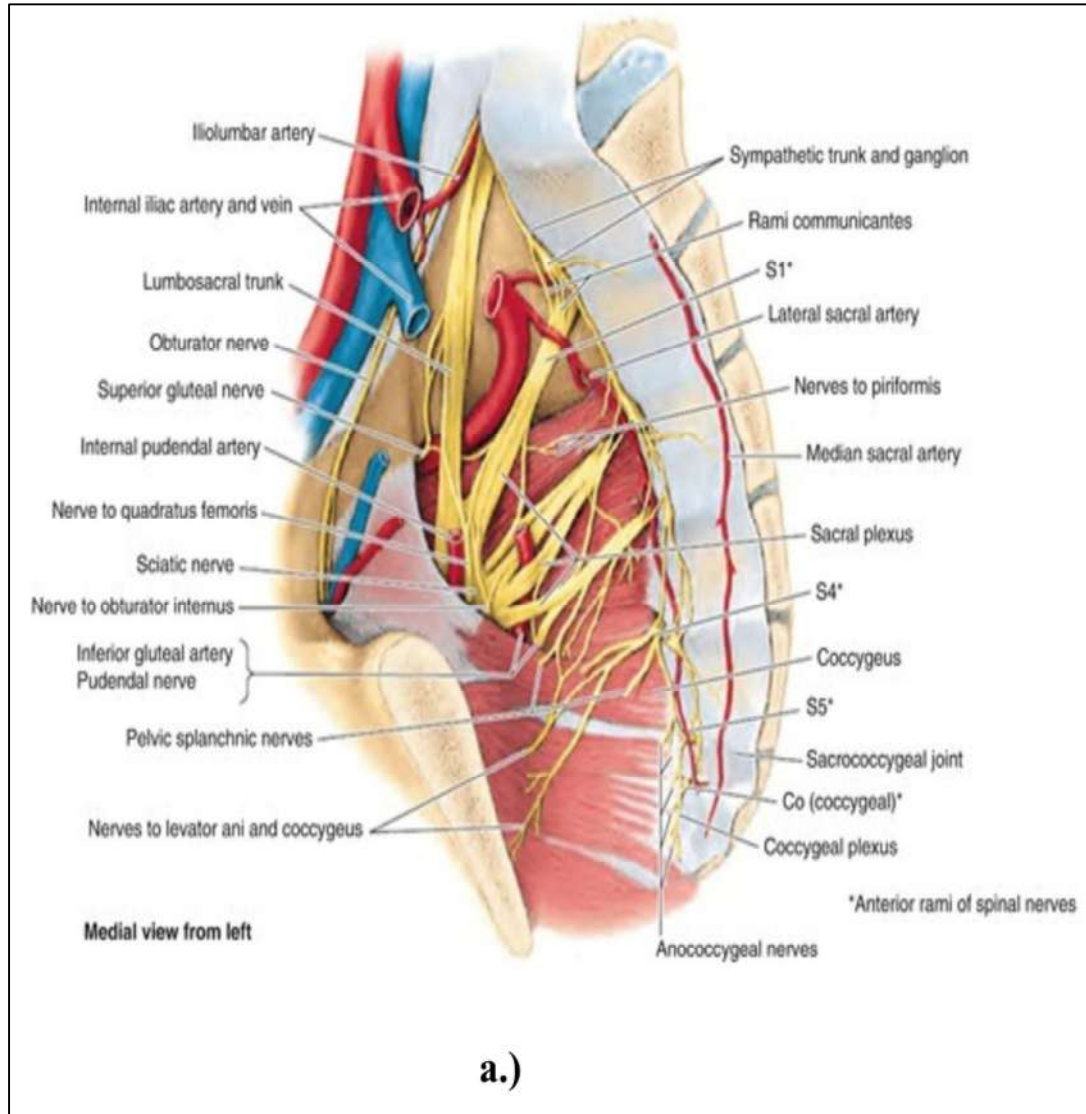


FIGURE 3.13 (a) SCHEMATIC DRAWING SHOWING NEUROVASCULAR STRUCTURES WITHIN THE PELVIS

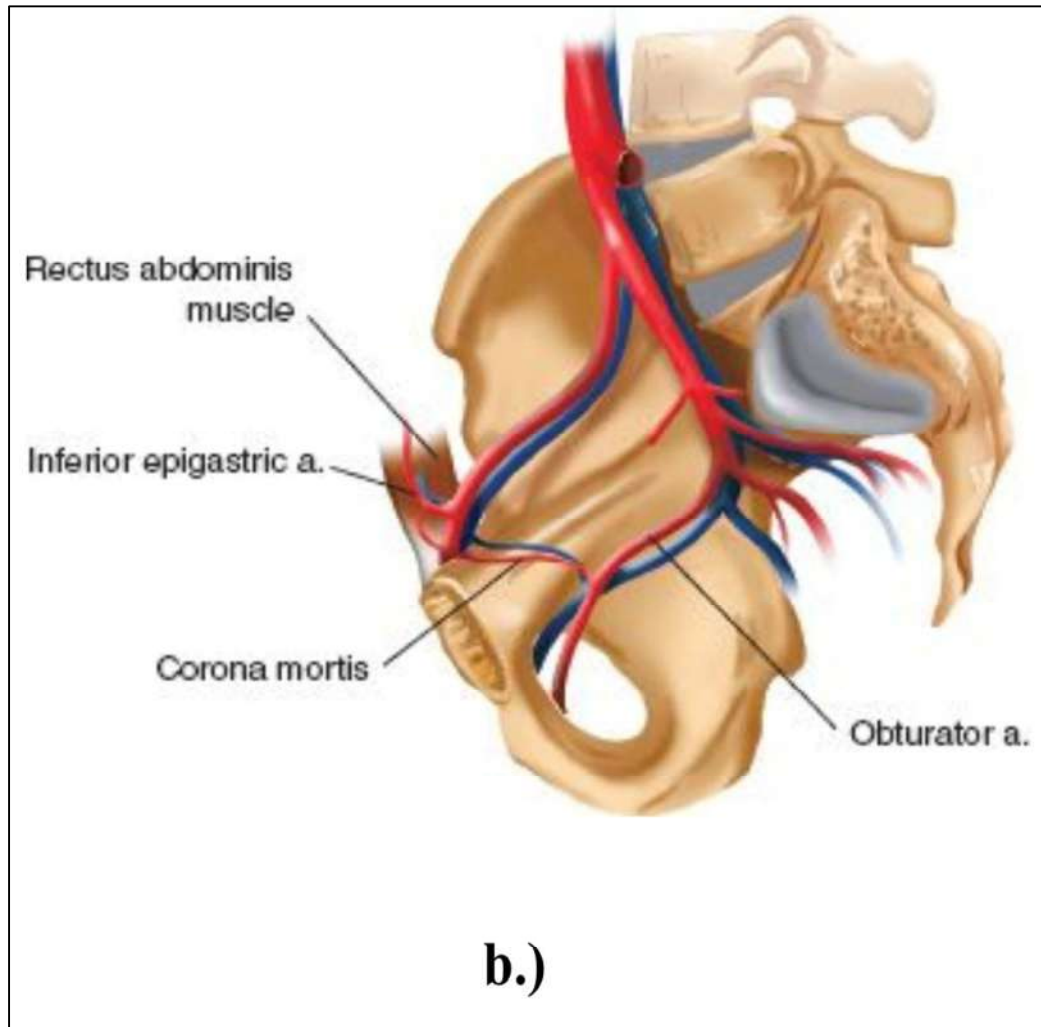


FIGURE 3.13 (b) SCHEMATIC DRAWING SHOWING NEUROVASCULAR STRUCTURES WITHIN THE PELVIS

In addition to supporting the soft tissue structures within the pelvis, pelvic ligaments help support the bony pelvis. Hemorrhage from injured venous and arterial arteries is possible when the ligaments are disrupted, compromising the pelvic ring's structural integrity. Notably, pelvic dislocation almost invariably results in some degree of injury to the venous plexus 1s. The internal iliac arteries and their main trunks exit the pelvis anterior to the SI joints through the greater and lesser sciatic notches and the obturator foramen. The larger sciatic notch is where the superior

gluteal vessels leave, and pelvic ring trauma frequently damages them. It takes a lot of force to break the pelvic ring, whether it is by ligamentous damage or fractures. The bony pelvis is closely linked to numerous visceral tissues, many of which are frequently hurt. As a result of the bladder and urethra lying immediately posterior to the pubic symphysis, urologic injuries often accompany pelvic ring injuries. Due to their proximity to the symphysis, scrotal hematomas and vaginal lacerations also occur with pelvic trauma. Injury is possible due to the rectum's proximity to the sacrum in front. Pelvic ring injuries can potentially be accompanied by neurologic damage. The L5 nerve root is susceptible to damage from pelvic ring injuries or following surgery on the front side of the sacral ala. Each of the five sacral foramina is where the sacral nerve roots leave the body. These combine to form the entire sacral plexus, which innervates the lower extremities and perineal tissues, as well as a portion of the lumbosacral plexus. Sacral fractures may cause damage to the nerve roots, and if zone II injuries are present, decompression may be necessary. The three main recognized peripheral nerves that exit the pelvis via the bigger sciatic notch are the sciatic nerve, the superior and inferior gluteal nerves, and the internal pudendal nerve. The obturator nerve exits the pelvis through the obturator foramen. The accompanying damage to other organ systems with pelvic ring injuries necessitate a multidisciplinary approach to therapy. In order to effectively treat these fractures, avoid iatrogenic injuries, and deliver the best outcomes, a thorough understanding of pelvic anatomy is necessary. It has been shown that the pelvic ring fracture alone is not as predictive of mortality and functional outcome as concurrent neurologic, thoracic, & abdominal visceral injuries. It is crucial to consult urologists and general surgeons as soon as possible.¹

ARTICLE REVIEW

Vivek Trikha in 2017 performed a retrospective analysis on 105 pelvic CT images of individuals who had been admitted to the emergency room. Before beginning sacro-iliac screw fixation in the Indian population, an individualised approach is required, and each patient's CT scan must be thoroughly examined.⁽⁴⁾

Florian Gras PD DR.Med in 2016 did study on 280 pelvises subjected to a biomorphometric study. Due to the sex-dependent individuality of the sacrum's morphologic traits and the sacral corridors' restricted width, trans-sacral implant implantation is technically difficult. Individual pre-operative CT scan analysis is recommended to establish the prevalence of sufficient sized osseous corridors on both levels for safe screw placements, especially in female patients due to their smaller corridor diameters and higher frequency of sacral dysmorphism.⁽¹³⁾

Daniel Wagner in 2016 concluded from his study that to avoid neurological and vascular damage, trans-sacral implants must be positioned within intra-osseous trans-sacral corridors. The percentage of sacra not allowing S1 trans-sacral implants has been reported to be 11-53% and is more commonly present in females. Due to this when using trans-sacral implants, anatomical evaluation with 3D CT scan is essential to prevent damage to neurological and vascular structures.⁽¹⁴⁾

T. Mendel in 2013 did study based on 125 CT dataset of intact normal human pelvis and concluded that sacro-iliac screw fixation for unstable pelvic fracture stands out as the only minimally invasive method among all other ORIF procedures. The study looks into the relationship between the presence of S1 and S2 transverse corridors and the fact that males have much larger S1 and S2 corridors than females. Sacral morphology is highly diverse.⁽¹⁵⁾

Scott P. Kaiser, MD in 2014 did study on 104 patients using CT scan. Sacral dimorphism was found in 41% of pelvises. The major determinants of sacral dysmorphism are upper sacral segment coronal and axial angulation. The sacral dysmorphism score quantifies dysmorphism and can be used in pre-operative planning of ilio-sacral screw placement.⁽¹⁶⁾

Michael Goetzen in 2016 analysed CT scan of 1000 patients. The importance of pre-operative assessment of the sacral morphology using CT scans and classify the morphology of the upper sacrum based on the risk of iatrogenic nerve lesion during percutaneous S1 screw fixation.⁽¹⁷⁾

METHODOLOGY

SOURCE OF DATA:

The present study conducted with mixed population with age ranging from 18-65 years. All participants were recruited from emergency department, out patients with trauma, hip and spine injury cases. Patients older than 18 years of either sex who had a 3D-CT scan done as a diagnostic test in polytrauma patients or for the assessment of a pelvis fracture OR patients older than 18 years of either sex who had a 3D-CT scan of the pelvis with both hips or the abdomen with the pelvis for orthopaedic purposes (pelvic trauma, pelvis with bilateral hip, whole spine, etc.) or non-orthopedic purposes (like patients who had a CT abdomen).

METHOD OF DATA COLLECTION :

➤ STUDY DESIGN :

A hospital based one year Cross-Sectional Study.

➤ SELECTION CRITERIA :

INCLUSION CRITERIA :

- Patient with normal pelvis
- Patient with pelvis fracture
- Patient with dysmorphic pelvis

EXCLUSION CRITERIA :

- Age less than 18 years
- CT reveals a severely comminuted fracture of posterior pelvic ring that precludes accurate CT findings.

➤ **METHOD:**

Prior to the study's start, informed consent and ethics board clearance were acquired.

Analysis of screw placement and reduction quality of the pelvis

HOROS, Radiant, and Iplan software were used to analyze the CT scans. Both the S1 and the S2 sacral segments were measured (**Fig.4.1**). The antero-posterior breadth of the constrictions and the length of the ilio-sacral and trans-sacral screws were measured in the axial sections. At the levels of constrictions (vestibule) of S1 and S2, the vertical height and breadth of the canal were measured in the sagittal sections. After aligning on a 3D CT scan, sagittal and axial slices were examined to estimate the size of the osseous corridors for screw implantation. The maximum distance from the anterior most point of the anterior cortex to the deepest point on the posterior cortex of the S1 segment of the sacrum, in a direction perpendicular to a horizontal line passing through the deepest part of the anterior cortex of S1 corridor, was measured as antero-posterior constrictions (axial cuts) of S1. Axial measurements were taken at 3 levels that is, center of promontory, narrowest, lateral to foramen (**Fig.4.2**). The superior most cortex of the first neural foramen and the deepest portion of the superior cortex of the S2 segment were used to measure the height and width of the S1 in sagittal cuts. The width of the canal was measured from the anterior cortex to the posterior cortex (**Fig.4.3.1**). Similar to this, the height and width of the S2 were

measured in sagittal cuts as the maximum vertical distance from the superior most extent of the second neural foramen to the inferiormost portion of the second sacral neural foramen, and width was measured from the anterior cortex to the posterior cortex of the canal (**Fig 4.3.2**). The sagittal cuts were taken at 3 levels, that is sacro-iliac joint, middle of the sacral foramen and middle of the promontory. On a 3D CT model, an iliaco-sacral screw trajectory was made, beginning at a point on the iliac bone and ending in the midline just behind the anterior cortex of the sacral promontory in such a way that the direction of the screw trajectory was perpendicular to a line measuring the constriction in axial planes. Using a 3D CT model, a trans-sacral screw route was constructed that spans both sacro-iliac joints and runs parallel to the anterior and posterior cortex of the sacral promontory (**Fig 4.4**). In axial and sagittal sections, bone limits were not compromised, and the use of the 6.5 mm screw was considered whenever a bony limit break occurred. When none of the 7.3 mm or 6.5 mm screw sizes were found to be suitable, screw sizes less than 6.5 mm were not attempted. Diagrammatic representation of 2mm safe corridor for trans- sacral and ilio-sacral corridor (**Fig 4.5**).

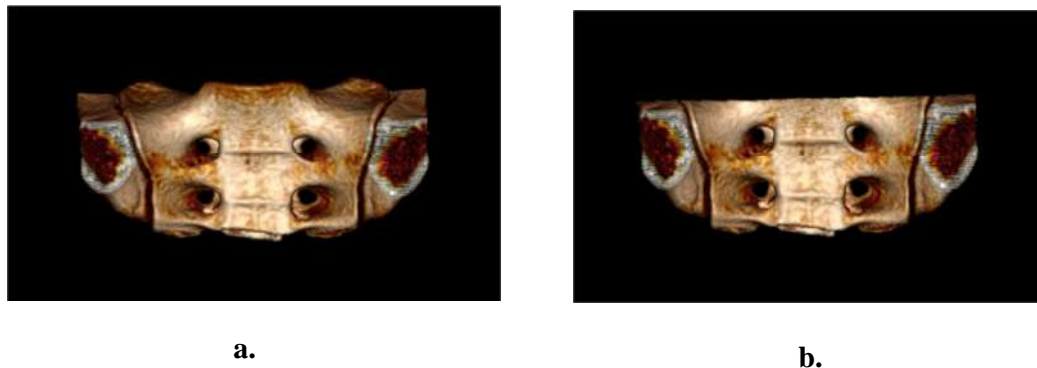


FIGURE 4.1 (a, b) SHOWING S1 AND S2 SACRAL SEGMENTS



a.



b.



c.

FIGURE 4.2 a) MEASUREMENTS FROM CENTER OF PROMONTORY, b) NARROWEST MEASUREMENT (CONSTRUCTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), c) MEASUREMENT LATERAL TO SACRAL FORAMEN

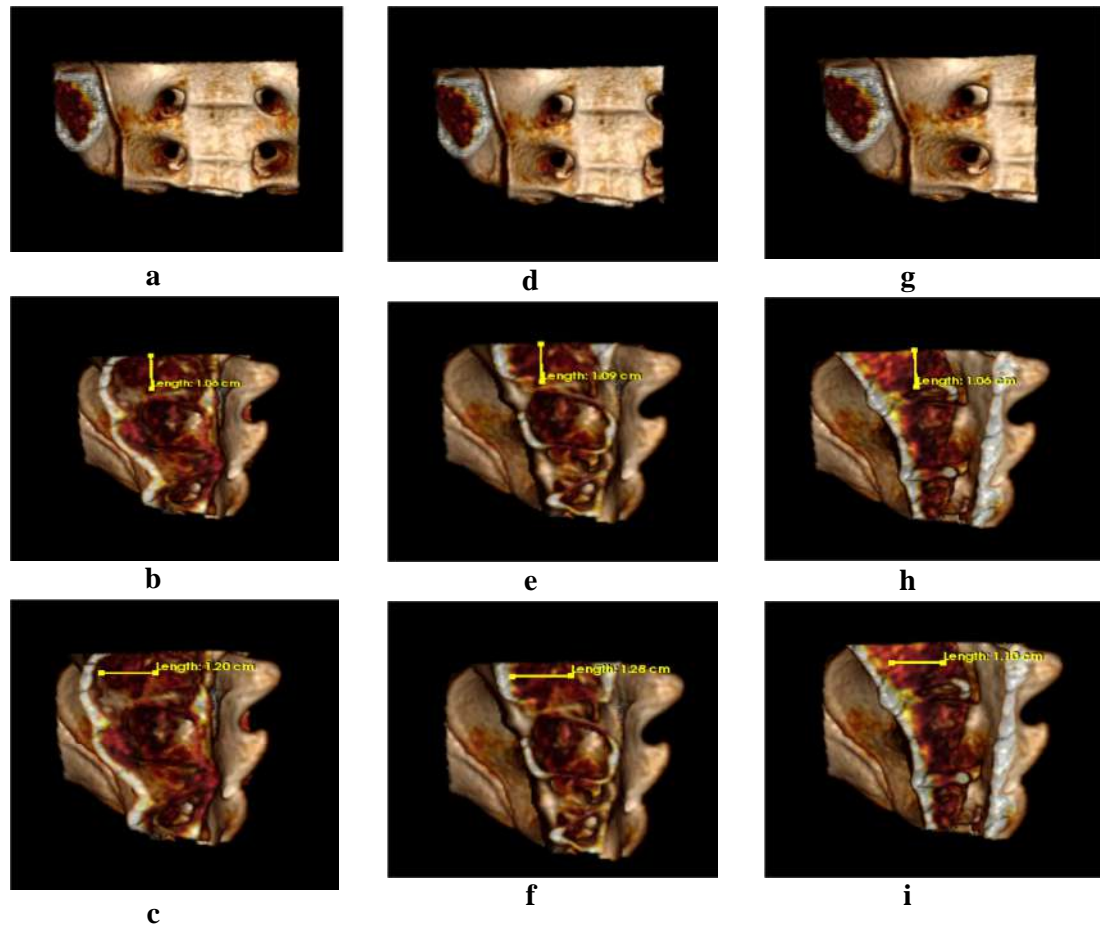


FIGURE 4.3.1 a) sagittal cut at the level of sacro-iliac joint, b) sagittal cut at the level of SI joint showing height of S1 (height 1), c) sagittal cut at the level of SI joint showing width of S1 (width 1), d) sagittal cut at the level of sacral foramens, e) sagittal cut at the level of sacral foramen showing height of S1(height 2), f) sagittal cut at the level of sacral foramen showing width of S1 (width 2), g) sagittal cut at the center of promontory, h) sagittal cut at the center of promontory showing height of S1(height), i) sagittal cut at the center of promontory showing width of S1 (width 3)

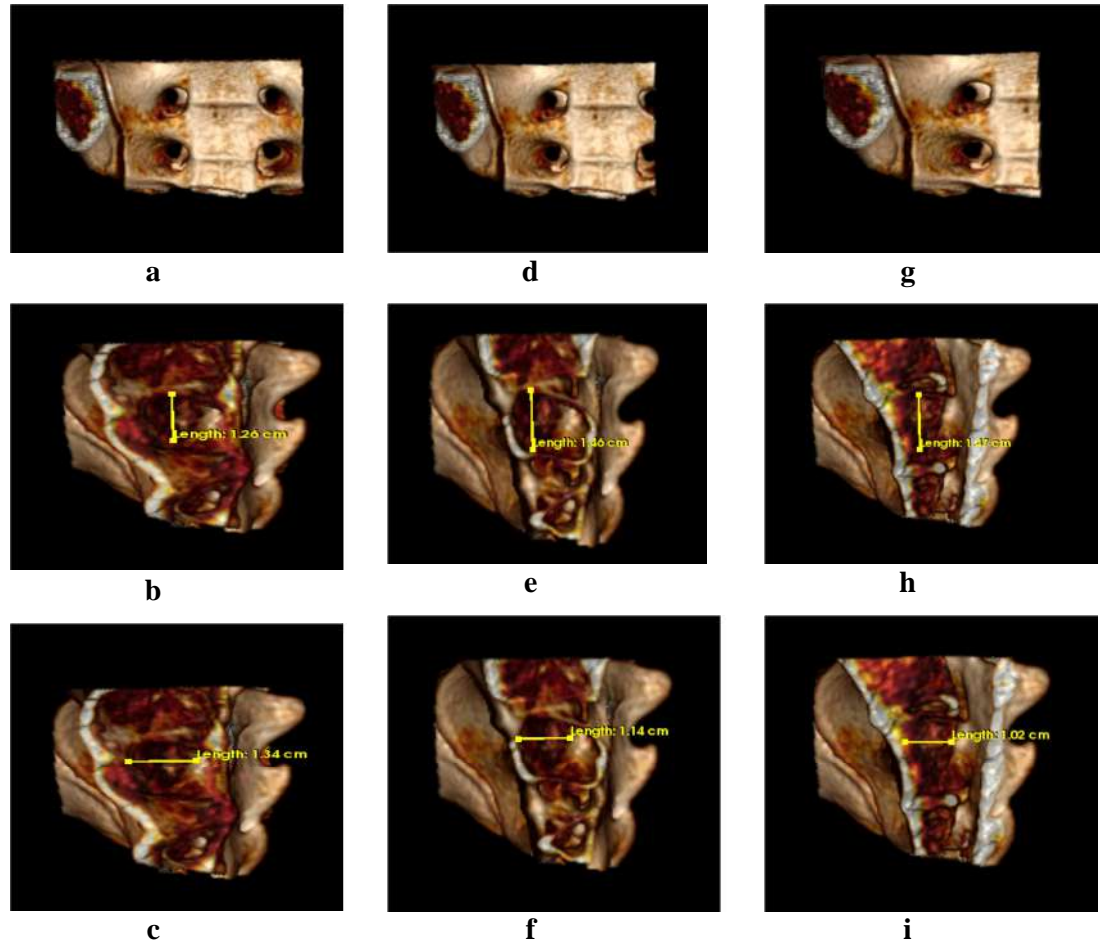
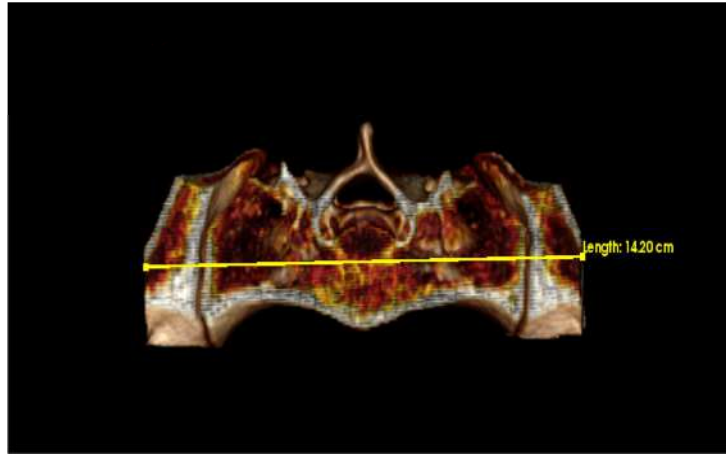
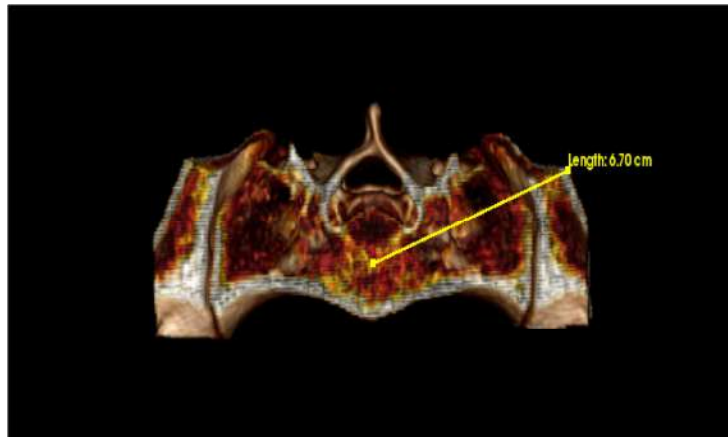


FIGURE 4.3.2 . a) Sagittal cut at the level of SI joint, b) Sagittal cut at the level of SI joint showing height of S2 (height 1), c) Sagittal cut at the level of SI joint showing width of S2 (width1), d) Sagittal cut at the level of sacral foramen, e) Sagittal cut at the level of sacral foramen showing height of S2 (height 2), f) Sagittal cut at the level of sacral foramen showing width of S2 (width 2), g) Sagittal cut at the center of promontory, h) Sagittal cut at the center of promontory showing height of S2(height 3), i) Sagittal cut at the center of promontory showing width of S2 (width 3)



a



b

FIGURE 4.4 a) AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW, b) AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR TRANS-SACRAL SCREW

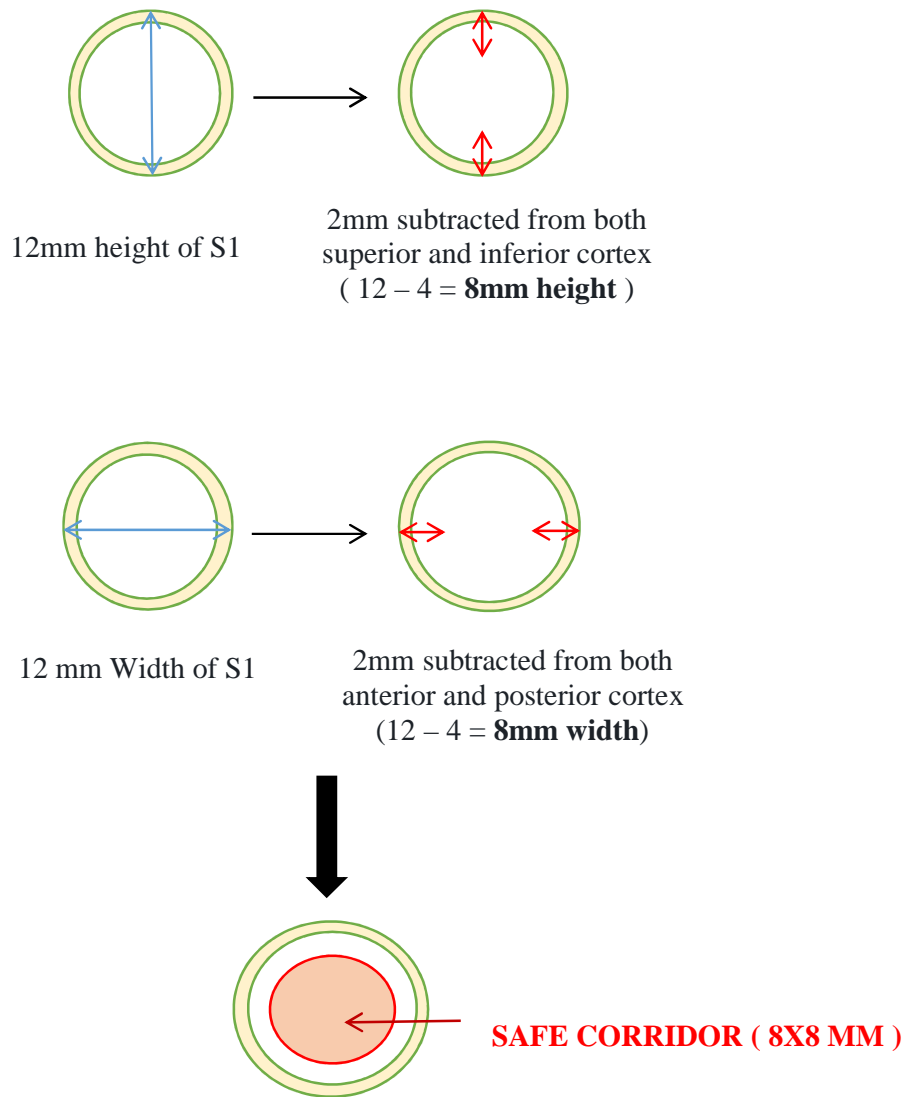


FIGURE 4.5 DIAGRAMMATIC REPRESENTATION OF TWO MM SAFE CORRIDOR (SAGGITAL SECTION OF SACRUM)⁽¹⁸⁾

STATISTICAL ANALYSIS

SPSS version 22.0 was used to analyze the data. Continuous data were presented in mean \pm SD and analyzed using student's unpaired t-test. $P < 0.05$ was considered as statistically significant.

The study is focused on comparison of two groups. Compute the mean and standard deviation for the continuous quantitative data. Utilizing appropriate statistical methods like the unpaired student's t test, the continuous variables between groups will be compared. The student's paired t test will be utilised to compare two quantitative variables within a group. Rates, ratios, and percentages will be used to express the categorical data. Using the Chi-square test or Fisher's exact test, the relationship between the result, clinical, and demographic factors will be examined. Median will be used to represent discrete variables. Discrete variable comparisons will be made using nonparametric testing. The comparison will be shown using the appropriate graphs. The value of p less than 5% (0.05) will be regarded as significant for all tests.

The minimum sample size formula based on mean and standard deviation is :

$$n = \frac{(z_{\alpha} + z_{\beta})^2 (s_1^2 + s_2^2)}{(\bar{X}_1 - \bar{X}_2)^2}$$

Where z_{α} is linked with the level of significance and z_{β} is linked with the power of the test. For 5% level of the significance $z_{\alpha} = 1.96$ and $z_{\beta} = 0.84$ for 80% power of the test.

Ref: Antero-posterior vestibular width S1 (Axial section) :- overall=21.30 (range 16.10-27.40)(SD 2.73,SEM21.30) ; Males-21.87mm(range 16.7-27.4)(SD2.57,SEM0.30) ; Females- 20.17mm(range16.10-26.10)(SD2.27,SEM0.46) ; p=0.002(significant)(unpaired t-test) ; Vivek Trikha. Safe corridor for iliosacral and trans-sacral screw placement in Indian population :A preliminary CT based anatomical study . Journal of clinical orthopaedics and trauma 10(2019) 427-431.

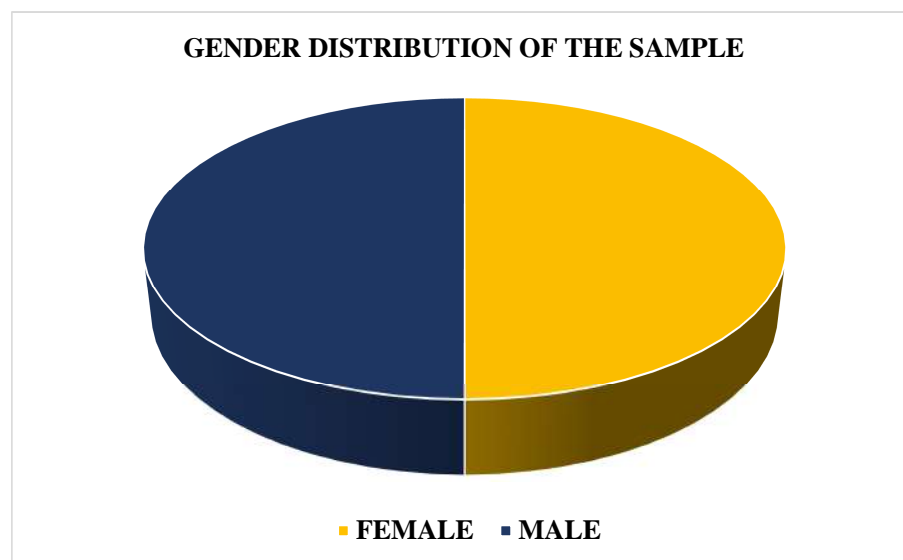
\bar{X}_1 is the mean of the first group (21.87) and \bar{X}_2 is the mean of the second group (20.17).

s_1 is the standard deviation of the first group (2.57) and s_2 is the standard deviation of the second group (2.72).

With these values the sample size obtained is 38.

There will be two groups with minimum 38 cases in each group.

TOTAL SAMPLE SIZE IS 76



GRAPH 4.1

RESULTS

- Comparison between the groups of male and female, with 38 male with range of 18-64 years (38 ± 11.8) and 38 female with age range 19-65 (39 ± 12.5).
- In the following tables p values are calculated using student's unpaired t test.

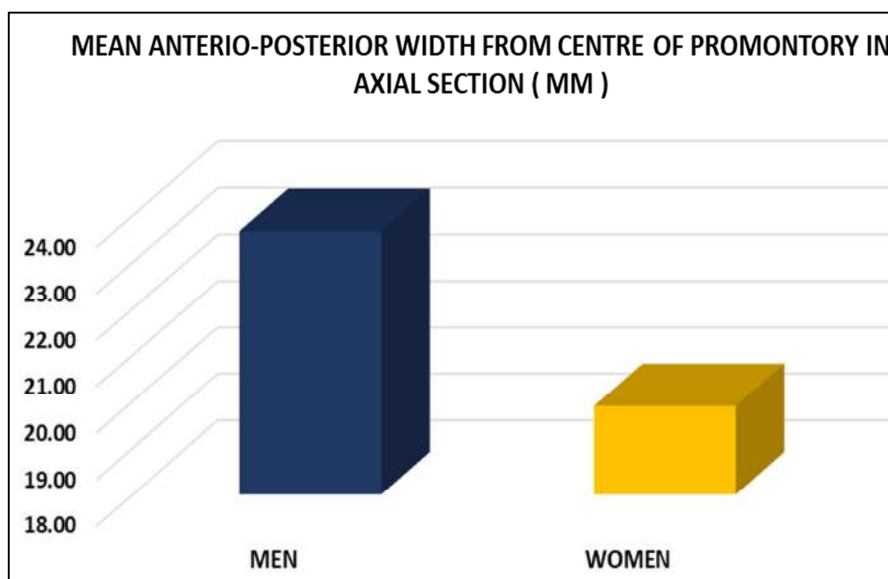
ABBREVIATIONS :

NS - Not Significant **S** – Significant **VS** - Very Significant **HS** - Highly Significant

MM – Millimeter

TABLE 5.1 ANTERO – POSTERIOR WIDTH FROM CENTRE OF PROMONTORY IN AXIAL SECTION

ANTERO-POSTERIOR WIDTH FROM CENTRE OF PROMONTORY IN AXIAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
23.66	3.32	16.1	31.2	19.89	3.78	13.3	29.2	<0.0001	HS

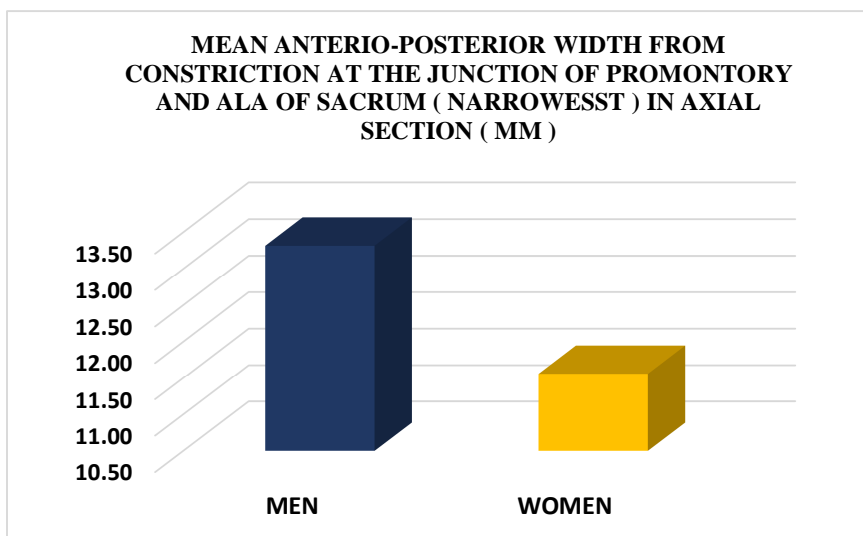


GRAPH 5.1

There is highly significant difference in the mean antero- posterior width from the centre of promontory in axial section between male and female with a p value of < 0.0001. Significantly higher antero- posterior width (centre) in males as compare to females.

TABLE 5.2 ANTERO- POSTERIOR WIDTH FROM CONSTRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM (NARROWEST) IN AXIAL SECTION

ANTERO-POSTERIOR WIDTH FROM CONSRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM (NARROWEST) IN AXIAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	p VALUE	INFERENCE
13.32	2.52	8.8	19.1	11.56	2.43	8.3	18.2	0.0028	VS

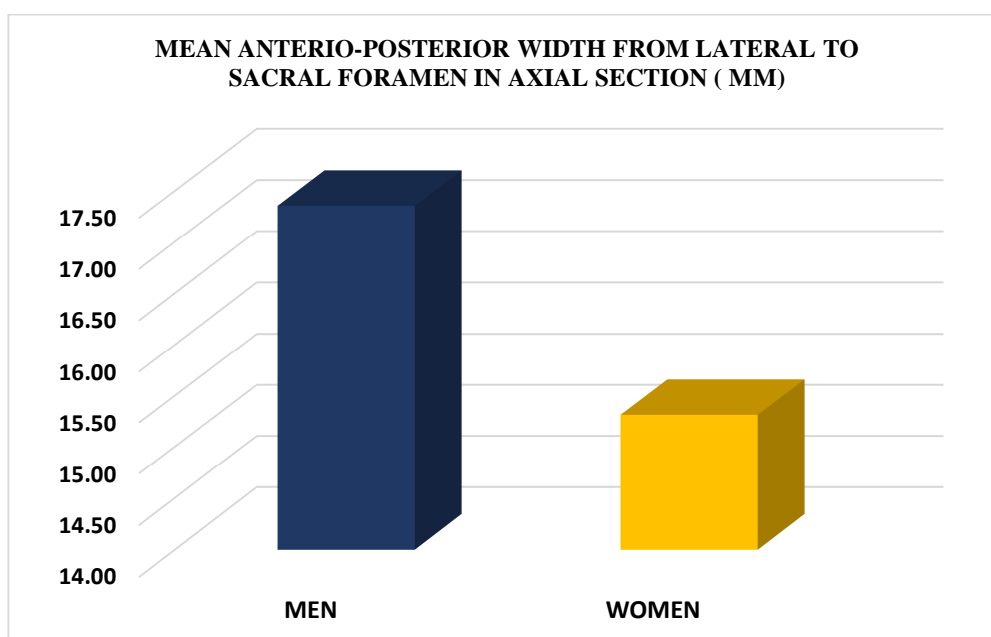


GRAPH 5.2

There is very significant difference in mean antero – posterior width from the constriction at the junction of promontory and ala of sacrum (narrowest measurement) in axial section between male and female with a p value of 0.0028. Significantly higher narrowest antero- posterior width in males as compare to females.

TABLE 5.3 ANTERO- POSTERIOR WIDTH FROM LATERAL TO SACRAL FORAMEN IN AXIAL SECTION

ANTERO-POSTERIOR WIDTH (mm) (AXIAL SECTION) LATERAL									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
17.36	3.89	11	26.4	15.31	3.39	10.1	22.9	0.0171	S

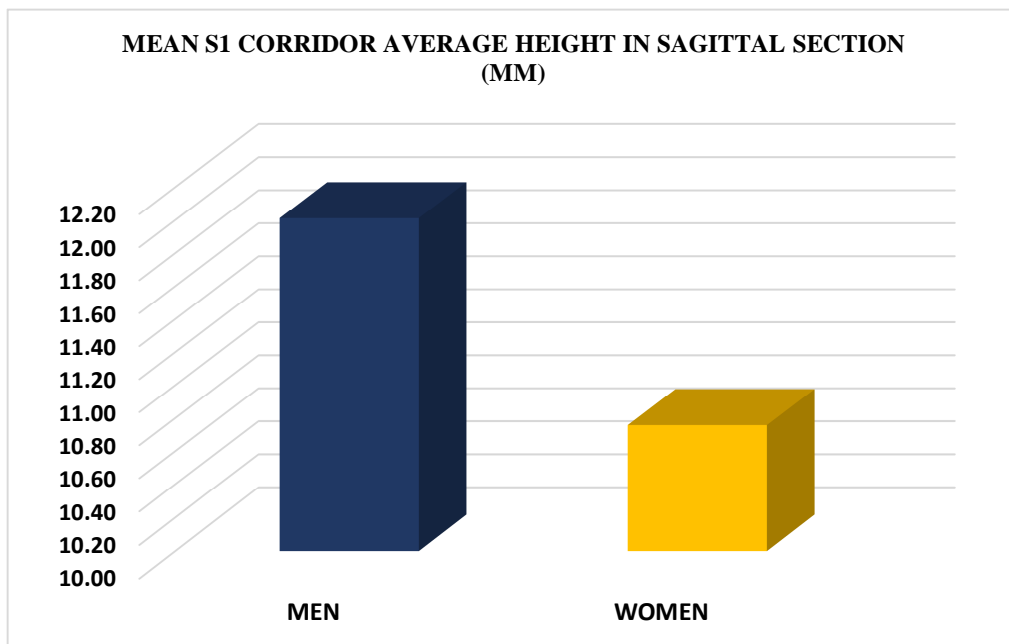


GRAPH 5.3

There is significant difference in mean antero- posterior width from lateral to sacral foramen in axial section between male and female with p value of 0.0171. Significantly higher antero- posterior width (lateral) in males as compare to females.

TABLE 5.4 S1 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION

S1 CORRIDOR AVERAGE HEIGHT IN SAGGITAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
12.01	1.83	8.9	17.1	10.76	1.13	9	13.4	0.0006	HS

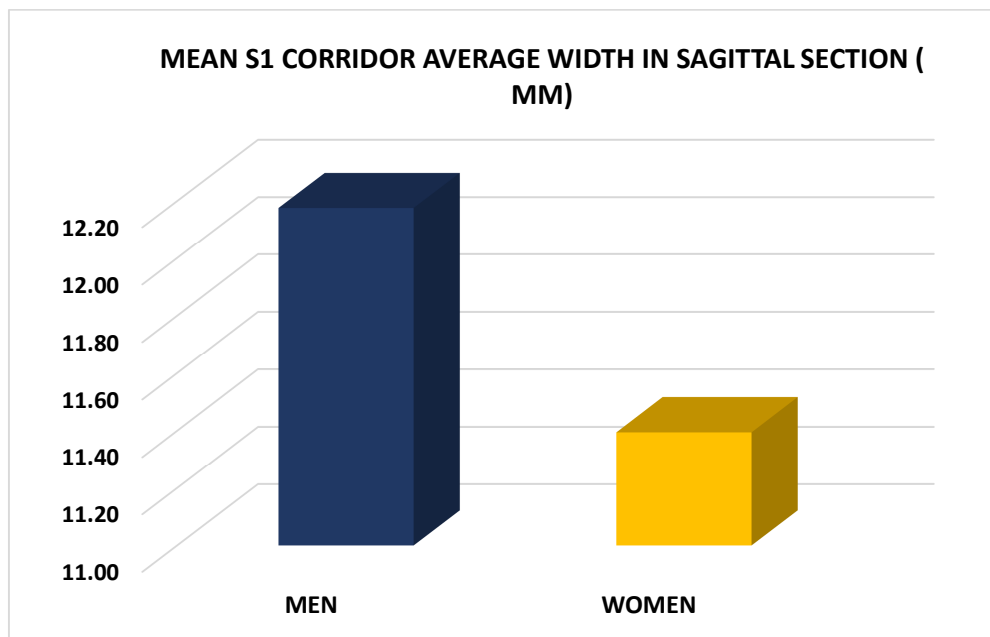


GRAPH 5.4

There is highly significant difference in mean average height of S1 corridor of sacrum in sagittal section between male and female with a p value of 0.0006. Significantly higher mean average height of S1 corridor of sacrum in males as compare to females.

TABLE 5.5 S1 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION

S1 CORRIDOR AVERAGE WIDTH IN SAGGITAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	p VALUE	INFERENCE
12.18	1.06	10.3	14.16	11.39	1.25	9.4	14.5	0.0045	VS

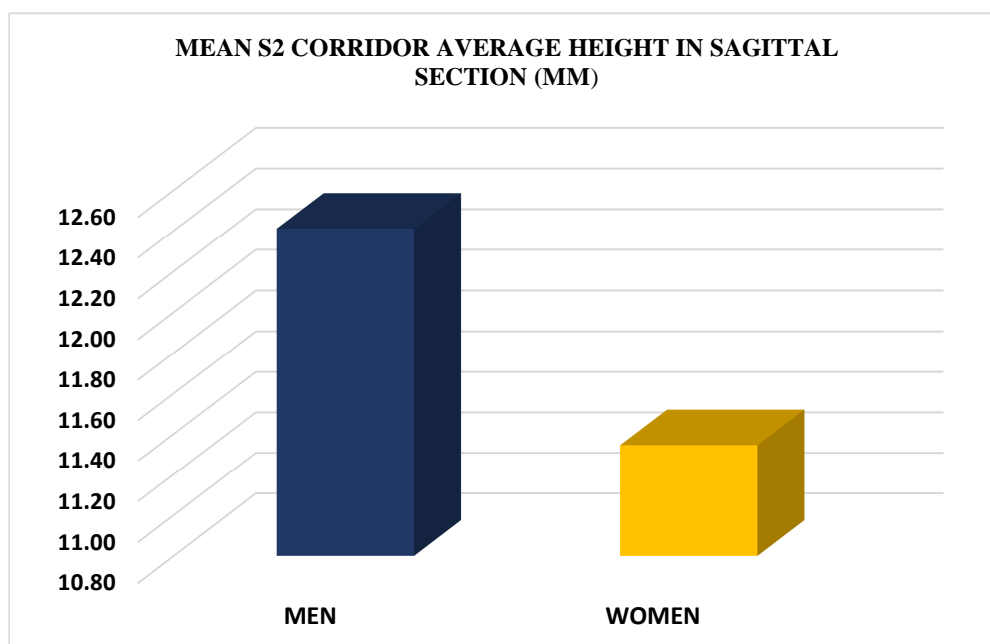


GRAPH 5.5

There is highly significant difference in mean average width of S1 corridor of sacrum in sagittal section between male and female with a p value of 0.0045. Significantly higher mean average width of S1 corridor of sacrum in males as compare to females.

TABLE 5.6 S2 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION

S2 CORRIDOR AVERAGE HEIGHT IN SAGITTAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
12.41	1.64	9.7	16	11.34	1.27	9.4	14.3	0.0022	VS

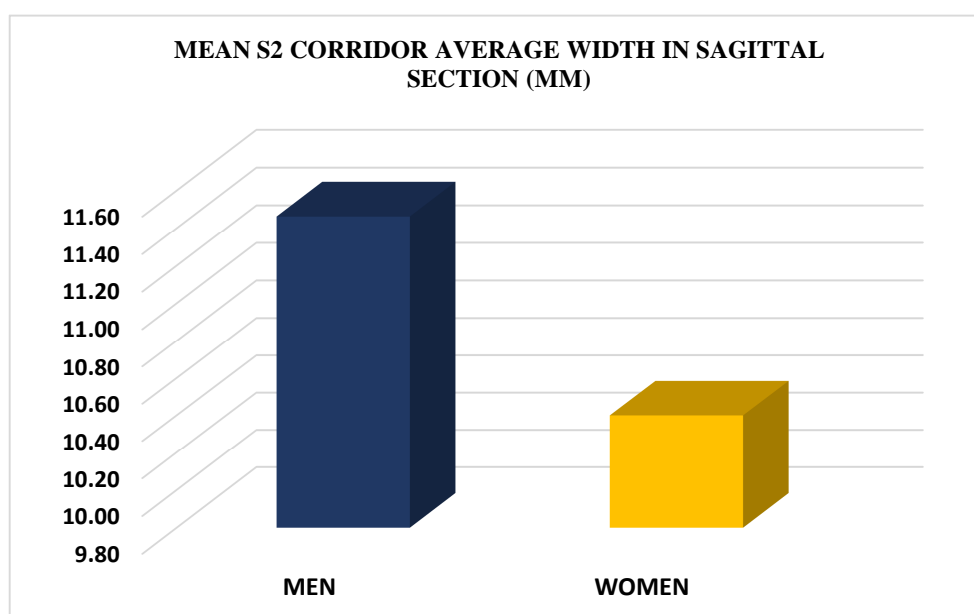


GRAPH 5.6

There is highly significant difference in mean average height of S2 corridor of sacrum in sagittal section between male and female with a p value of 0.0022. Significantly higher mean average height of S2 corridor of sacrum in males as compare to females.

TABLE 5.7 S2 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION

S2 CORRIDOR AVERAGE WIDTH IN SAGITTAL SECTION (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
11.46	1.39	9.5	15.7	10.40	0.97	8.9	12.5	0.0002	HS

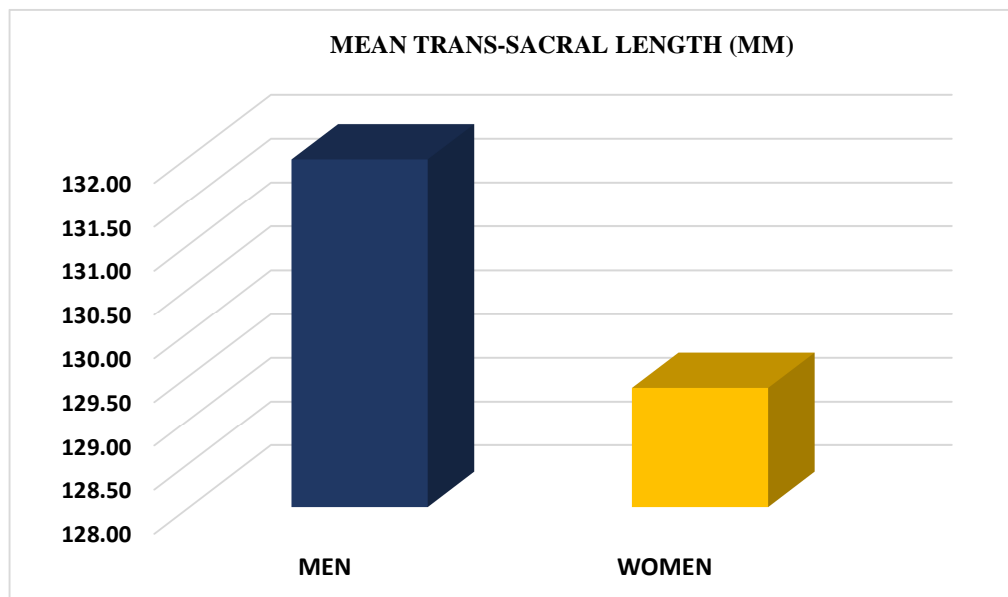


GRAPH 5.7

There is highly significant difference in mean average width of S2 corridor of sacrum in sagittal section between male and female with a p value of 0.0002. Significantly higher mean average width of S2 corridor of sacrum in males as compare to females.

TABLE 5.8 TRANS-SACRAL LENGTH

TRANS-SACRAL LENGTH (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
131.97	8.13	114.6	146	129.36	7.22	113.8	148.9	0.14344	NS

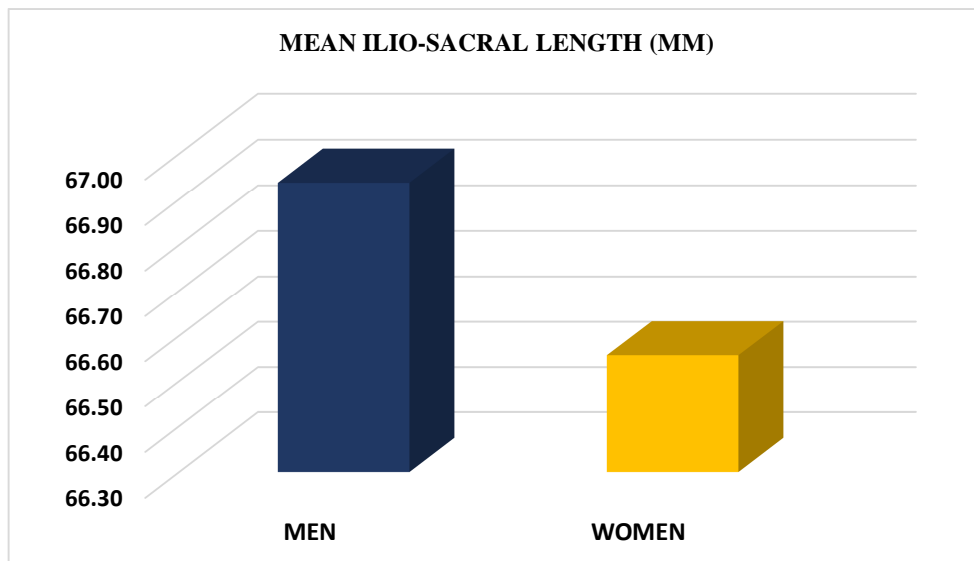


GRAPH 5.8

There is no significant mean trans-sacral length between male and female with a p value of 0.14344.

TABLE 5.9 ILIO- SACRAL LENGTH

ILIO-SACRAL LENGTH (MM)									
MALE				FEMALE					
MEAN	S.D.	MINIMUM	MAXIMUM	MEAN	S.D.	MINIMUM	MAXIMUM	P VALUE	INFERENCE
66.94	3.56	60.4	75.5	66.56	4.11	59.2	75	0.6682	NS

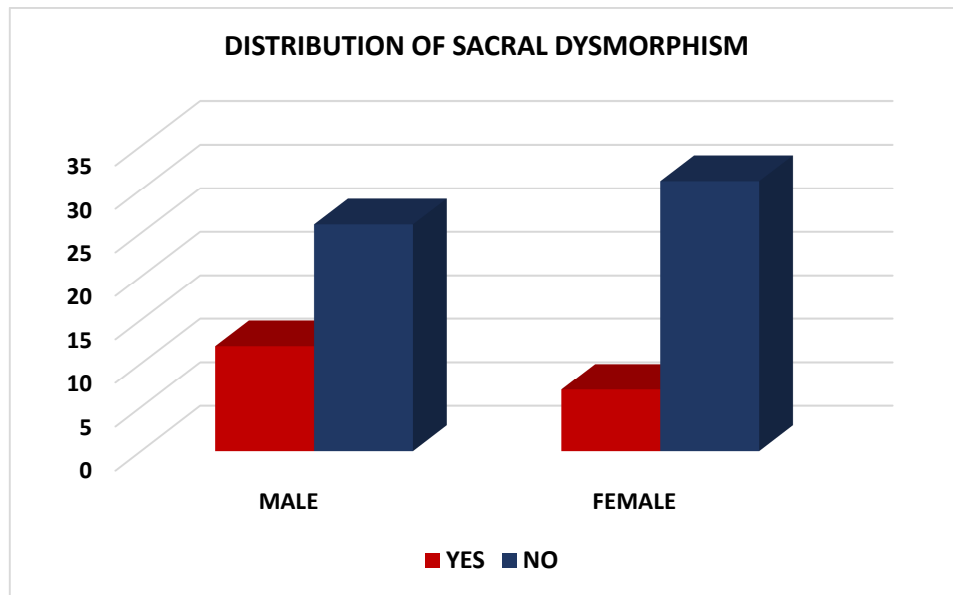


GRAPH 5.9

There is no significant mean ilio-sacral length between male and female with a p value of 0.6682

TABLE 5.10 SACRAL DYSMORPHISM

SACRAL DYSMORPHISM				
	MALE		FEMALE	
	NUMBER	PERCENTAGE	NUMBER	PERCENTAGE
YES	12	31.58	7	18.42
NO	26	68.42	31	81.58
TOTAL	38	100.00	38	100.00



GRAPH 5.10

Among study population, 12 out of 38 male patients (31.58 percent) and 7 out of 38 female patients (18.42 percent) were having sacral dysmorphism.

TABLE 5.11 SUMMARY OF VARIABLES MEASURED ON PELVIC 3D CT SCAN SECTIONS (AXIAL & SAGITTAL) IN THE PROSPECTIVE PATIENTS (N = 76), STRATIFIED BY GENDER

		Male (Mean ± SD)	Female (Mean ± SD)	P value
Trans-sacral length (mm)		131.97± 8.13	129.36± 7.22	0.14
Ilio-sacral length (mm)		66.94± 3.56	66.56± 4.11	0.66
Antero-posterior width in axial section (mm)	Center of promontory	23.66± 3.32	13.3-29.2	0.0001*
	Narrowest	13.32± 2.52	8.3-18.2	0.002*
	Lateral tsacral foramen	17.36 ± 3.89	10.1-22.9	0.01*
Average heighth of S1 corridor in sagittal section (mm)		12.01± 1.83	10.76± 1.13	0.0006*
Average width of S1 corridor in sagittal section (mm)		12.18± 1.06	11.39± 1.25	0.0045
Average height of S2 corridor in sagittal section (mm)		12.41± 1.64	11.34± 1.27	0.0022
Average width of S2 corridor in sagittal section (mm)		11.46± 1.39	10.40± 0.97	0.0002

**Significant*

**TABLE 5.12 SUMMARY OF APPLICABILITY OF SCREWS IN PATIENTS
(2 MM IS LEFT ON ALL THE 4 CORTICES)**

	Males, n (%)	Females, n (%)
S1		
7.3 mm	32 (84.21%)	18 (47.37%)
6.5 mm	4 (10.53%)	10 (26.32%)
Not applicable	2 (5.26%)	10 (26.32%)
S2		
7.3 mm	26 (68.42%)	12 (31.58%)
6.5 mm	4 (10.53%)	9 (23.68%)
Not applicable	8 (21.05%)	17 (44.74%)

A total of 76 3D CT images were studied, with 38 men and 38 women. Sacral dysmorphism was present in 12 (31.58%) male and 7 (18.42%) female patients.

Dimensions and application of screws in both genders are summarized in above mentioned tables (Table 1-12). Trans-sacral length and ilio-sacral length were comparable in either gender. Males had considerably larger height of S1 corridor in sagittal section and antero-posterior width in axial section ($P < 0.05$). While average width of S1 corridor as well as width and height of S2 corridor in sagittal sections were comparable in either gender ($P > 0.05$).

Comparatively, 10.53% male and 26.32% female pelvises were susceptible to 6.5 mm screw fixation, whereas 84.21% male and 47.37% female pelvises were receptive to S1 trans-sacral and S1 ilio-sacral screw fixation with 7.3 mm screw. 2 mm safe corridor was kept on all over sides, i.e. all 4 cortices of the sacral corridor. When the S2 segment was examined, 68.42% male and 31.58 % female pelvises were receptive with a 7.3 mm screw, whereas 10.53% male and 23.68% female pelvises were amenable with a 6.5 mm screw (Table 12).

DISCUSSION

- Iliosacral screw fixation is becoming more needed due to an increase in high-velocity traffic accidents to fix posterior pelvic ring injuries and expedite mobilization.⁽⁴⁾ Iliosacral screws are placed using a percutaneous procedure while being viewed under fluoroscopy, which reduces the risk of infection and solves problems with implant prominence.
- However, presence of dysmorphic sacrum poses a higher risk of mal-positioned implant.⁽⁶⁾ with an incidence of about 3-29%.⁽¹²⁾ In dysmorphic sacrum, although the corridor was adequate for ISS at S1 segment, it cause mal-alignment and results in neurovascular complication.⁽⁶⁾ Consequently, a 3D navigation system based on CT may result in a lower rate of improperly positioned screws.⁽⁹⁾
- Additionally, in order to perform these treatments properly, one must have a detailed awareness of the morphology of the sacral complex and the "safe corridor". As a result, in our study, we did a 3D CT scan of the pelvis to determine a safe space for the ilio-sacral and trans-sacral screw insertion in the South Indian pelvis. We also compared the screw size and its application in the pelvis of males and females. A representative trauma population was found to have a significant prevalence of sacral dysmorphism (25%) in the study. Analysis of CT sections' antero-posterior width in the axial section as well as the height and width of the S1 and S2 corridors in the sagittal section revealed a significant difference between the genders. Female patients' measurements were lower than those of their male counterparts, despite the difference being small; this shows that finding "safe" surgical corridors for potential SI-screw insertion in female patients is a challenging issue.⁽²¹⁾

- The prevalence of sacral dysmorphism in our study was comparable to other previous studies ranging from 6.6%-54 %.^(4,25) However, the trend was comparatively higher in male subjects. Dysmorphic sacrum was found in 31.58 % of males and 18.42% of females in our study. While female patients showed a higher prevalence of dysmorphic sacrum morphology (19.2%) than male patients (12.2%) in a research by Hasenboehler et al., the difference was statistically insignificant ($p = 0.069$).⁽²⁰⁾
- Gras et al., also demonstrated a higher prevalence of sacral dysmorphism in female patients against males (16% vs. 7%; $P < 0.003$).⁽¹³⁾
- In our study, males had significantly greater antero-posterior breadth of S1 and S2 constriction and vertical height than females. Only height and width at the level of the vestibule of S1 were found to be considerably greater in men in a Trikha et al. research.⁽⁴⁾ Males had greater S2 vestibule height and width, but this difference was statistically insignificant.⁽⁴⁾
- Hasenboehler et al observational cohort study on 344 skeletally mature trauma patients in the western population discovered substantial differences between males and females in all CT parameters.⁽¹⁴⁾ Overall, the study shows that compared to male patients, women have a 3-dimensional "safe" surgical corridor that is substantially smaller at S1 and S2.^(4,21)
- Another research done by Gras et al. showed female pelvises' corridor diameters were less than those of male pelvises for both S1 (11.7 mm vs. 13.5 mm; $P < 0.01$) and S2 (10.6 mm vs. 12.2 mm, $P < 0.0001$).⁽¹³⁾
- In our study, the majority of the male patients were receptive to S1 (84.21%) and S2 (68.42%) trans-sacral and ilio-sacral screw fixation with 7.3 mm screw when a safe corridor of 2 mm was maintained on all over sides. While Trikha et

al findings.'s suggested that both male and female pelvises may be fixed with 7.3 mm screws at a safe 2 mm on all sides in the S1 Trans-sacral and S1 Ilio-sacral regions. While only 25.7% of female and 42.9% of male pelvises could be fixed with a 7.3 mm trans-sacral screw using the S2 screw method.⁽⁴⁾

- According to a related study by Gras et al., female pelvises are more amenable to screw insertion than male ones because their corridor diameters are smaller.(females versus males for S1: 11.7 mm [95% CI, 10.6-12.8 mm] versus 13.5 mm [95% CI, 12.6-14.4 mm] versus 12.2 mm [95% CI, 11.8-12.6 mm], $p < 0.0001$.)⁽¹³⁾
- Most of the female pelvises in our study could not be fixed with 7.3 mm or 6.5 mm S1 and S2 trans-sacral and ilio-sacral screws. While in a Trikha et al study, more of male patients were not amenable to S2 trans-sacral screw fixation with 6.5 screw (25 case versus 11 cases, $p < 0.299$).⁽⁴⁾
- In another study Jackle et al., with 2 mm of safety distance, the trans-sacral screws of 8 mm diameter was safely placed at the S1 level in 70% of patients and 92% of patients at the S2 level.⁽²⁶⁾
- The results indicate study of sacral anatomy and morphology is extremely important to the orthopedic surgeon to avoid encountering unnecessary complications during surgery.
- Furthermore, CT scan need to be frequently scheduled for patients who were supposed to undergo percutaneous screw fixation for posterior pelvic ring injuries to eliminate superfluous neurovascular complications.
- In cases where 6.5 mm screw insertion is not feasible, trans-iliac plating, spino-pelvic fixation can be advised.⁽³⁰⁾

- There are some constraints in our research. Our sample size is small, to start with. To ascertain the substantial gender-associated differences in sacral dysmorphism prevalence, a large sample size is required. Few errors may have occurred despite all efforts to rule out human error in the various CT-based assessments. Finally, because the radiography measurements were made on relatively unharmed pelvises, the safe corridor drastically decreases in fractures that have been improperly reduced.
- Despite these drawbacks, the information provided by our data about the sacral anatomy of South Indian pelvises in both males and females was considerable. Furthermore, the study emphasizes that 2 mm safe corridor appears to be applicable of all screws in actual surgical operation.
- There is nil incidence of neurovascular injuries in present study as all cases were thoroughly evaluated, measurement of canal were done for both S1 & S2 sacral segment pre-operatively. In all cases screws were fixed under intra-operative fluoroscopy (C-arm guidance) so that screw advancement in the canal can be done taking proper trajectory without breaching the cortex.⁽³¹⁾
- Study was done together with canal diameter for both ilio-sacral type and trans-sacral type of screws for the applicability of different sizes of screws i.e 7.3mm and 6.5 mm. Patients with small size pelvis or sacral dysmorphism (i.e canal size < 7mm) , both 7.3mm & 6.5mm screws were not applicable. In sacral dysmorphism S1 ilio-sacral screw (6.5mm) and S2 trans-sacral screw (6.5mm /7.3 mm screw) were used.
- In patients in whom canal size is larger on CT scan measurement (canal size 8mm or more), preferred bigger size screw (7.3 mm), whereas in patients with canal size is between 8 – 7 mm , 6.5mm screw was preferred. For trans- sacral

screw placement it was preferred bigger size screw for better stability and less or nil chances of screw breakage. Whereas for ilio-sacral screw placement 6.5mm screw is preferred. In cases with pelvic dysmorphism, 6.5mm S1 ilio-sacral screw and 6.5/7.3mm S2 trans-sacral screw is preferred (Tile et al.). S1 segment as dysmorphic segment when it differ from normal S1 segment in the: Qualitative characteristics like Sacrum not recessed in the pelvis, Presence of mammillary processes, Acute alar slope , Residual disc between S1 & S2, Non circular sacral foramen and Quantitative characteristics like Narrow corridor and Increased angulation.

- The importance of this study is especially for trans-sacral screw, as the pure ilio-sacral screw has less chances of canal breach as it is smaller in size (preferred 6.5mm) and end point of the ilio-sacral screw is in the body of S1 or S2 directing antero-medially. However, in trans-sacral type the safety zone is much less as compare to ilio-sacral type screw where in there is chance of in-out-in type of cortex breach of sacral canal.

CONCLUSION

Pelvic ring injuries are incredibly complex and difficult for an orthopaedic trauma surgeon to treat. Due to its intricate fracture patterns, anatomical variances, and nearby important structures, pelvic fracture treatment is difficult. Examples of posterior pelvic ring injuries include sacral fractures, disruption of the sacroiliac joint, and combos of the two. Anatomical reduction with proper fixation is crucial with these injuries since the posterior pelvic ring contributes 60–70% of the pelvis' stability.

As a result, pelvic ring injuries should be individualized to each patient's clinical presentation, taking into account implant possibilities as well as surgical approach and placement options. Sacroiliac (SI) screw fixation is a less intrusive method for treating unstable posterior pelvic ring injuries because of its improved understanding of radiological sacral anatomy and the availability of intra-operative fluoroscopy. Regardless of soft tissue damage, SI screws are adaptable and can be placed in the prone, supine, or lateral positions. However, because there are few bone corridors in the sacrum that may accommodate screws, the threads of the screws could penetrate the cortex and harm the nearby tissues.

Our data suggest that sacral dysmorphism is quite prevalent (25%) in a prospective, representative trauma group, and that there is a higher chance of trans-sacral and ilio-sacral screw misplacement at the S1 and S2 sacral segment, whether with 7.3 mm or 6.5 mm screws. There was a "high level of suspicion" that female patients might have had trans-sacral and ilio-sacral percutaneous screw misplacement since the S1 and S2 corridors in all planes were significantly narrower in female

patients than in male patients. Overall, the findings show that, when treating any sacrum fracture case, preoperative preparation is crucial. Additionally, routine pelvic CT scans in all three dimensions (3D) enable establishing the ideal entrance point and screw orientation by determining the correct size of the "vestibule."

SUMMARY

- This is a hospital based one year cross- sectional study done which is done on 76 patients (38 male ; 38 female).
- The purpose of this study is to evaluate the safety of screw implantation in the S1 and S2 sacral segments utilizing computer tomography (CT)-based 3D assessment.
- These CT scans were done on polytrauma patients as a screening procedure or to assess pelvic fractures in patients undergoing 3D CT scans of the pelvis with both hips or the pelvis with the abdomen for orthopaedic purposes (polytrauma trauma, pelvis with bilateral hip, whole spine, etc.) or non-orthopedic purposes (like patients undergoing CT abdomen with pelvis advised by any other department who otherwise having no pelvic complaints, that is having normal pelvis). Patients with a dysmorphic sacrum were included in the study. Exclusion criteria included being under the age of 18, having a CT scan that showed a substantial disruption of the posterior pelvic ring, and not being able to take correct CT measurements.
- Based on statistical analysis consolidated data, sacral dysmorphism (sacralization of L5 vertebra) was present in 12 (31.58%) male and 7 (18.42%) female patients.
- In the representative trauma population, 25% of people had sacral dysmorphism
- The vertical height and antero-posterior width of the S1 and S2 sacral segments were substantially greater in males. While 10.53% of male and 26.32% of female pelvis were susceptible to 6.5 mm screw fixation when a safe corridor of 2 mm was kept on all over sides, 84.21% of male and 47.37% of female pelvis

were amenable to S1 trans-sacral and S1 ilio-sacral screw fixation with 7.3 mm screw. In the S2 segment, a 7.3 mm screw could be placed in the pelvis of 68.42% of men and 31.58% of women, whereas a 6.5 mm screw could be placed in the pelvis of 10.53% of men and 23.68% of women.

- Based on our study we can easily conclude that preoperative planning, and a personalized approach is imperative while handling any sacrum fracture case. Furthermore, regular 3 dimensional (3-D) pelvic CT scans allow estimation of the proper size of the "vestibule" to establish the appropriate entrance site and screw alignment.

BIBLIOGRAPHY

1. Tornetta P, Ricci W, Ostrum R, McQueen M, Agarwal A. Rockwood and Green's fracture in adults. 9th edition. Chapter 49. Pelvic Ring injuries. Philadelphia : Wolters Kluwer;2020
2. Woolf AD, Åkesson K. Chapter 7 - The Patient with Osteoporosis. In: Lane NE, Sambrook PN, editors. Osteoporosis and the Osteoporosis of Rheumatic Diseases. Philadelphia: Mosby; 2006. p. 55-65.
3. Taller S, Lukás R, Srám J, Krivohlávek M. [Urgent management of the complex pelvic fractures]. *Rozhledy v chirurgii : mesicnik Ceskoslovenske chirurgicke spolecnosti*. 2005;84(2):83-7.
4. Trikha V, Gaba S, Kumar A, Mittal S, Kumar A. Safe corridor for iliosacral and trans-sacral screw placement in Indian population: A preliminary CT based anatomical study. *Journal of clinical orthopaedics and trauma*. 2019;10(2):427-31.
5. Petryla G, Uvarovas V, Bobina R, Kurtinaitis J, Purnaitė R, Kvederas G, et al. Comparison of One-Year Functional Outcomes and Quality of Life between Posterior Pelvic Ring Fixation and Combined Anterior-Posterior Pelvic Ring Fixation after Lateral Compression (B2 Type) Pelvic Fracture. *Medicina (Kaunas, Lithuania)*. 2021;57(3).
6. Iorio JA, Jakoi AM, Rehman S. Percutaneous Sacroiliac Screw Fixation of the Posterior Pelvic Ring. *The Orthopedic clinics of North America*. 2015;46(4):511-21.
7. Routt ML, Jr., Simonian PT, Mills WJ. Iliosacral screw fixation: early complications of the percutaneous technique. *Journal of orthopaedic trauma*. 1997;11(8):584-9.
8. Patrick E, Ghislaine E, Fernand DP. Fractures of the Pelvic Girdle: CT-guided Percutaneous Fixation. *Interventional Radiology in Pain Treatment*. p. 171-8.
9. Ghisla S, Napoli F, Lehoczky G, Delcogliano M, Habib N, Arigoni M, et al. Posterior pelvic ring fractures: Intraoperative 3D-CT guided navigation for accurate positioning of sacro-iliac screws. *Orthopaedics & Traumatology: Surgery & Research*. 2018;104(7):1063-7.

10. Xu R, Ebraheim NA, Robke J, Yeasting RA. Radiologic evaluation of iliosacral screw placement. *Spine*. 1996;21(5):582-8.
11. Rose P, Goldberg BA, Lindsey RW, Foglar C, Hedrick TD, Mielau T, et al. Computed tomography assessment of sacroiliac screw placement relative to the first sacral neuroforamen. *J Spinal Disord*. 2001;14(4):330-5.
12. Zwingmann J, Konrad G, Kotter E, Südkamp NP, Oberst M. Computer-navigated iliosacral screw insertion reduces malposition rate and radiation exposure. *Clinical orthopaedics and related research*. 2009;467(7):1833-8.
13. Gras F, Gottschling H, Schröder M, Marintschev I, Hofmann GO, Burgkart R. Transsacral osseous corridor anatomy is more amenable to screw insertion in males: a biomorphometric analysis of 280 pelvises. *Clin Orthop Relat Res*. 2016 Oct 1;474(10):2304–2311.
14. Daniel W, Lukas K, Takeshi S, R.Geoff R, Hansrudi N, Masafumi U, Christian O, Pol M.Rommens. Critical dimensions of trans-sacral corridors assessed by 3D CT model: Relevance for implant positioning in fractures of the sacrum. *J of orthopaedic research; Wiley online library(wileyonlinelibrary.com)*, 13 March 2017; DOI 10.1002/jor.23554
15. Mendel.T, Noser.H, Kuervers.J, Goehre.F, Hofmann.G, Radetzki.F. The influence of sacral morphology on the existence of secure S1 and S2 transverse bone corridors for iliosacroiliac screw fixation. *Injury.Int.J.Care Injured* 44 ;2013;1773-1779.
16. Scott.K, Gardner.M, JosephLiu, ChipRouttJrMLJr, MorshedS. Anatomic determinants of sacral dysmorphism and implications for safe iliosacral screw placement. *J Bone Joint Surg*. 2014;96(14):e120.
17. Goetzen.M, Ortner,K, Lindtner.R, Schmid.R, Blauth.M, Krappinger.D. A simple approach for the preoperative assessment of sacral morphology for percutaneous S1 screw fixation. *Arch Orthop Trauma Surg*; 2016; 136:1251-1257; DOI 10.1007/s00402-016-2528-3.
18. Tile M, Helfet DL, Kellam JF, Vrahas M. *Fractures of the pelvis and acetabulum*. Baltimore: Williams & Wilkins; 1995 Jan.
19. Protas M, Davis M, Bernard S, Alonso F, Moisi M, Oskouian RJ, et al. Sacroiliac screw fixation: a systematic review of complications and their causes. *The Spine Scholar*. 2017:2110.

20. Chen JP, Tsai PJ, Su CY, Tseng IC, Chou YC, Chen IJ, et al. Percutaneous iliosacral screw and trans-iliac trans-sacral screw with single C-arm fluoroscope intensifier is a safe treatment for pelvic ring injuries. *Scientific reports*. 2022;12(1):368.
21. Hasenboehler EA, Stahel PF, Williams A, Smith WR, Newman JT, Symonds DL, et al. Prevalence of sacral dysmorphism in a prospective trauma population: Implications for a "safe" surgical corridor for sacro-iliac screw placement. *Patient safety in surgery*. 2011;5(1):8.
22. Miller AN, Routt ML, Jr. Variations in sacral morphology and implications for iliosacral screw fixation. *The Journal of the American Academy of Orthopaedic Surgeons*. 2012;20(1):8-16.
23. Kaiser SP, Gardner MJ, Liu J, Routt ML, Jr., Morshed S. Anatomic Determinants of Sacral Dysmorphism and Implications for Safe Iliosacral Screw Placement. *The Journal of bone and joint surgery American volume*. 2014;96(14):e120.
24. Kim JJ, Jung CY, Eastman JG, Oh HK. Measurement of Optimal Insertion Angle for Iliosacral Screw Fixation Using Three-Dimensional Computed Tomography Scans. *Clinics in orthopedic surgery*. 2016;8(2):133-9.
25. Conflitti JM, Graves ML, Chip Routt ML, Jr. Radiographic quantification and analysis of dysmorphic upper sacral osseous anatomy and associated iliosacral screw insertions. *Journal of orthopaedic trauma*. 2010;24(10):630-6.
26. Jäckle K, Paulisch M, Blüchel T, Meier MP, Seitz MT, Acharya MR, et al. Analysis of trans-sacral corridors in stabilization of fractures of the pelvic ring. *Journal of orthopaedic research : official publication of the Orthopaedic Research Society*. 2022;40(5):1194-202.
27. Sciulli R.L., Daffner R.H., Altman D.T. CT-guided iliosacral screw placement: technique and clinical experience. *Am J Roentgenol*. 2007;188:W181–W192.
28. Takao M., Nishii T., Sakai T. Iliosacral screw insertion using CT-3D-fluoroscopy matching navigation. *Injury*. 2014;45:988–994.
29. Peng K.-T., Li Y.-Y., Hsu W.-H. Intraoperative computed tomography with integrated navigation in percutaneous iliosacral screwing. *Injury*. 2013;44:203–208.

30. Reilly M.C., Bono C.M., Litkouhi B., Sirkin M., Behrens F.F. The effect of sacral fracture malreduction on the safe placement of iliosacral screws. *J Orthop Trauma*. 2006;20(Suppl. 1):S37–S43.
31. Wolinsky P., Lee M. The effect of C-arm malrotation on iliosacral screw placement. *J Orthop Trauma*. 2007;21:427–434.
32. Sagi H.C., Lindvall E.M. Inadvertent intraforaminal iliosacral screw placement despite apparent appropriate positioning on intraoperative fluoroscopy.
33. Giannoudis P.V., Pape H.C. Damage control orthopaedics in unstable pelvic ring injuries. *Injury*. 2004;35:671–677

ANNEXURE - I

CONSENT FORM

TITLE OF THE STUDY

“ DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION- A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHROPOMETRIC STUDY ”

_____, _____, _____
INTRODUCTION

Sacral screw fixation is becoming a widely used minimally invasive technique in the treatment of unstable posterior pelvic ring injuries and sacral fractures. However, the misalignment of SI-screws under fluoroscopic guided-percutaneous approach results in high chances of neurovascular damage.

PURPOSE OF STUDY

The study aims in computer tomography (CT)-based 3D identification of safe screw placement and determine the feasibility of screw placement in both the S1 and S2 sacral segments.

METHODOLOGY

The prospective cross-sectional study analyzed pelvic 3D CT scans from patients. Sagittal sections were used to evaluate vertical height at the level of constriction of S1 and S2, whereas axial sections were used to quantify antero-posterior constriction width. In axial and sagittal sections, we established that bone boundaries were not breached. We checked the application of the 6.5 mm screw whenever there was a violation in the bone limit.

VOLUNTARY PARTICIPATION / WITHDRAWAL

Taking part in this study is voluntary. I may choose not to take part in this study, or if I decide to take part I can later change my mind and withdraw from the study. My decision will not change the present or future health care or other services that I receive. The investigator or the sponsor may stop my participation in this study. I will tell any important new findings that may change my willingness to continue to take part. If I choose not to take part in the study, I will receive the standard treatment for patients with my condition.

COMPENSATION

As the subject voluntarily consents to be a part of the study, no compensation will be given.

CONFIDENTIALITY

All information collected about the subject during the course of the study will be kept confidential to the extent permitted by the law. The code numbers will identify the subject in this research record. Information from this study may be presented but the subjects identification will be kept confidential in any publication.

If any enquiries in the future or in case of study related injury or illness, you may contact following person: **Dr. Harsha Hedge** Chairperson, Ethical Committee for Human Subject Research, Professor, Department of Pediatrics, Jawaharlal Nehru Medical College, Belagavi- 590010

CONSENT TO PARTICIPATE IN RESEARCH STUDY

“ I voluntarily agree to take part in this study by signing below. I may withdraw at any time. I am not giving up any of my legal rights by signing this form. My signature below indicated that I have read this entire consent form or it has been read to me, and had all my questions answered. I will be given a copy of this consent form.”

Signature of the Participant or legally authorized representative

Participant’s Name:

Signature:

Name of legally authorized representative:

Signature:

Witness’s Name:

Signature:

Investigators Name and Signature:

Date and Place:

ANNEXURE - II

PROFORMA

DEPARTMENT OF ORTHOPAEDICS

JAWAHARLAL NEHRU MEDICAL COLLEGE, BELAGAVI

TITLE OF THE STUDY

“ DEFINING SAFE CORRIDORS FOR ILIO-SACRAL AND TRANS-SACRAL SCREW PLACEMENT IN INDIAN POPULATION- A CROSS SECTIONAL PRELIMINARY COMPUTERIZED TOMOGRAPHY SCAN BASED ANTHOPOMETRIC STUDY ”

PATIENT NUMBER	
CT SCAN NUMBER	
NAME	
AGE	
SEX	
NATIONALITY	
ADDRESS	
CONTACT NUMBER	

MEASUREMENTS

AXIAL SECTION	TRANS-SACRAL LENGTH			
	ILIO-SACRAL LENGTH			
	ANTERIO-POSTERIOR WIDTH	CENTRE OF PROMONTORY		
		NARROWEST		
		LATERAL TO SACRAL FORAMEN		
SAGITTAL SECTION	S1 CORRIDOR HEIGHT	HEIGHT 1		
		HEIGHT 2		
		HEIGHT 3		
	S1 CORRIDOR AVERAGE HEIGHT			
	S1 CORRIDOR WIDTH	WIDTH 1		
		WIDTH 2		
		WIDTH 3		
	S1 CORRIDOR AVERAGE WIDTH			
	S2 CORRIDOR HEIGHT	HEIGHT 1		
		HEIGHT 2		
		HEIGHT 3		
	S2 CORRIDOR AVERAGE HEIGHT			
	S2 CORRIDOR WIDTH	WIDTH 1		
WIDTH 2				
WIDTH 3				
S2 CORRIDOR AVERAGE WIDTH				

*All Measurements Are In Millimeters

➤ **SACRAL DYSMORPHISM**

YES

NO

➤ **PURPOSE OF CT SCAN**

TRAUMATIC

NON- TRAUMATIC

➤ **IF TRUMATIC PURPOSE OF CT SCAN**

CHIEF COMPLAINTS :

HISTORY OF PRESENT ILLNESS :

NATURE OF INJURY

1. ROAD TRAFFIC ACCIDENT :
2. TRIVAL FALL :
3. ASSAULT :

DURATION SINCE INJURY :

PAST HISTORY

1. DIABETES MELLITUS :
2. HYPERTENSION :
3. CARDIAC DISEASE :

PREVIOUS HISTORY OF PELVIC SURGERY : YES NO
(if yes, then type and duration since surgery : _____)

GENERAL PHYSICAL EXAMINATION

BUILT : WELL MODERATE POOR

VITALS :

LOCAL EXAMINATION

1. INSPECTION :

- ATTITUDE OF LIMB :
- SKIN CONDITION : BLEBS / ECCHYMOSIS / AVULSED / BRUISE
- SWELLING :

2. PALPATION :

- TENDERNESS :
- CREPITUS :
- DISTAL NEURO-VASCULAR STATUS :

3. X-RAYS PELVIS WITH BOTH HIP AP VIEW :

DIAGNOSIS :

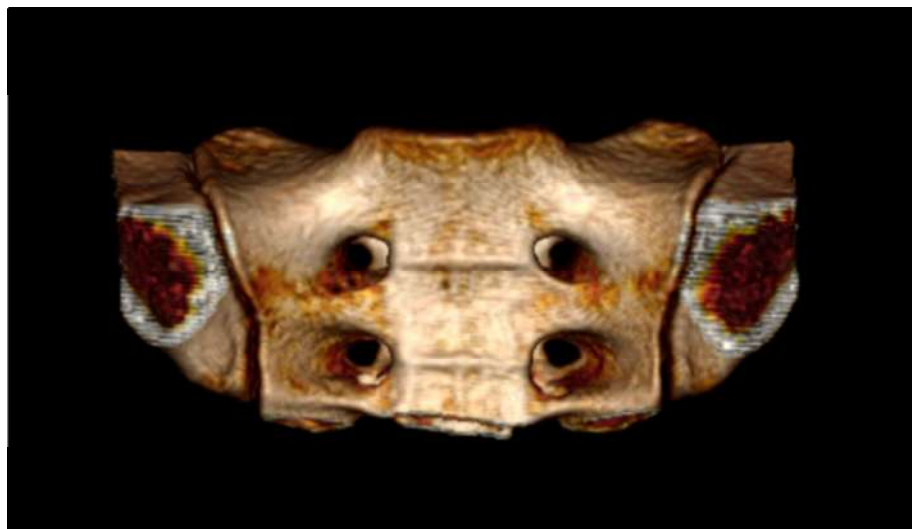
TREATMENT :

ANNEXURE – III

PHOTOGRAPHS

MALE CASES

1. CASE NO.5

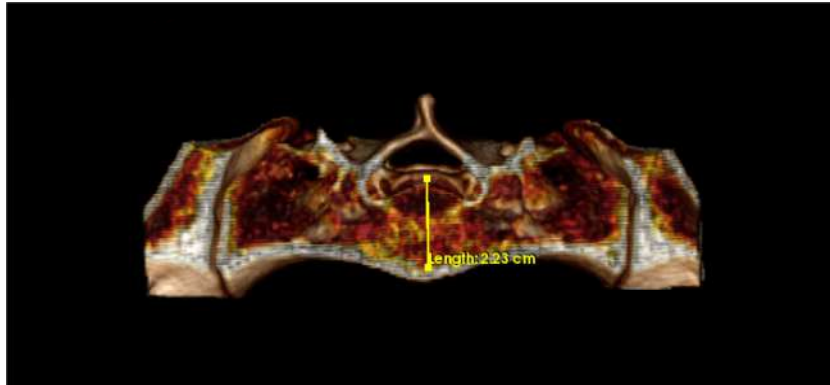


A.

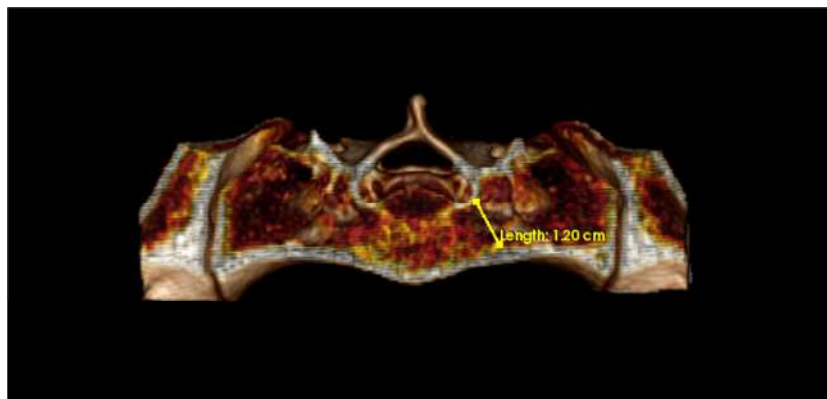


B.

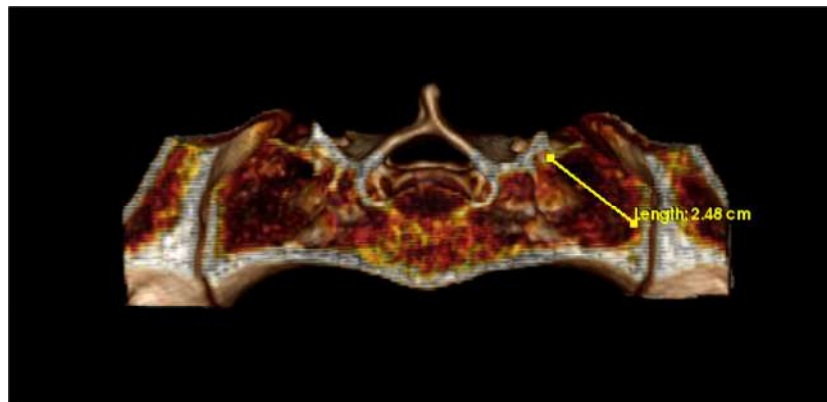
FIGURE 1.1 (A,B) SHOWING S1 AND S2 SACRAL SEGMENTS



A.



B.



C.

FIGURE 1.2 A) MEASUREMENTS FROM CENTER OF PROMONTORY, B) NARROWEST MEASUREMENT (CONSTRICION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), C) MEASUREMENT LATERAL TO SACRAL FORAMEN

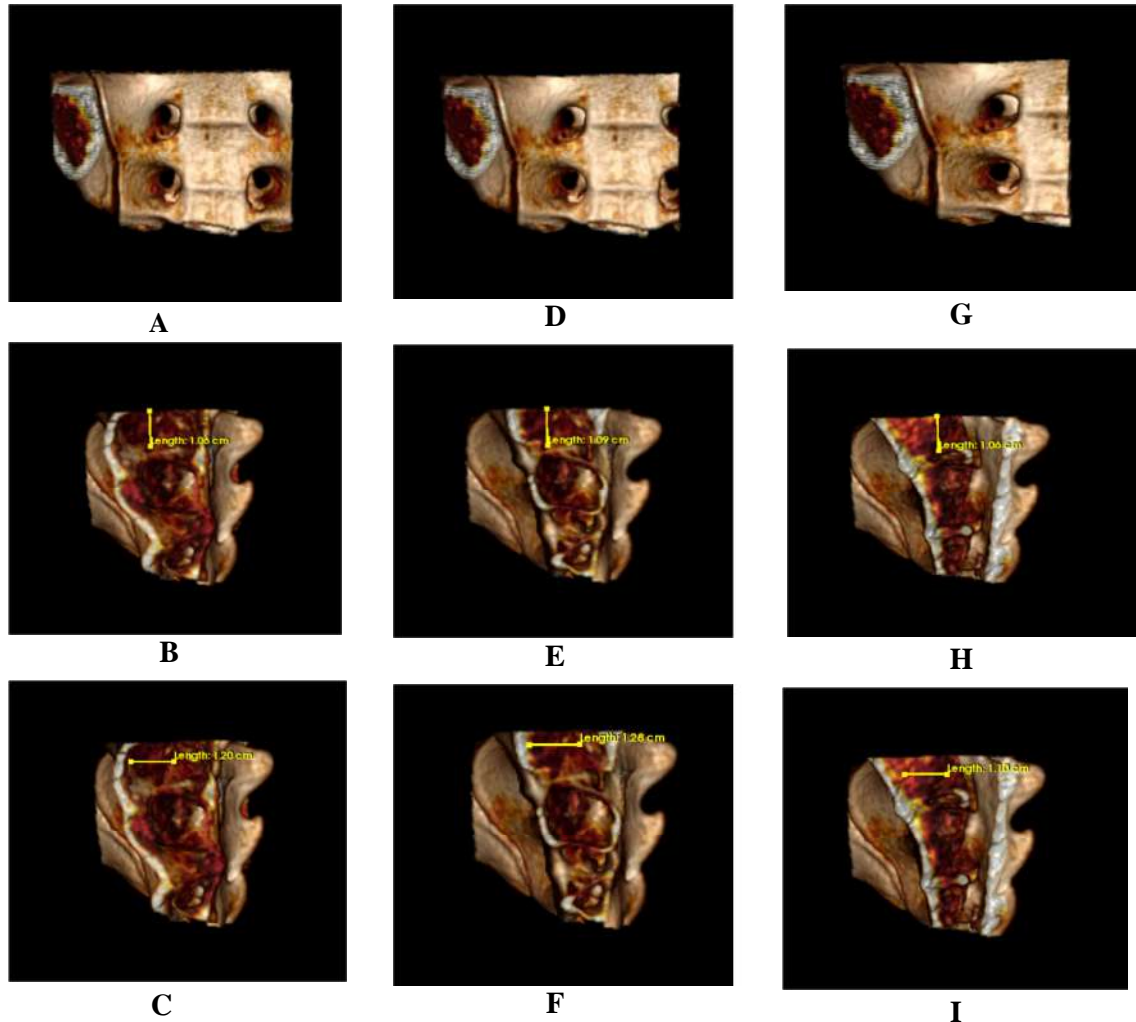


FIGURE 1.3 A) SAGITTAL CUT AT THE LEVEL OF SACRO-ILIAC JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S1 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S1 (WIDTH 1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMENS, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S1(HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S1 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S1(HEIGHT), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S1 (WIDTH 3)

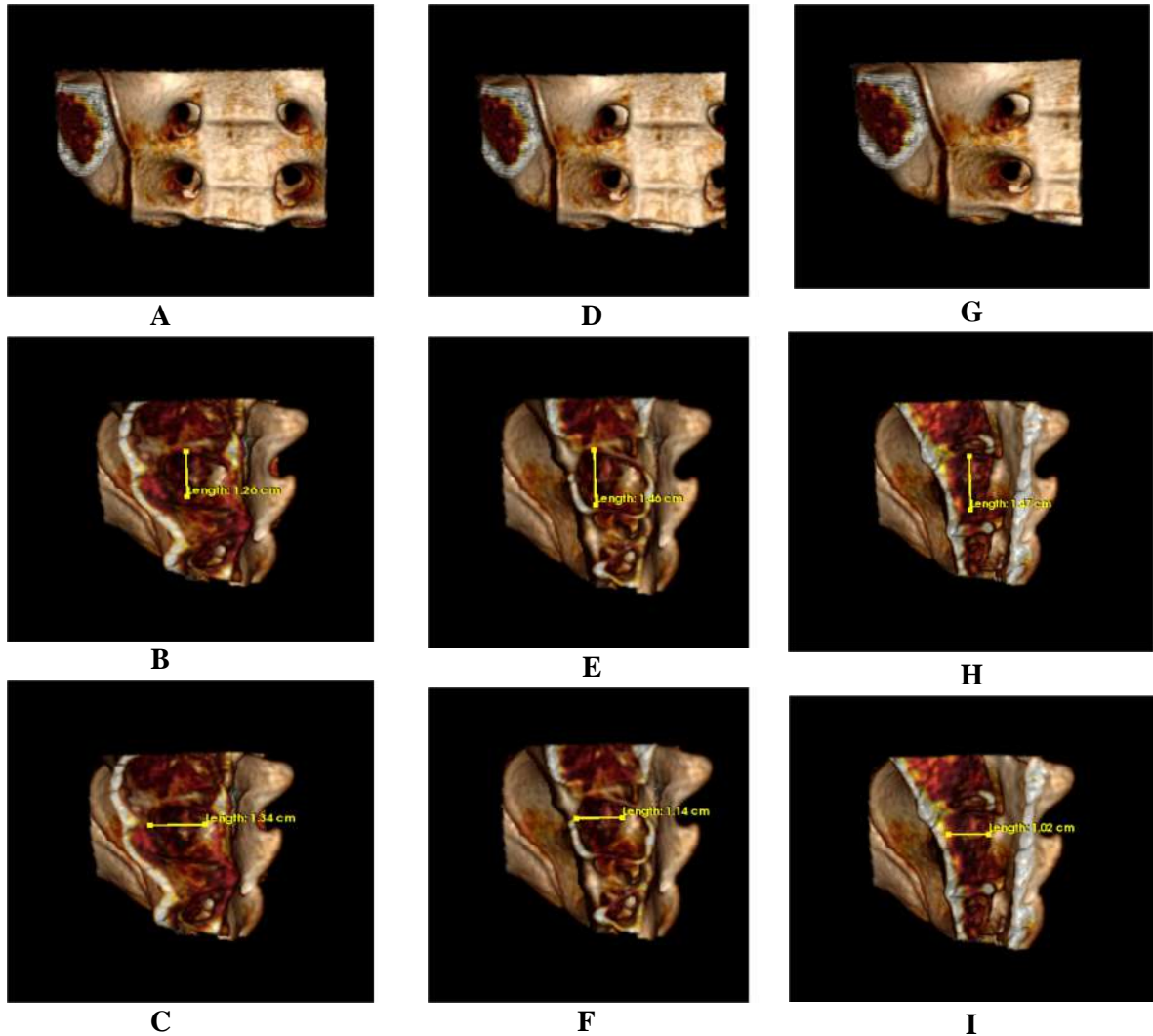
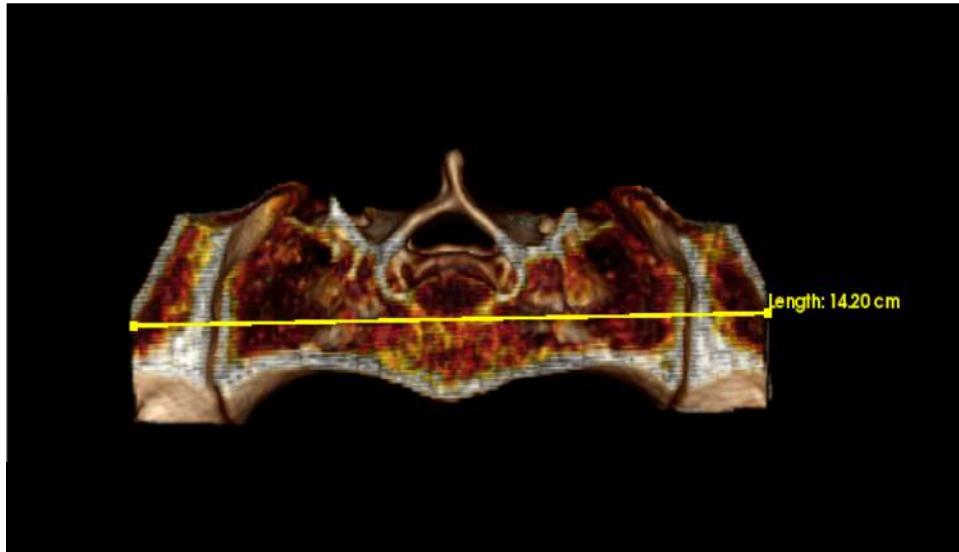
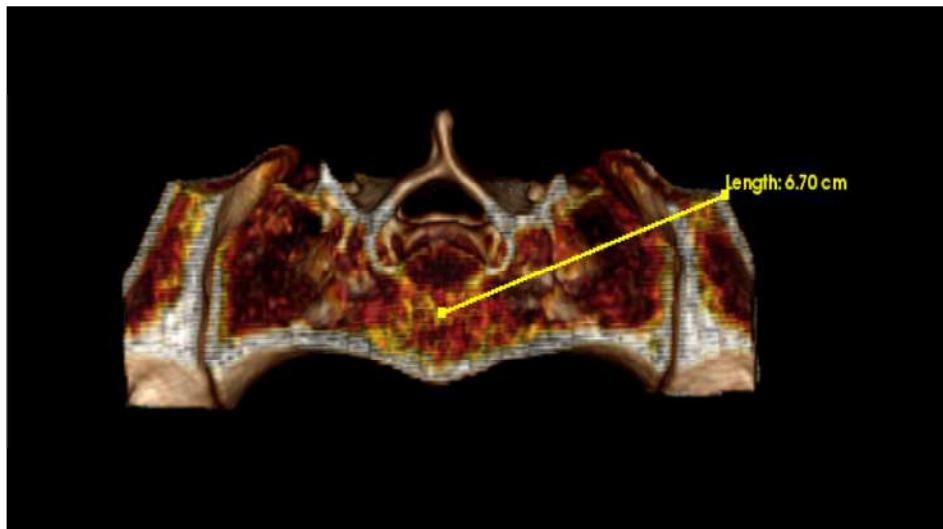


FIGURE 1.4 A) SAGITTAL CUT AT THE LEVEL OF SI JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S2 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S2 (WIDTH1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S2 (HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S2 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S2(HEIGHT 3), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S2 (WIDTH 3)



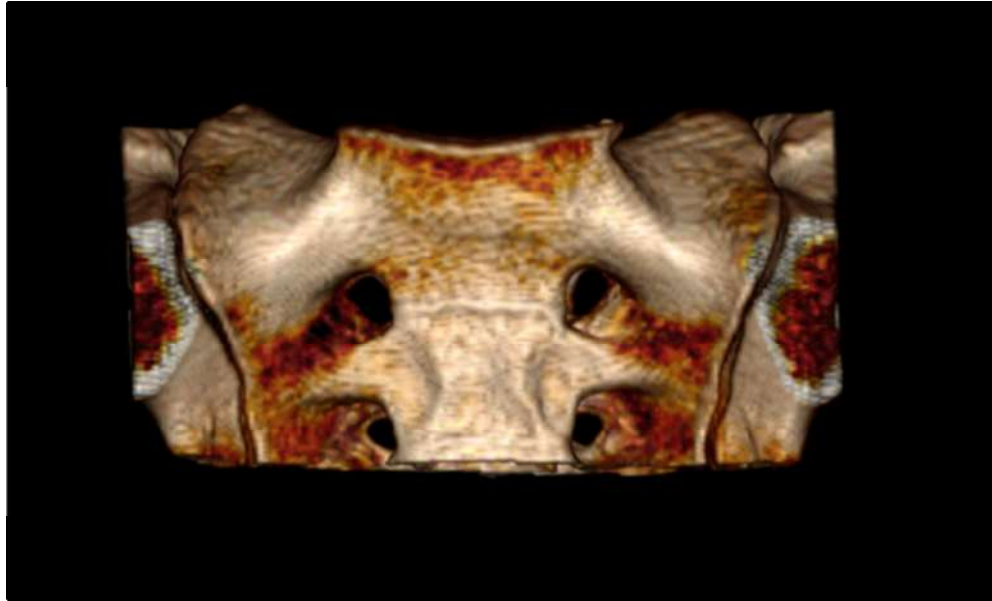
A



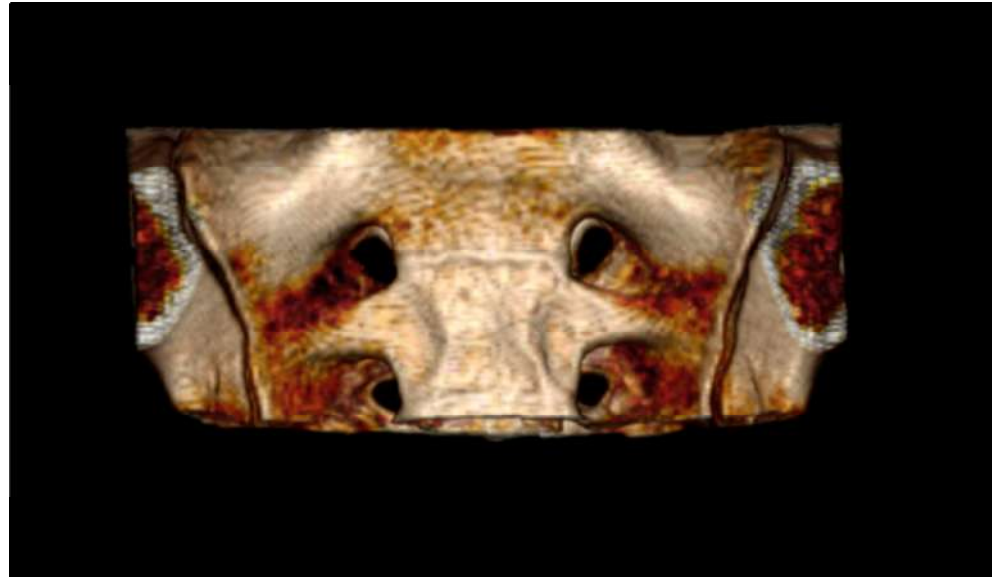
B

FIGURE 1.5 A. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR TRANS-SACRAL SCREW, B. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW

2. CASE NO.16

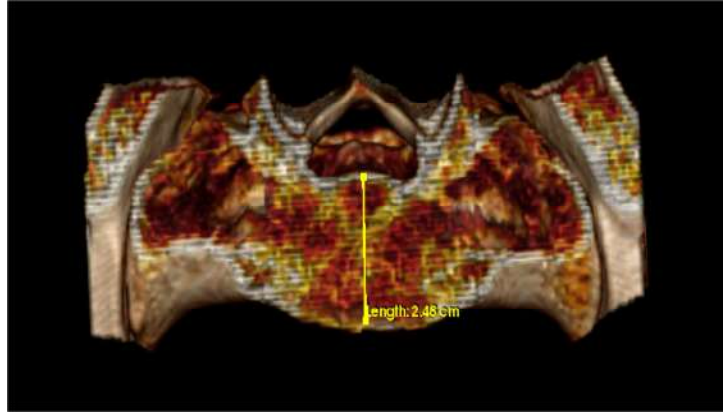


A

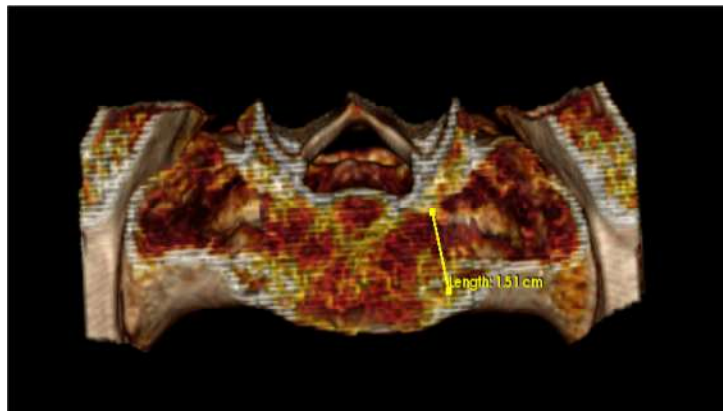


B

FIGURE 2.1 (A,B) SHOWING S1 AND S2 SACRAL SEGMENTS



A



B



C

FIGURE 2.2 A) MEASUREMENTS FROM CENTER OF PROMONTORY, B) NARROWEST MEASUREMENT (CONSTRUCTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), C) MEASUREMENT LATERAL TO SACRAL FORAMEN

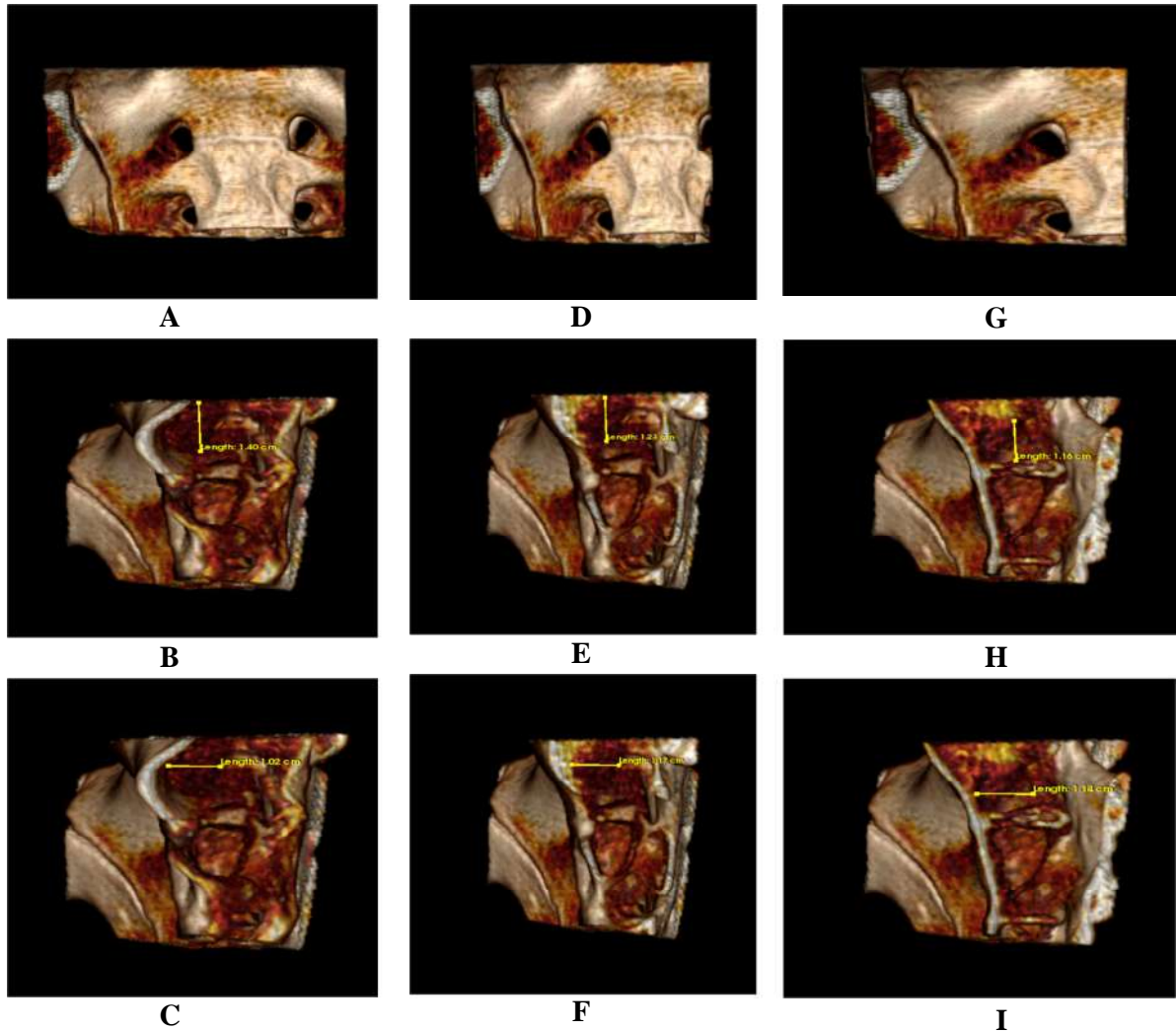


FIGURE 2.3 A) SAGITTAL CUT AT THE LEVEL OF SACRO-ILIAC JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S1 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S1 (WIDTH 1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMENS, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S1(HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S1 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S1(HEIGHT), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S1 (WIDTH 3)

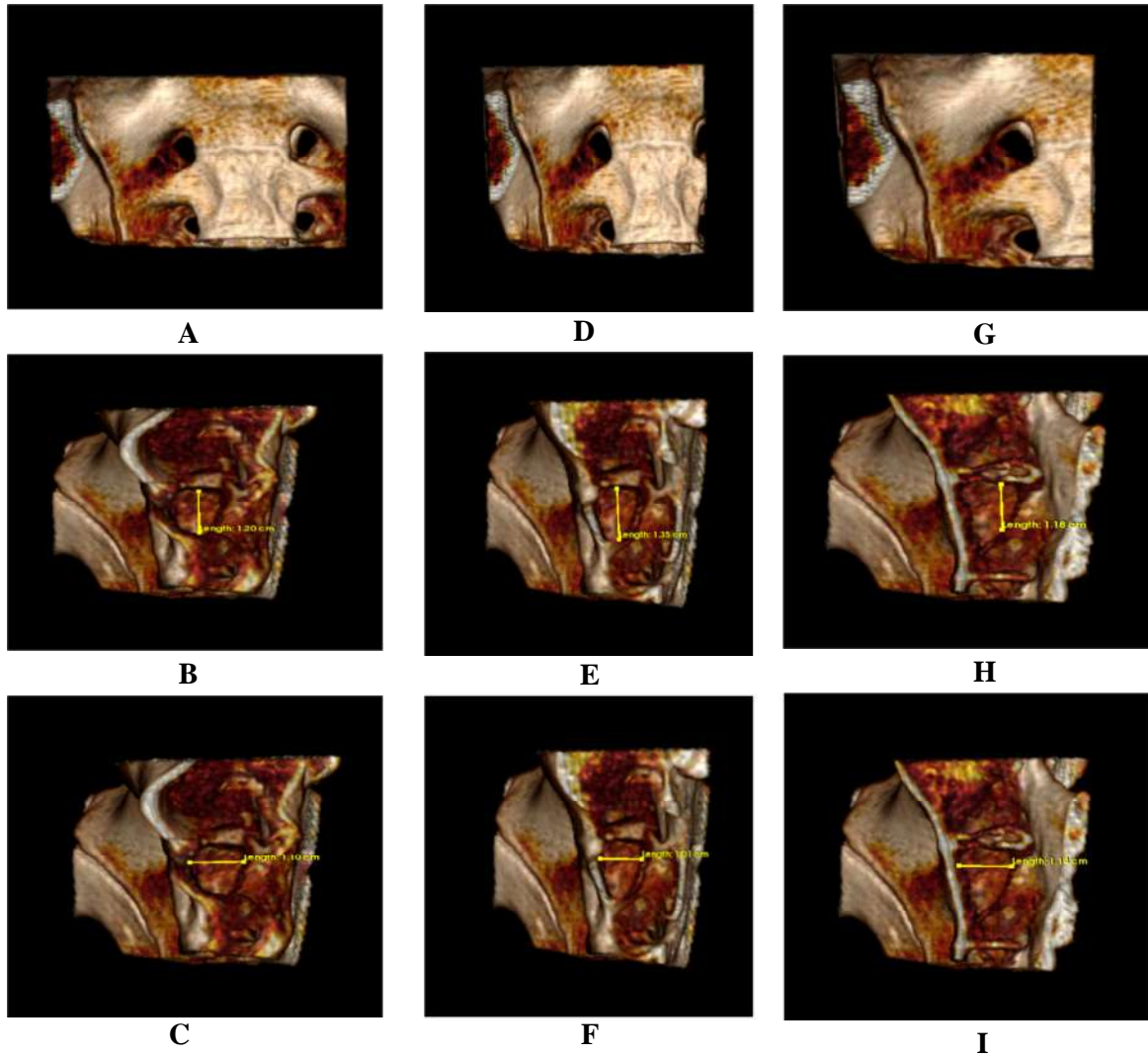
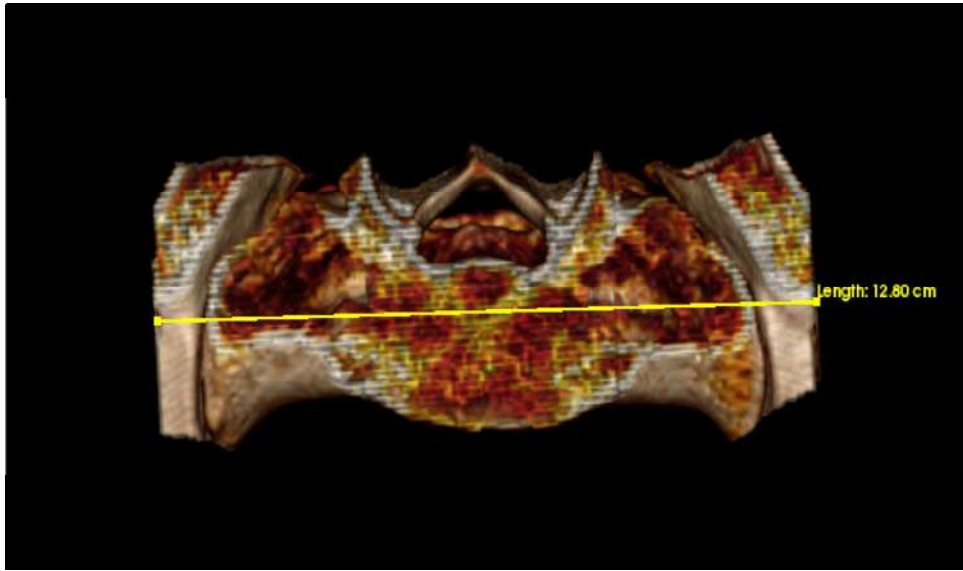
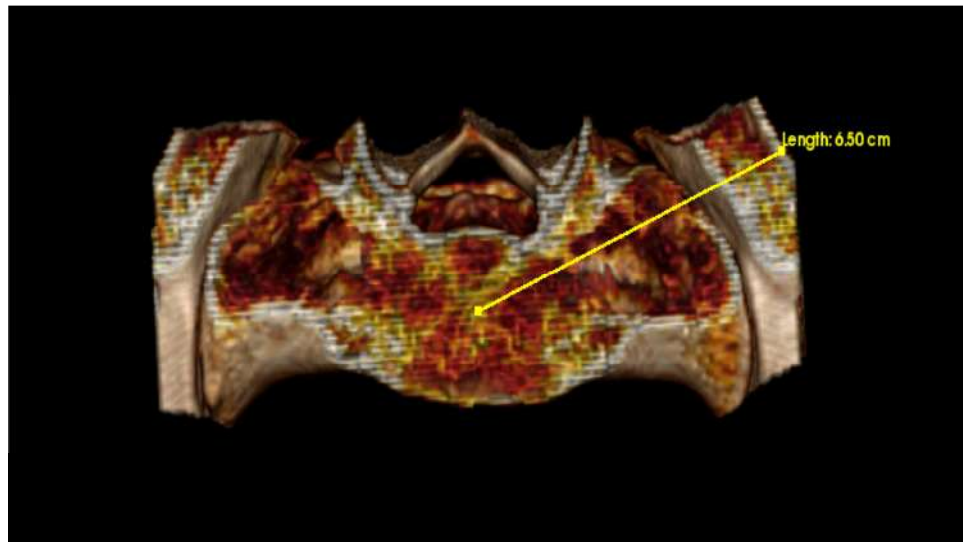


FIGURE 2.4 A) SAGITTAL CUT AT THE LEVEL OF SI JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S2 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S2 (WIDTH1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S2 (HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S2 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S2(HEIGHT 3), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S2 (WIDTH 3)



A



B

FIGURE 2.5 A. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR TRANS-SACRAL SCREW,

B. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW

FEMALE CASES

1. CASE NO. 2

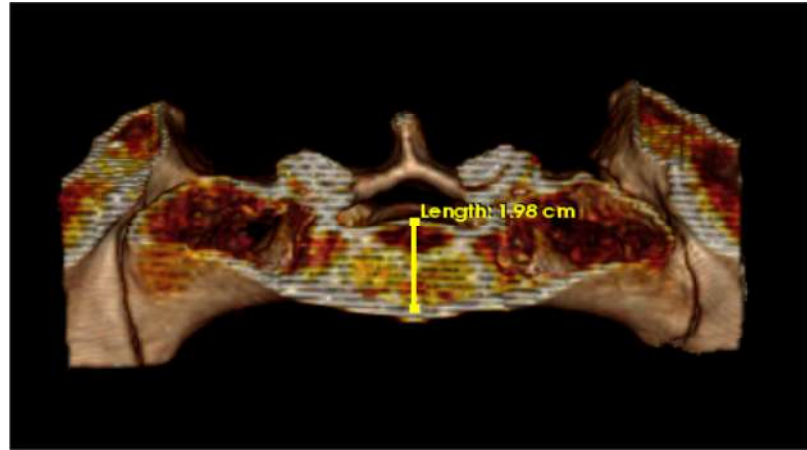


A



B

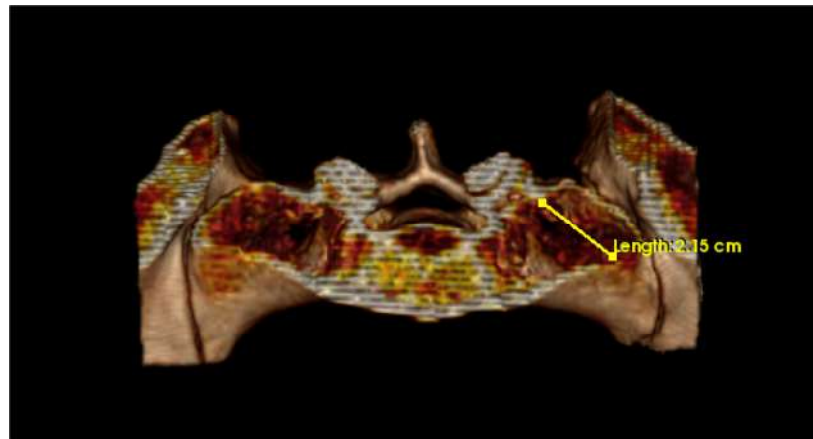
FIGURE 1.1 (a,b) SHOWING S1 AND S2 SACRAL SEGMENTS



a



b



c

FIGURE 1.2. a) MEASUREMENTS FROM CENTER OF PROMONTORY, b) NARROWEST MEASUREMENT (CONSTRICTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), c) MEASUREMENT LATERAL TO SACRAL FORAMEN

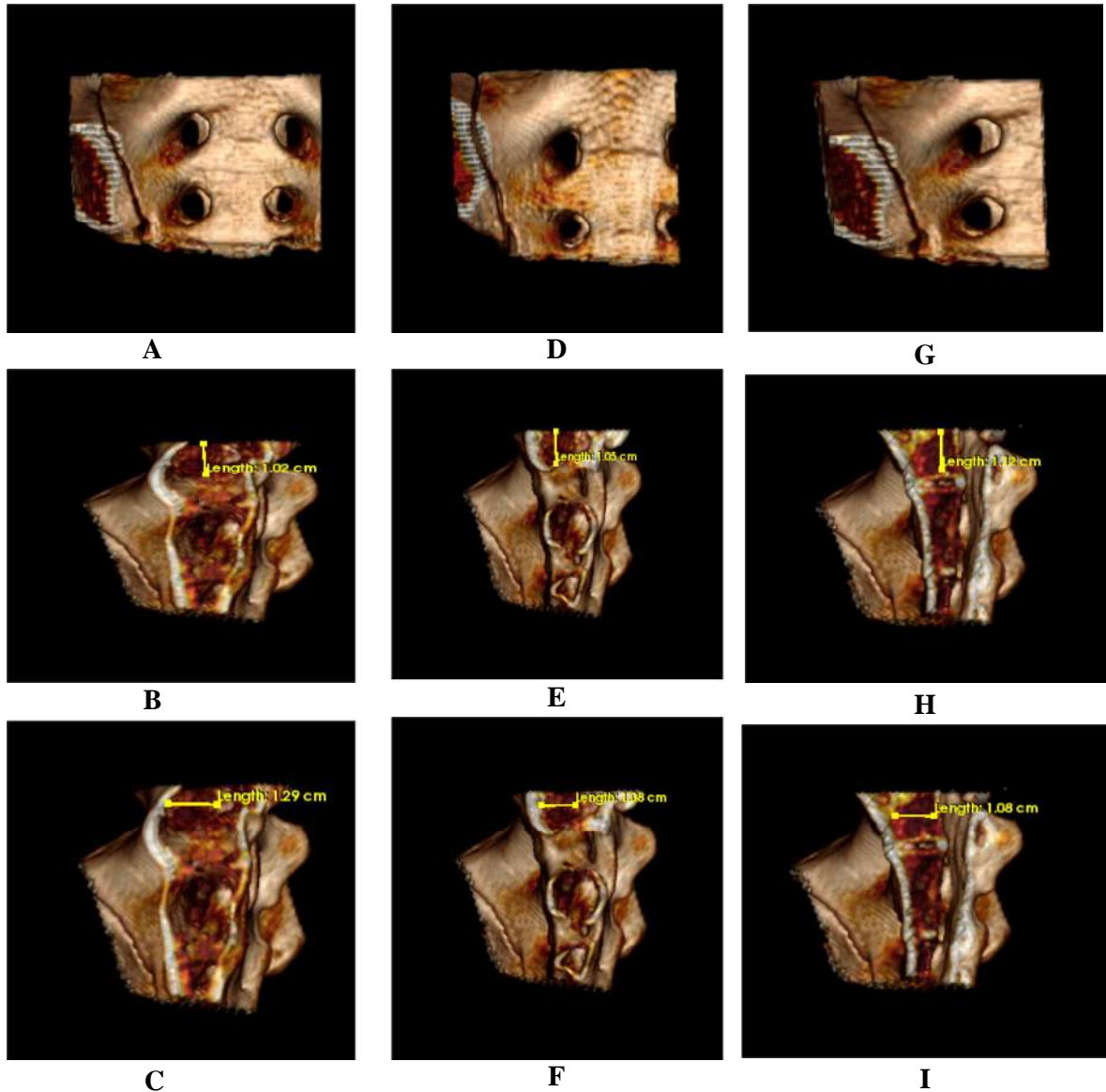


FIGURE 1.3 A) SAGITTAL CUT AT THE LEVEL OF SACRO-ILIAC JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S1 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S1 (WIDTH 1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMENS, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S1(HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S1 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S1(HEIGHT), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S1 (WIDTH 3)

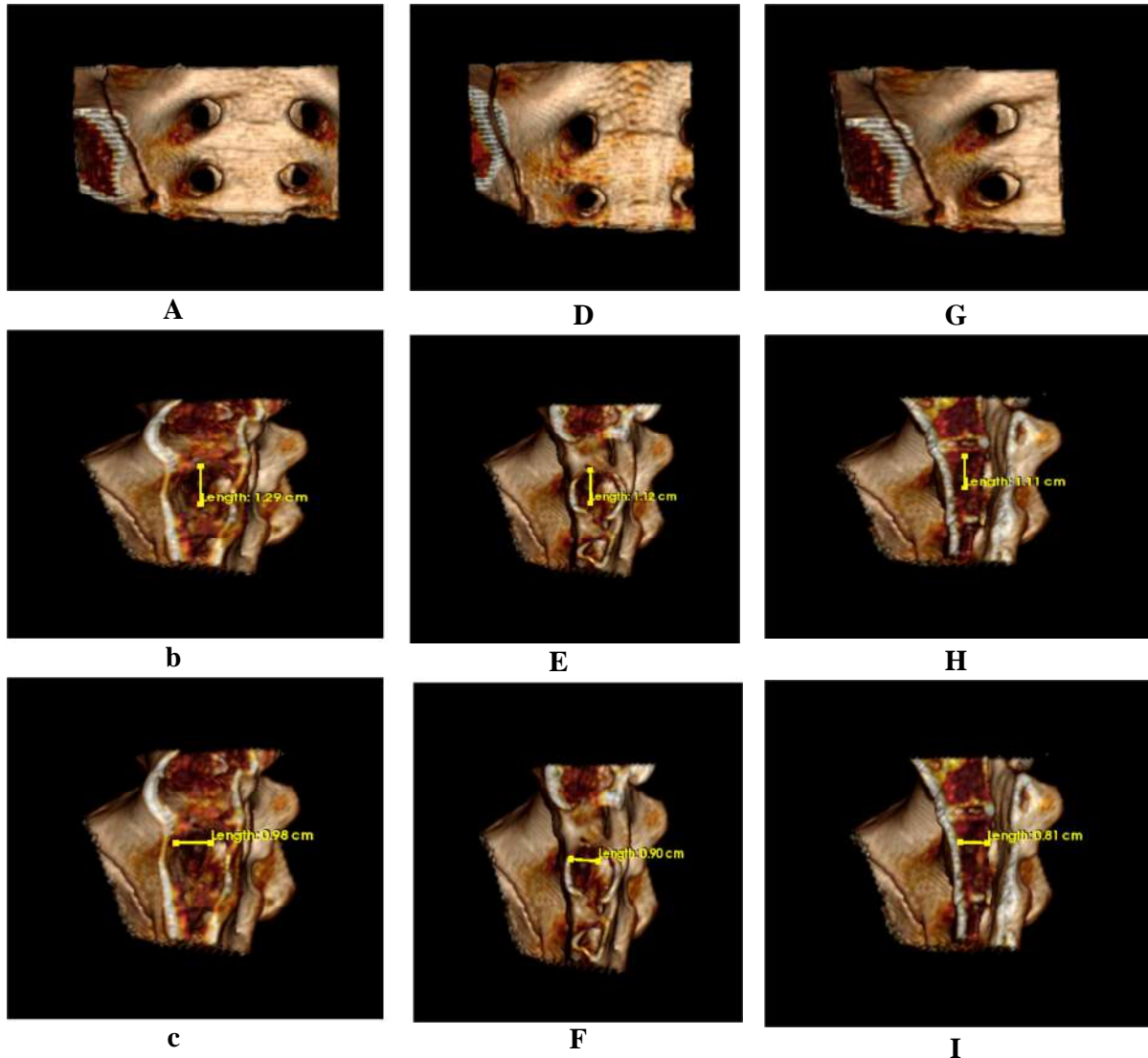
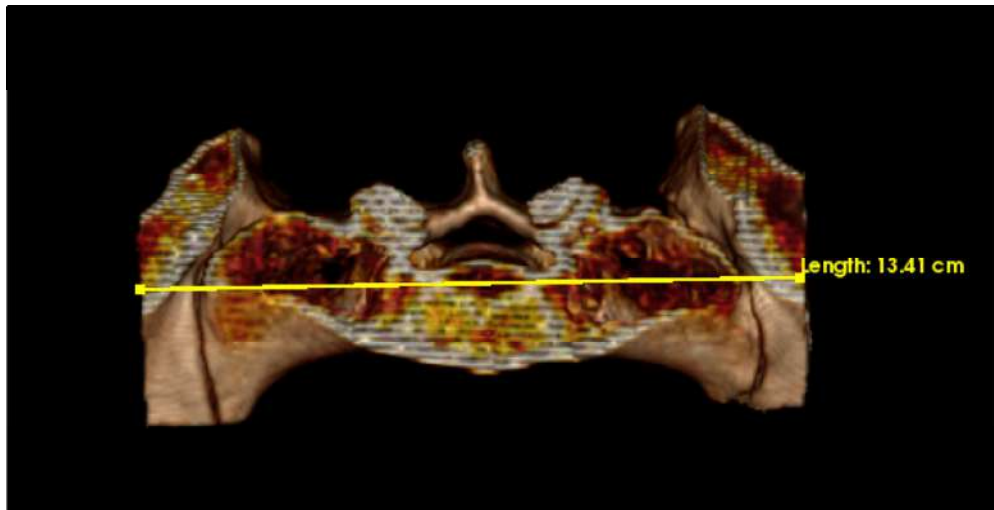
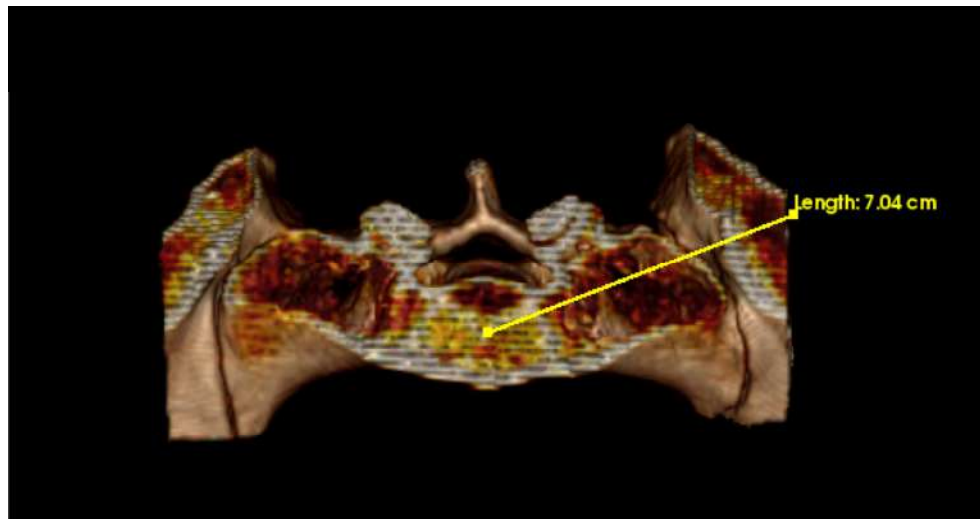


FIGURE 1.4 A) SAGITTAL CUT AT THE LEVEL OF SI JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S2 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S2 (WIDTH1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S2 (HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S2 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S2(HEIGHT 3), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S2 (WIDTH 3)



A

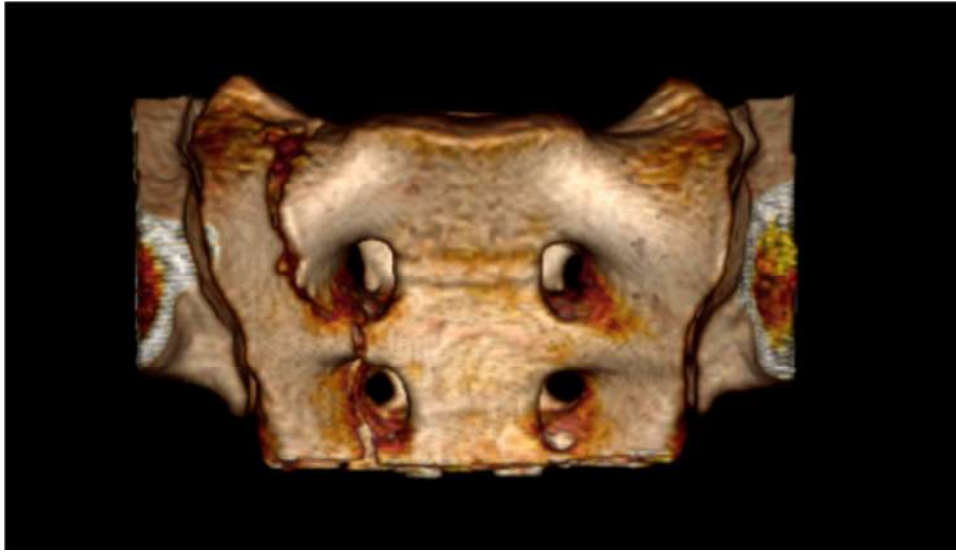


B

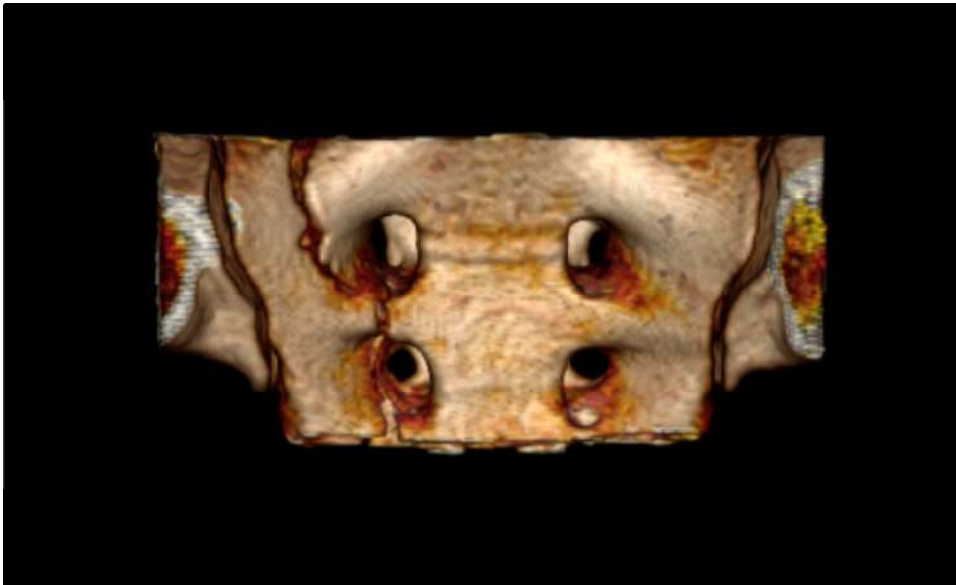
FIGURE 1.5 A. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR TRANS-SACRAL SCREW,

B. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW

2. CASE NO. 13

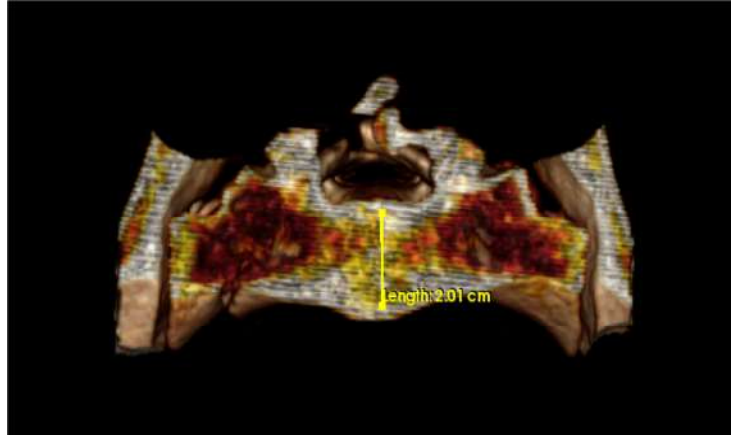


A

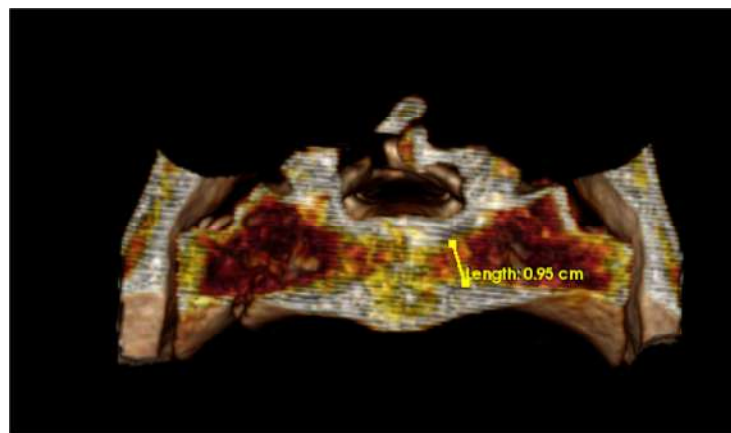


B

FIGURE 2.1 (A,B) SHOWING S1 AND S2 SACRAL SEGMENTS



A



B



C

FIGURE 2.2. A) MEASUREMENTS FROM CENTER OF PROMONTORY, B) NARROWEST MEASUREMENT (CONSTRUCTION AT THE JUNCTION OF PROMONTORY AND ALA OF SACRUM), C) MEASUREMENT LATERAL TO SACRAL FORAMEN

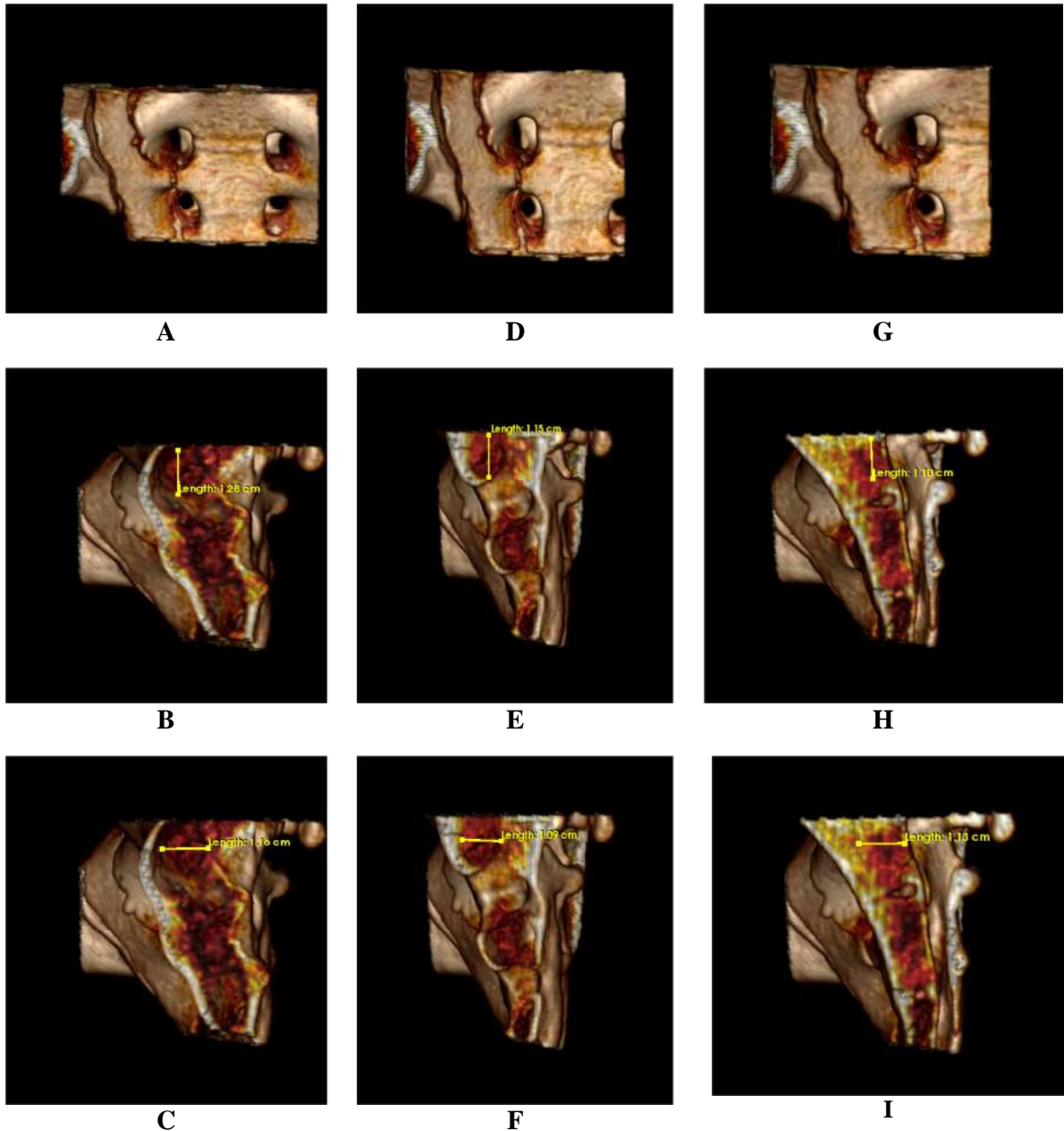


FIGURE 2.3 A) SAGITTAL CUT AT THE LEVEL OF SACRO-ILIAC JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S1 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S1 (WIDTH 1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMENS, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S1(HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S1 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S1(HEIGHT), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S1 (WIDTH 3)

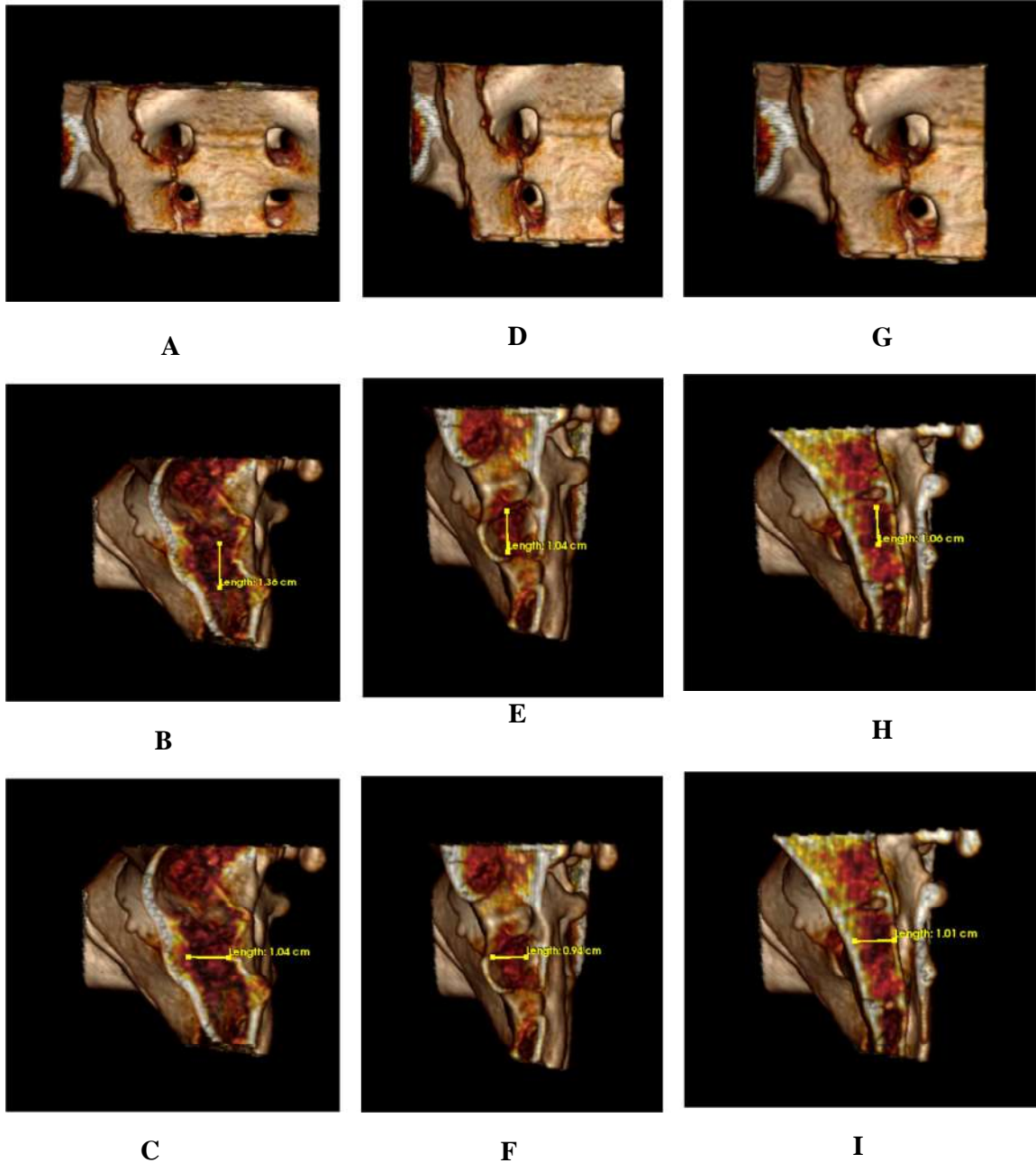
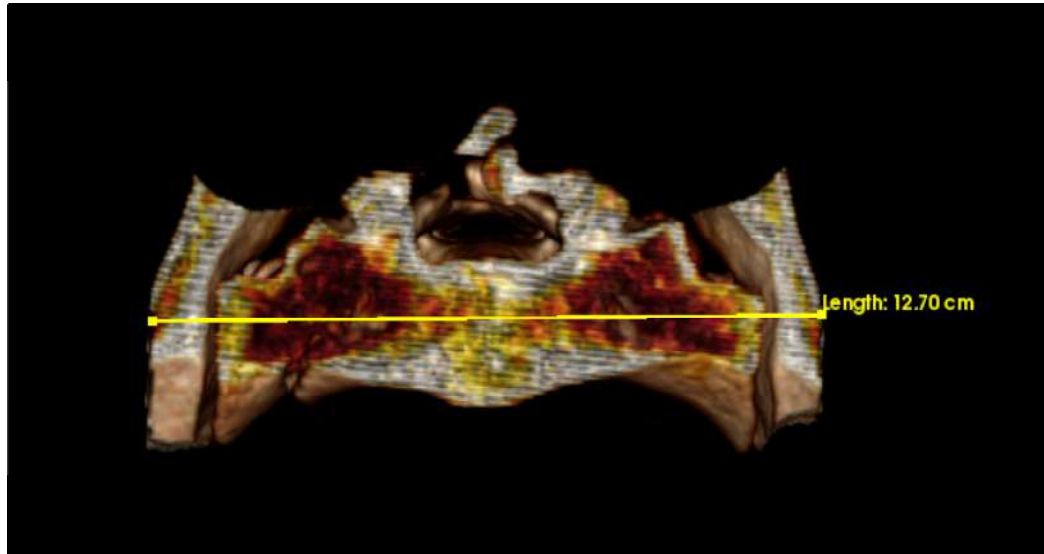
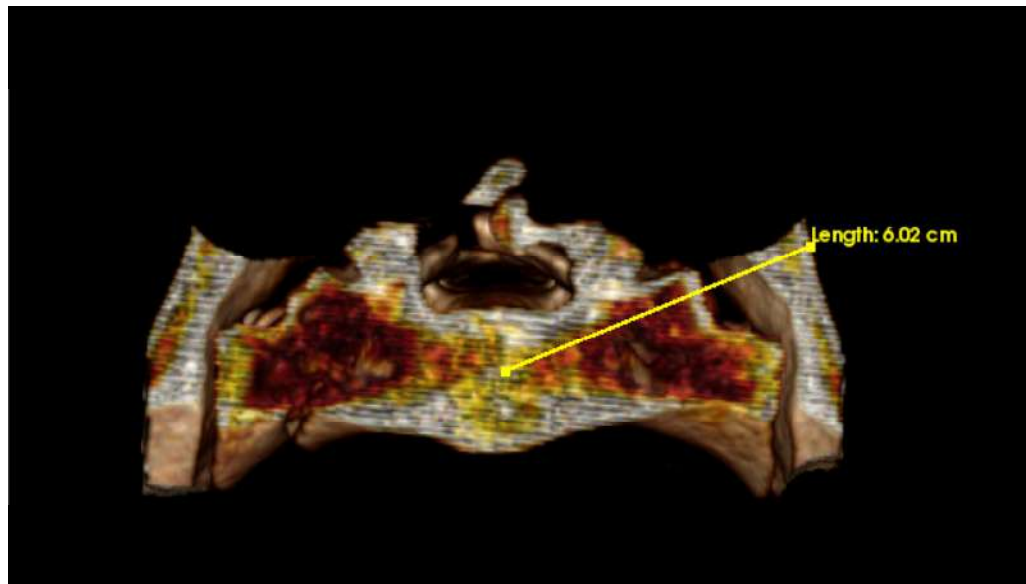


FIGURE 2.4 A) SAGITTAL CUT AT THE LEVEL OF SI JOINT, B) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING HEIGHT OF S2 (HEIGHT 1), C) SAGITTAL CUT AT THE LEVEL OF SI JOINT SHOWING WIDTH OF S2 (WIDTH1), D) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN, E) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING HEIGHT OF S2 (HEIGHT 2), F) SAGITTAL CUT AT THE LEVEL OF SACRAL FORAMEN SHOWING WIDTH OF S2 (WIDTH 2), G) SAGITTAL CUT AT THE CENTER OF PROMONTORY, H) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING HEIGHT OF S2(HEIGHT 3), I) SAGITTAL CUT AT THE CENTER OF PROMONTORY SHOWING WIDTH OF S2 (WIDTH 3)



A



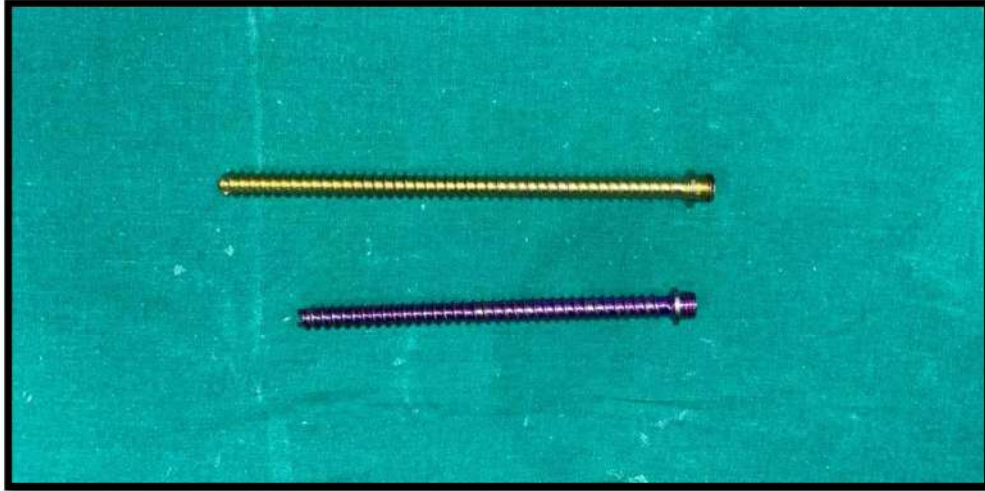
B

FIGURE 2.5 A. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR TRANS-SACRAL SCREW,

B. AXIAL SECTION SHOWING TRAJECTORY AND LENGTH FOR ILIO-SACRAL SCREW

MISCELLANEOUS PICTURES

1. ILIO- SACRAL AND TRANS-SACRAL SCREW (CUSTOMISED SCREW HEADS)



2. CUSTOMISED SCREW DRIVER



S. NO	NAME	AGE (YRS)	GENDER	DATE	CT NUMBER	SACRAL DYSMORPHISM	TRANS-SACRAL LENGTH (mm)	L1-L5 SACRAL LENGTH (mm)	ANTERIO-POSTERIOR WIDTH (mm) (AXIAL SECTION)			S1 CORRIDOR HEIGHT (mm) (SAGGITAL SECTION)			S1 CORRIDOR AVERAGE HEIGHT (mm) (SAGGITAL SECTION)	S1 CORRIDOR WIDTH (mm) (SAGGITAL SECTION)			S1 CORRIDOR AVERAGE WIDTH (mm) (SAGGITAL SECTION)	S2 CORRIDOR HEIGHT (mm) (SAGGITAL SECTION)			S2 CORRIDOR AVERAGE HEIGHT (mm) (SAGGITAL SECTION)	S2 CORRIDOR WIDTH (mm) (SAGGITAL SECTION)			S2 CORRIDOR AVERAGE WIDTH (mm) (SAGGITAL SECTION)
									CENTRE	NARROWEST	LATERAL	HEIGHT 1	HEIGHT 2	HEIGHT 3		WIDTH 1	WIDTH 2	WIDTH 3		HEIGHT 1	HEIGHT 2	HEIGHT 3		WIDTH 1	WIDTH 2	WIDTH 3	
1	AJIT KUMAR	38	M	24/11/20	C25347	NO	139.4	69.4	21.7	11.4	21	13.2	13.2	9.8	12.06	15.3	13.8	13.4	14.16	15.1	13	14.8	14.3	15.8	13.9	11.9	13.8
2	APPASAB ANNUR	48	M	03-06-2021	C31042	YES	144.7	67.1	23.7	12.3	26.4	16.9	12.4	12.2	13.8	13.8	11.8	12.4	12.6	13.2	13.8	15.6	14.2	12.6	12.9	10.3	11.9
3	ASHWIN BENKAPUR	44	M	03-05-2021	C30998	YES	144.4	75.5	20.9	10.8	16.2	15.5	11.1	11.3	12.6	16.5	11.3	12.9	13.5	15.4	12	12	13.1	11.5	10.2	12.5	11.4
4	ADDUSIDA ODEYAR	28	M	17/9/20	C21876	YES	137	71.9	22.5	11	19.4	13.9	10	9.6	11.2	14.9	11	9.8	11.9	13.3	16.1	12.5	13.9	13.9	15.7	11.6	13.7
5	BASAVRAJ UPPAR	23	M	02-06-2021	C29644	NO	142	67	22.3	12	24.8	10.6	10.9	10.6	10.7	12	12.8	11	11.9	12.6	14.6	14.7	13.9	13.4	11.4	10.2	11.6
6	BHIMARAO MAHENDRAKAR	47	M	02-05-2021	C29575	YES	143.7	69	30.3	19.1	17.7	9.6	9	9.5	9.3	11.4	13.5	12.4	12.4	13	12.4	12	12.4	14.2	13.5	11	12.9
7	DEEPAK SUTTAR	26	M	02-04-2021	C29526	NO	140	66	21.5	12.8	20.1	13.5	13.4	13.1	13.3	13.1	12.2	10.5	11.9	13.9	10.6	12.7	12.4	10.9	10.7	12	11.2
8	DURGAPRASAD YADAV	23	M	23/12/20	C26846	YES	132.7	62.3	22.1	12.4	24.5	13	12.2	11.9	12.4	12.1	13.2	12.1	12.4	11.6	11.9	11.7	11.7	12.5	10.8	12.1	11.8
9	ERAGOOND RUDRAGOOND	30	M	31/12/20	C27228	NO	146	71.6	24.1	14.6	20.2	11.1	11.1	11.5	11.2	11.6	12.6	11.9	12.03	15.6	14.6	12.7	14.3	10.1	10.9	11.3	10.7
10	FAHIM OTIGERI	30	M	12-05-2020	C25967	NO	131.9	64.6	20.1	18.1	25.3	10.1	10.9	11.7	10.8	14.9	11.2	13.9	13.3	11.1	11.5	10.4	11	10.9	10.2	11.3	10.8
11	IMTIYAZ MESTRI	58	M	30/12/20	C27188	YES	145.6	66	26.6	13.4	18.6	10.8	10.4	11.5	10.9	11.7	12.6	12.9	12.4	14.2	10.9	10.5	11.8	10.3	11.4	12.6	11.4
12	KRISHNA S	19	M	28/11/20	C25578	YES	129.1	71.5	24.3	12.7	16.1	10.9	11.2	10.6	10.9	12.5	13.8	11.8	12.7	13.4	14.6	12.4	13.4	12.2	11.8	10	11.3
13	KUSTA PAGI	64	M	12-05-2020	C25959	NO	129.2	67.3	23.3	9	13.2	12.5	11.1	10.5	11.4	10.3	11.4	10.7	10.8	10.5	11.2	10.1	10.6	10.9	10.9	10.6	10.8
14	MAHADEV JADAV	52	M	16/12/20	C26540	NO	120.2	66	27.4	15	18.1	13.4	11.5	10.3	11.7	13.9	12.3	13.4	13.2	12.1	13.5	10.9	12.1	12.6	12.5	11.3	12.1
15	MAHADEV KOPPAD	63	M	11-09-2020	C24656	NO	145.1	66.6	26.5	16.2	23.3	11.5	12.8	13.1	12.4	10.5	10.8	10	10.4	16.2	16.7	15.3	16	11.4	13.5	14.3	13
16	MURSIDDA PATIL	46	M	23/11/20	C25294	YES	121.4	63.3	31.2	16.1	20.3	11.9	9.4	11.9	11.1	13.6	12.3	12.4	12.7	13.2	11.2	10.8	11.7	12.5	11.9	12.4	12.2
17	NAGRAJ D	42	M	02-05-2021	C29581	NO	126.2	62.2	21.2	13.3	15.4	12.2	9.1	10.9	10.7	12.9	12.6	11.5	12.3	11.2	10.8	10.8	10.9	9.9	10	10.3	10
18	NAVEEN HALAKATTI	39	M	02-06-2021	C29630	NO	122.8	60.4	16.1	15.7	20.8	14.2	11.8	11.9	12.6	12.6	10.7	9.3	10.8	14	12.7	12	12.9	10.6	10.1	9.8	10.1
19	NIKHIL PARESHWAD	18	M	03-06-2021	C31049	YES	129.1	60.8	26.8	15	16.6	10.9	10.4	11.9	11	14.2	14	13.1	13.7	16	16.2	12.2	14.8	17.6	14.7	15	15.7
20	NITIN CHOUGALE	43	M	29/12/20	C27114	NO	122.6	65.5	25.9	16.6	16	14.3	12.1	10.8	12.4	12.6	11.1	11	11.5	11.8	11.8	11.1	11.5	12.1	11.3	11.3	11.5
21	PANDURANG G	38	M	23/11/20	C25295	YES	135	68.5	23.8	11.1	11.9	16.6	16.9	16.8	16.8	13.9	14.3	12.8	13.6	12.9	14.1	13.6	13.5	11.2	12	10.6	11.2
22	PRASHANT HUGAR	23	M	02-04-2021	C29523	YES	132.2	62.2	23.1	12	14.6	18.9	16.9	15.6	17.1	10.8	11.6	11.3	11.2	11.7	9.3	10.5	10.5	9.8	9.3	9.4	9.5
23	RAJU MUDHOLKAR	45	M	29/12/20	C27113	NO	134	69.4	25.5	13.6	15.5	16.9	15	12.2	14.7	13.4	14.5	11	12.9	16.3	15.7	13.3	15.1	11.8	12.1	13.3	12.4
24	RAJUGOUDA M	50	M	24/12/20	C26941	NO	141.7	74	30.6	15.9	17.5	17.8	11	12.6	13.8	17	12	12.1	13.7	15.6	11.8	12.9	13.4	12.7	12.5	11	12
25	RAVEGOUDA PATIL	43	M	30/12/20	C27181	NO	128	66.9	26.2	16	18.6	13.1	14.5	12.4	13.3	12.9	13.8	11.7	12.8	16.8	12.1	13.3	14.1	14.8	12.8	12.1	13.2
26	ROHIT W	31	M	28/11/20	C25565	NO	127	69.3	23.1	11.6	14.5	14.4	11.1	10.2	11.9	10.6	12.1	10.4	11	10.6	13.3	12.9	12.2	9.8	9.2	10.5	9.8
27	SANDEEP JADHAV	40	M	02-04-2021	C29547	NO	128.6	70.2	16.6	13.3	14.5	12.7	9.7	9.3	10.5	14.6	11	10.9	12.2	9.4	9.2	11	9.8	11	9.3	9.4	9.9
28	SANTOSH GOUDAR	36	M	29/12/20	C27151	YES	128.1	68.9	23.7	9.1	13.4	12.4	9	10.9	10.7	14.9	12.7	13.1	13.5	11	16.2	14.2	13.8	12	12.5	12.2	12.2
29	SANTOSH SAHNI	36	M	14/11/20	C24856	NO	114.6	62.1	21.2	12.9	14	9	8.6	10	9.2	10.4	10.8	11.3	10.8	10.1	9.8	9.4	9.7	11.9	10.1	10.9	10.9
30	SHIVANAND MATHAD	49	M	12-05-2020	C25945	NO	131.6	67.2	22.4	16.6	18.1	11.9	10.9	9.5	10.7	11.8	11.7	11.7	11.7	12	10.9	10.7	11.2	11.9	11.9	12.3	12
31	SHIVKUMAR MISHRA	56	M	14/11/20	C24855	NO	128.3	65	23	11.9	14.7	9.4	8.3	9.1	8.9	11.4	10.6	10.8	10.9	10.6	9.1	10.4	10	10.2	9.3	9	9.5
32	SHRISHAIL JAGANUR	45	M	02-04-2021	C29561	NO	131.8	70.3	25.4	13.7	15.3	12.1	12.2	11.7	12	11.8	13.7	14.4	13.3	11.3	10.7	11.5	11.1	11.6	10.2	12	11.2
33	SUNIL KOLKAR	37	M	02-04-2021	C29542	NO	130.6	64.3	21.9	12.9	15.7	15.3	15	15.8	15.3	10.7	10.3	9.9	10.3	13.9	13.2	14.8	13.9	10.1	10.4	9.9	10.1
34	SURAJ BABU RAUT	25	M	31/12/20	C27210	NO	127.7	64.4	21.7	9.2	14.2	13.5	11.7	11.5	12.2	13	12.4	11.3	12.2	10.5	10.2	10.4	10.3	10.6	8.9	9.7	9.7
35	VUJAY CHALAWADI	29	M	31/12/20	C27245	NO	122.5	65	27	10.9	11	15.5	12.1	10.8	12.8	15.2	12.3	11.1	12.8	12.7	12.5	12.4	12.5	13.6	13.2	13.1	13.3
36	VITHAL SIDARAM	53	M	30/12/20	C27209	NO	129.4	70	19.6	13.9	15	11.8	9.9	9.4	10.3	11.8	12.3	11.4	11.8	11.3	10.3	9.7	10.4	9	11.7	10.4	10.3
37	ZUBERAHEMMED BEPARI	36	M	02-04-2021	C29529	NO	122.6	66.9	21.1	8.8	11.8	12.8	9.1	11.9	11.2	10.7	10.1	10.2	10.3	11.6	9.9	10.9	10.8	9.1	9.9	10.3	9.7
38	MAHANTESH	40	M	02-04-2021	ID-22724	NO	128	65	24.8	15.1	15.2	14	12.3	11.6	12.6	10.2	11.7	11.4	11.1	12	13.5	11.8	12.4	11	10.1	11.4	10.8
AVERAGE							132 mm	67 mm	23.7 mm	13.3 mm	17.4 mm			12 mm					12.2 mm			12.4 mm					11.4 mm

