

**COMPUTERIZED TOMOGRAPHIC MORPHOMETRIC ANALYSIS
OF SUBAXIAL CERVICAL SPINE PEDICLES IN A SOUTH INDIAN
POPULATION FOR GUIDING PEDICULAR MASS FIXATION**

By

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DISSERTATION SUBMITTED TO THE SRI DEVARAJ URS ACADEMY OF
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DEGREE OF

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IN

ORTHOPAEDICS

Under the Guidance of **Dr. N.S.GUDI**

And co-guidance of **DR. ANIL KUMAR SAKALECHA**



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2016

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Dr. ASADHI NITHN TEJA

ABBREVIATIONS

ALC	Anterior ligamentous complex
ALL	Anterior longitudinal ligament
CE	Compressive extension
CF	Compressive flexion
CPS	Cervical pedical screw
DE	Distractive extension
DF	Distractive flexion
DSC-TF	Distance between spinal canal and transverse foramens
LF	Lateral flexion
MDCT	Multi-detector computerized tomography
PL – L	Pedicle length (Left)
PL – R	Pedicle length (Right)
PDW – L	Pedicle width (Left)
PDW – R	Pedicle width (Right)
PDH – L	Pedicle height (Left)
PDH – R	Pedicle height (Right)
PTA – L	Pedicle transverse angle (Left)
PTA – R	Pedicle transverse angle (Right)
PLC	Posterior ligamentous complex
PLL	Posterior longitudinal ligament
PSA	pedicle sagittal angle
OPW	Outer pedicle width
IPW	Inner pedicle width
OPH	Outer pedicle height
IPH	Inner pedicle height
SCD	Sagittal canal diameter
SFD	Sagittal foramen diameters
TFD	Transverse foramen diameters
VC	Vertical compression

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ABSTRACT

BACKGROUND:

Our hospital Sri R. L. Jalappa Hospital is located on national high way in South-India we receive many patients with history of trauma following road traffic accidents and fall from height. Most of the patients have sustained injuries to head and spine including cervical spine. The general population also presents with neck pain of various etiologies (e.g. cervical myelopathy). The age group of the trauma victims is at the peak earning phase of life. Cervical spine injuries with or without neurological deficits can be devastating to the individual and the family.

AIM OF THE STUDY:

1. To assess the morphometry of the subaxial cervical spine pedicles through computerized tomography.
2. To determine the frequency of neurovascular injuries in patients who undergo pedicular mass fixation in cervical spine.

MATERIALS AND METHODS:

This study was a hospital based prospective intervention study centered in department of Orthopedics and Radio-diagnosis at R.L.Jalappa Hospital and Research Centre attached to Sri Devaraj Urs Medical College, Kolar, from November 2013 to July 2015 in which data of 200 patients who underwent CT-scans of the cervical spine and neck for various pathologies was collected and assessed.

RESULTS: the mean values of pedicle lengths, widths have been found to be progressively in-creasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right side. A little fluctuating nature is observed for women though the values are smaller than those for men. For this parameter, very little difference is observed between left side values and right side values for men.

But, for women, some appreciable difference is noted. We found that transverse and sagittal plane angulations were significantly dependent on spinal level. Transverse angulation was approximately 45 ° at C3 through C5 and decreased caudally to approximately 33° at C7 for both sexes.

CONCLUSION:

Through this study we found that there is less significance in the demographic profile. There was a progressive increase in the lengths, widths and height of the pedicles from C3-C7 vertebra. pedicle transverse angle (PTA), which are supposed to determine the direction of screw advancement, it is found from the present study that the angle is varying from 28.93° to 63.73° with mean value of 47.50° for Indian males, while the corresponding values are from 31.6° to 57.85° with mean value of 46.17° for Indian females. Though the literature describes the use of 3.5 mm cervical pedicular screws Indian population will require a smaller size.

KEY WORDS:

Morphometric analysis, Cervical spine pedicles, Computerized tomography, Pedicular mass fixation

INTRODUCTION

Our hospital Sri R. L. Jalappa Hospital is located on a national high way in South-India and we receive many patients with history of trauma following road traffic accidents and fall from height. Most of the patients have sustained injuries to head and spine including cervical spine. The general population also presents with neck pain of various etiologies (e.g. cervical myelopathy). The age group of the trauma victims is at the peak earning phase of life. Cervical spine injuries with or without neurological deficits can be devastating to the individual and the family.

The need for surgical intervention exists in the selected population of patients.

Cervical canal decompression and surgical stabilization of the spine are methods of choice. Posterior stabilization involves lateral screw mass placements. Pedicle screws are an alternative to lateral mass screws for posterior stabilization of the cervical spine. Transpedicular screw fixation proved to be the overall most effective fixation technique, in terms of stiffness, for flexion, extension, torsion, and compression. Pedicle screws also have higher pull-out strengths and a lower risk of loosening during cyclic loading as compared with bicortical lateral mass screws. Although pedicle screws have been shown to be biomechanically superior to lateral mass screw, the danger of injury to vital neural and vascular structures exists which has limited its wide spread acceptance. There are no morphometric studies in south Indian rural population measuring the pedicle morphometry to guide pedicle fixation. Variation of cervical morphometry in any sub population should guide us to accurately use implants.

OBJECTIVES

1. To assess the morphometry of the subaxial cervical spine pedicles through computerized tomography.
2. To determine the frequency of neurovascular injuries in patients who undergo pedicular mass fixation in cervical spine.

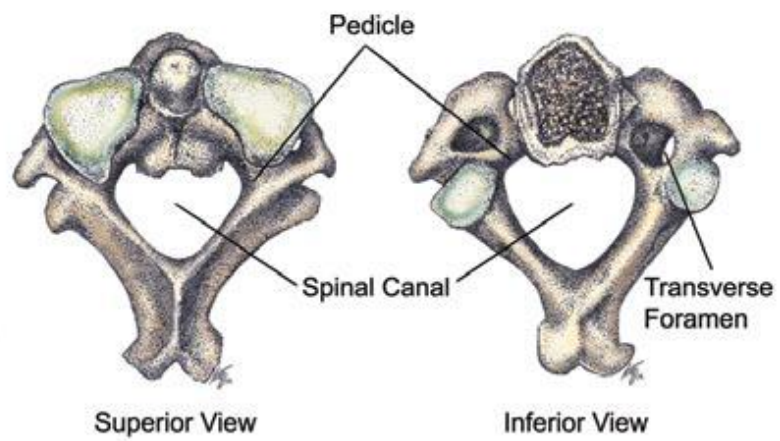
REVIEW OF LITERATURE

Anatomy of cervical:

Pedicles:

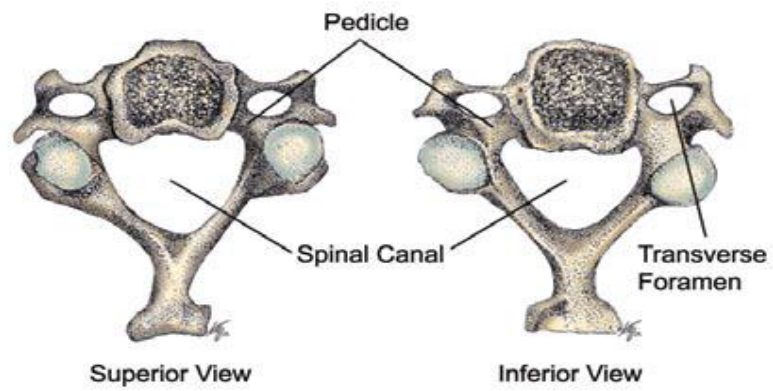
The C2 pedicle is unique in the cervical spine and has an oblique orientation from the latero-inferior to the medio-superior. It is situated directly posteromedial to the transverse foramen and covered medially by the superior articular facet. The superior pedicle is wider than the inferior pedicle. The narrowest portion of the pedicle is the area adjacent to the transverse foramen¹ The lateral wall of the pedicle in this area is thin compared with the medial and superior walls and is more vulnerable to penetration by a pedicle screw.

The pedicles of the C3 through C6 vertebrae are more uniform. They are short, tubular structures originating from the posterolateral corner of the vertebral body and attaching to the anteromedial aspect of the lateral mass between the superior and inferior articular processes. In the transverse plane, the pedicle is between the spinal canal and transverse foramen of the transverse process oriented posterolateral to anteromedial. In the sagittal plane, the C3–C4 pedicle is slightly cephalad, the C5 horizontal, and the C6–C7 slightly caudal.² Pedicle dimensions are smaller in the lower cervical spine than in the thoracic or lumbar region. For C3–C7, pedicle widths average 5 to 6 mm, and pedicle heights average 7 to 8 mm.^{3,4,5} In general, pedicle width is *smaller* than pedicle height, and the lateral cortex of the pedicle is thinnest. The C7 pedicle is slightly larger than the C3–C6 pedicle. In most cases, the C7 vertebra has no transverse foramen, as it is a transitional vertebra.



Second Cervical Vertebra (Axis)

FIGURE-1



Fifth Cervical Vertebra

FIGURE-2

Vertebral artery:

The vertebral artery is the main tributary for the cervical spine. It originates from the subclavian artery on the right side and from the brachiocephalic artery on the left side at the T1–T2 level or the lower portion of the T1. At the C7 level, the vertebral artery is situated lateral to the vertebral body, anterior to the spinal nerve and in the front of the mid portion of the lateral mass. It enters the transverse foramen at C6 and courses cephalad through all the foramina above. In the transverse plane, the vertebral artery lies lateral to the pedicle and in front of the lateral mass. As it courses cephalad from C6 to C2, it becomes gradually more anterior and medial. Within the transverse foramen of C2, the course of the vertebral artery is infero-medial to supero-lateral. However, it should be noted that the course of the vertebral artery within the C2 transverse foramen may vary. The C2 pedicle may be significantly smaller if the vertebral artery courses more medial within the transverse foramen. As the vertebral artery emerges from the transverse foramen of the atlas, it courses medially, rests on the anterior portion of the superior surface of the curved posterior ring, and enters the dura at the lateral aspect of the foramen magnum, becoming the basilar artery.

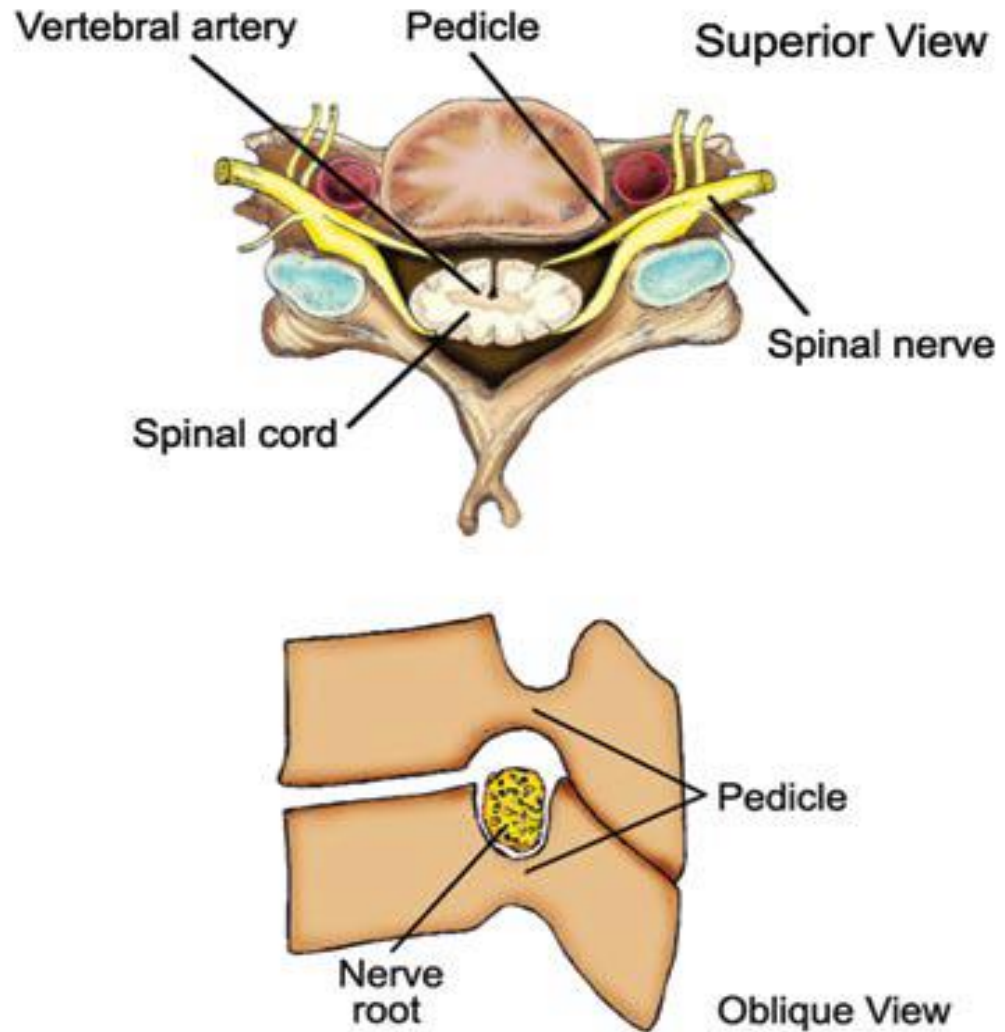


FIGURE-3

Spinal nerve:

The spinal nerve exiting from the spinal canal passes through the inter-pedicular foramen, which is bounded by the adjacent pedicles superiorly and inferiorly, the posterolateral wall of the vertebral body anteriorly, and the anteromedial aspect of the superior articular process posteriorly. Laterally, in the inter-transverse foramen, it divides into a larger ventral ramus and a smaller dorsal ramus. The ventral ramus of the cervical spinal nerve courses on the transverse process antero-laterally to form the cervical plexus and the brachial plexus. The dorsal ramus branching off the spinal nerve in the inter-transverse foramen runs posteriorly against the anterolateral corner of the base of the superior articular process just above the origin of the posterior ridge of the transverse process and supplies the facet joint, ligaments, deep muscles, and skin of the posterior neck. On oblique sagittal images of the cervical spine, the cervical nerve is located in the lower portion of the inter-pedicular foramen and occupies the majority of the inferior part of the inter-transverse foramen.^{6,7} Xu and colleagues¹⁴ found that there is no space between the pedicle and the superior nerve root in the lower cervical region; however, there is a little space (~1.5 mm) between the pedicle and the inferior nerve root. The C7 spinal nerve is relatively larger and closer to the anterior aspect of the lateral mass because its course is more posterior in the transverse plane.

Cervical pedicle morphology:

Cervical curvature plays an integral role in the proper functioning of the cervical spine. The summation of small movements occurring at the cervical intervertebral joints accounts for the high mobility and flexibility of the neck as an entity. The skeleton of the neck comprises seven small cervical vertebrae out of which four (C3-C6) are typical. Each vertebra consists of an

anterior vertebral body and a posterior neural arch. The vertebral body has a central part of cancellous bone and a peripheral cortex of compact bone. The margins of upper and lower surfaces of the vertebral body are thickened to form vertebral rings. The neural arch is constituted by pedicles, laminae, spinous process, and articulating facets. The vertebral bodies are connected anteriorly by a long strong strap like anterior longitudinal ligament and a similar posterior longitudinal ligament. Fractures and dislocations of the spine are serious injuries as they may be associated with damage to the spinal cord or cauda equina. Instrumentation of the cervical spine is often used for the orthopedic management of pathologies resulting in cervical instability as well as for the decompression of neural structures. One of the most frequent and complex procedures for this is the placement of trans-pedicular screws.^{8,9,10,11} The neural arches of adjacent vertebrae articulate with each other through facet joints which form synovial joints. Remaining portions of the neural arch of consecutive vertebrae are joined together by ligamentum flavum and other ligaments which are collectively termed as posterior ligament complex. Size of the vertebral bodies and both direction and size of the articular facets are different in different regions of the vertebral column. Previously morphometric studies of the cervical, thoracic, and lumbar vertebrae have been undertaken, and they have highlighted the importance of such studies in the development of vertebral column instrumentation.^{12,13,14,15}

Cervical Spine Fracture Classification:¹⁶

Holdsworth Classification:

In 1949, Nicoll¹⁷ introduced the concept of stability and instability in the treatment of thoracolumbar injuries. In 1963, based on clinical, radiological, surgical, and postmortem observational studies, Holdsworth^{18,19,20} proposed his 2-column concept of thoracolumbar and cervical spine stability/ instability, emphasizing the importance of posterior ligamentous complex (PLC) and the morphology of facet joint sustaining violence. PLC was composed of inter-spinous, supraspinous, and capsular ligaments, and ligamentum flavum. Holdsworth's observational studies indicated the absolute necessity of flexion/ rotation for disruption of PLC; pointing out that direct longitudinal pull along PLC fibers rarely, if ever, results in rupture, unless the intensity of trauma is extremely high. According to Holdsworth, 5 patterns of trauma can cause fractures or fracture dislocations of the spine:

- (1) Flexion: Flexion results in wedge fractures, which are usually stable.
- (2) Flexion/rotation: flexion/ rotation forces result in fractures or fracture/dislocations that are usually unstable.
- (3) Extension: Extension will rupture the disc space; however, the PLC stays intact (stable in flexion).
- (4) Compression: Compression will produce a burst, but because of the intactness of the PLC, these fractures are usually stable.
- (5) Shear: Stability is lost in shearing injuries.

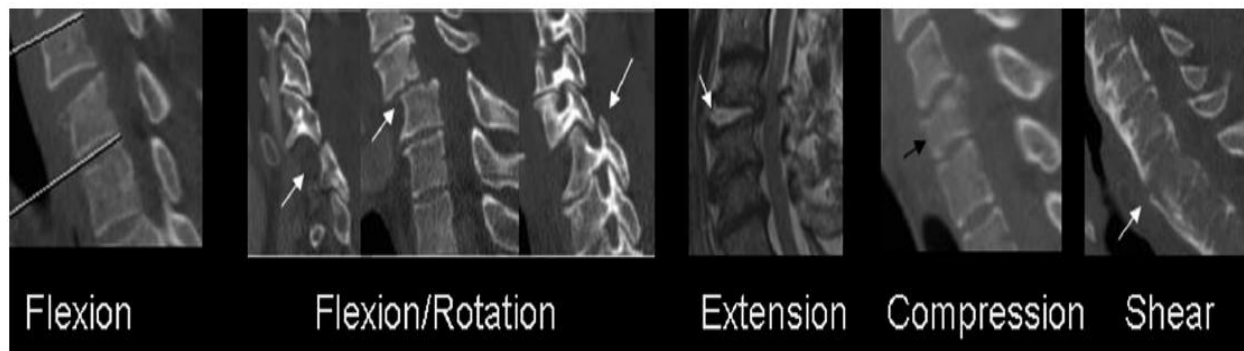


FIGURE-4

Holdsworth's classification system establishes the importance of segmental ligaments and the influence of facet anatomy in determining stability. However, despite its apparent simplicity, it has not been widely put into practice and has never been validated.

Allen's Mechanistic Classification:^{16,21}

As conceptualized by Allen and associates, translation of kinetic energy into fractures and dislocations is determined by 2 independent variables: injury vector and the posture of the cervical spine at the time of accident. Using these mechanistic analogies and the pattern of segmental failure on radiographs of the cervical spine from 165 patients, in 1982 Allen et al introduced their classification of the sub-axial cervical spine fractures and dislocations. These investigators presumed that identical segmental failures could result from injury vectors of the same magnitude when applied to cervical spines set in similar postures. Based on the mechanism of injury, fractures and dislocations occur in families, or phylogenies, with specific anatomic derangements. These families of fractures and dislocations include:

(1) Compressive Flexion (CF): Up to 36 percent patients had evidence of compressive flexion injury of 5 degrees of severity. This fracture most frequently occurred at C5/6 with the C5 body sustaining the CF injury.

- a. CF stage 1: Blunting of the anterior superior vertebral margin was seen in 36 patients, none of which had any evidence of neurological deficit and failure of posterior arch ligaments.
- b. CF stage 2: A “Beak” vertebral body and loss of height is characteristic of CF stage 2. Seven of the 165 patients had this radiographic pattern of injury, 1 of whom had central cord syndrome.
- c. CF stage 3: There is a fracture line through the “beak-form” vertebral body but there is no translation of the vertebral bodies. Two of the 4 patients in this category had a neurological deficit; 1 had a central cord injury, and the other 1 had a complete spinal cord injury.
- d. CF stage 4: Patients in CF stage 4 had less than 3 mm translation of the fractured bodies. Of 8 patients in this category, 2 had central cord syndrome, 1 had a partial lesion, and 3 had a complete spinal cord injury.
- e. CF stage 5: There is more than 3 mm of translation of the vertebral bodies. One of 11 patients with CF stage 5 had a central cord injury and the remaining 10 had complete spinal cord injuries. In CF stage 5, the posterior aspect of the anterior element ligaments and the entire posterior arch ligaments are disrupted.

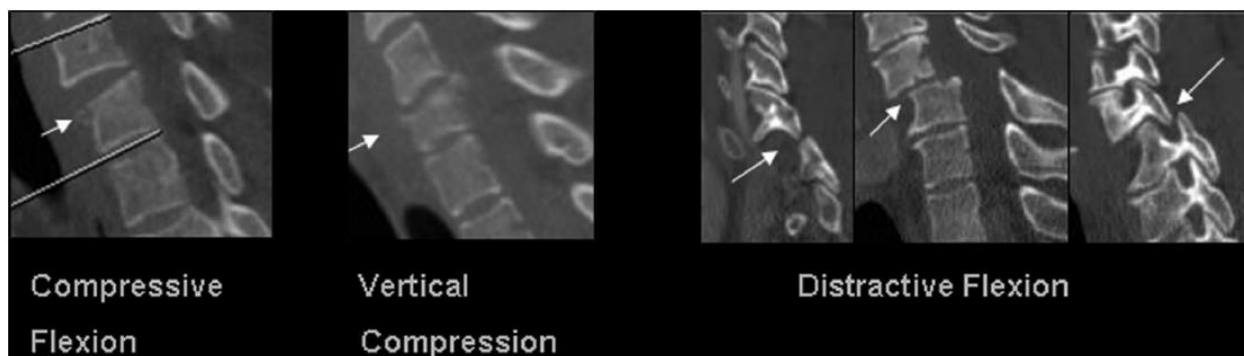


FIGURE-5



FIGURE-6

(2) Vertical Compression (VC): In vertical compression, the compressive force is transmitted to the cervical spine with the neck in a neutral position.

- a. VC stage 1: There is a “cupping” deformity of either the superior or the inferior endplate, without evidence of ligamentous failure.
- b. VC stage 2: There is a “cupping” deformity of both endplates. None of the 4 patients in this series had a neurological deficit.

- c. VC stage 3: There is extensive fragmentation and bursting of the vertebral body in this category. The posterior part of the body may be bulging into the canal and the ligamentous structures may or may not be disrupted.



FIGURE-7

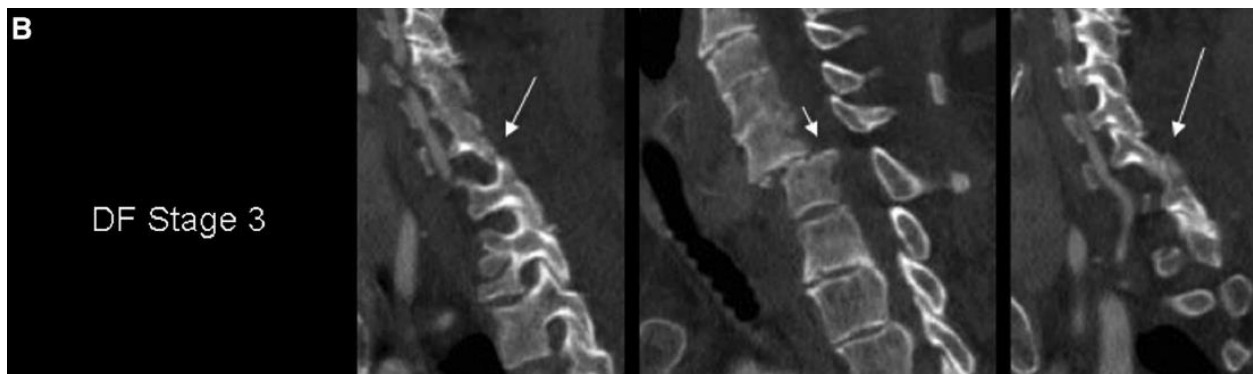


FIGURE-8

C

DF Stage 4

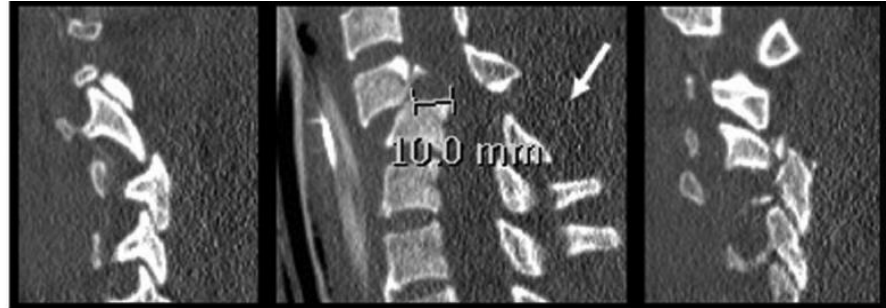


FIGURE-9

Reformatted sagittal computed tomography views of cervical spine indicating distractive flexion (DF) stages 2 to 4 of Allen et al Classification. In DF stage 2 (A), there is unilateral locked facets. In DF stage 3 (B) facets are bilaterally locked with partial translation of the rostral vertebral body and in DF stage 4 (C) there is significant translation of the rostral vertebral body in conjunction with bilateral locked facets.

(3) Distractive Flexion (DF): In distractive flexion injury, vector force is transmitted to the occiput while the neck is in flexion. In descending levels in the sub-axial spine, there is an increase in stage and the degree of severity of neurological deficit with the C6/7 interspace most commonly involved in DF stage 4 and with the greatest number of complete injuries. Fifty seven percent of DF stage 4 occurred at C6/7. The DF category is a typical example of tension-shear of the posterior arch ligaments.

- a. DF stage 1: There is facet subluxation in flexion with divergence of the spinous processes.
- b. DF stage 2: There is a unilateral facet dislocation (locked facet, interlocked facet) with varying degrees of posterior arch ligamentous failure. Rotary listhesis may be seen in the injured motion segment.

c. DF stage 3: In this stage there is a bilateral facet dislocation with a degree of listhesis of up to 50%.

d. DF stage 4: There is extreme translation of 1 vertebral body on the other 1, hence “floating vertebra,” and there are bilateral locked facets. There is significant failure of the posterior arch ligaments and there may be significant injury to the posterior arch (Figure 7C).

(4) Compressive Extension (CE): In CE, there is a blow to the forehead or face that forces the neck into extension and thrusts the head toward the torso. The major injury vector stresses posterior elements in compression. There is fracture or impaction of the posterior arch. Although theoretically sound, the authors did not present any CE stage 3 or CE stage 4 cases. The majority of CE stage 1 and CE stage 2 injuries were concentrated at the C6/C7 motion segment.

a. CE stage 1: Unilateral fracture of an articulating process combined unilateral pedicle and laminar fracture (floating lateral mass) or combined pedicle and articulating process fractures are grouped in CE stage 1. There may be slight rotary listhesis of subjacent bodies. The majority of patients with CE stage 1 injury had no deficit.

b. CE stage 2: Pathology in CE stage 2 is a bilaminar fracture of the posterior arch that could occur at multiple levels.

c. CE stages 3 and 4: There are bilateral vertebral arch fractures at the corners (e.g. facets, pedicles or laminae). In CE stage 4, but not in CE stage 3, there is partial vertebral body width displacement anteriorly.

d. CE stage 5: Two motion segments are involved with bilateral posterior arch fractures and full anterior displacement of 1 vertebral body on the other.

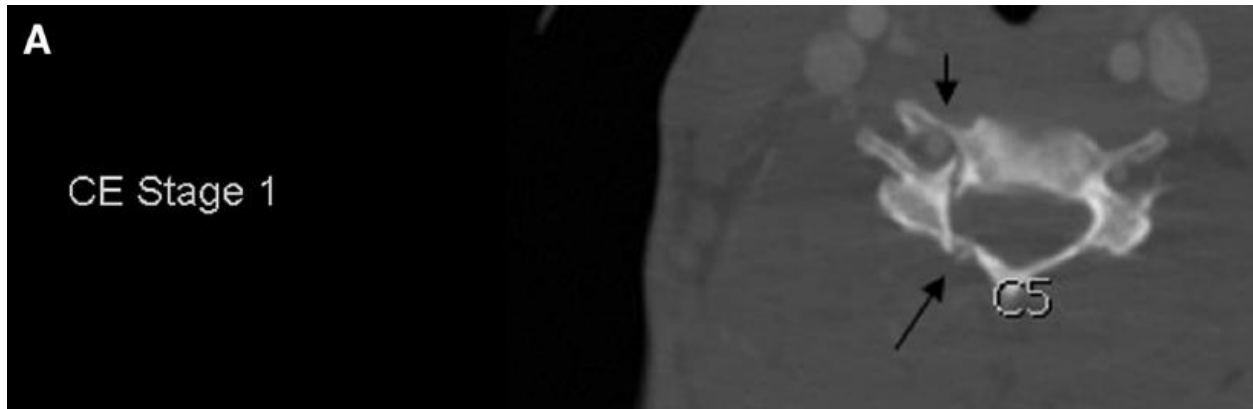


FIGURE-10



FIGURE-11

Reformatted axial computed tomography indicating a typical floating lateral mass of C5 vertebral body compatible with compressive extension (CE) stage 1 (A), and reformatted sagittal computed tomography views of cervical spine indicating fracture of the superior articulating processes of C7 bilaterally compatible with CE stage 4 of Allen et al Classification (B).

(5) Distractive Extension (DE): In DE, the neck is extended and the vector force is applied over the anterior calvarium or face. This is typically seen in the elderly who fall on their faces from a sitting or standing position. There is widening of the disc space or a transverse non-deforming fracture of the vertebral body.

a. DE stage 1: In DE stage 1, there is widening of the disc interspace with possible chip fracture of the anterior lips of the cephalad or caudad vertebrae.

b. DE stage 2: In addition to a widened disc space, there is failure of the posterior arch ligaments, with an added opportunity for spinal cord injury.

(6) Lateral Flexion (LF): A major compressive injury vector (slow forced flexion of the head towards 1 shoulder) on 1 side causes vertebral arch fracture and a minor distractive injury vector on the opposite side produces asymmetric compression of 1 motion segment. In LF stage 2, in addition to an ipsilateral compression fracture of the posterior arch, there is displacement of 1 body on the other.

In summary, Allen's classification system for sub-axial cervical spine fractures provides more mechanistic detail than that proposed by Holdsworth, but the utility of such detail remains unknown. Attempt at measurement of reliability has been undertaken and the intra-class correlation coefficient is only 0.53. The additional intricacies make the system more complicated and likely explain why, despite having been published almost 30 years ago, this classification system is not widely used.

The nomenclature in each category describes the forces upon the cervical spine at the time of injury and the magnitude of the force vector. Within each category, a series of injuries were described from mild to severe stages.

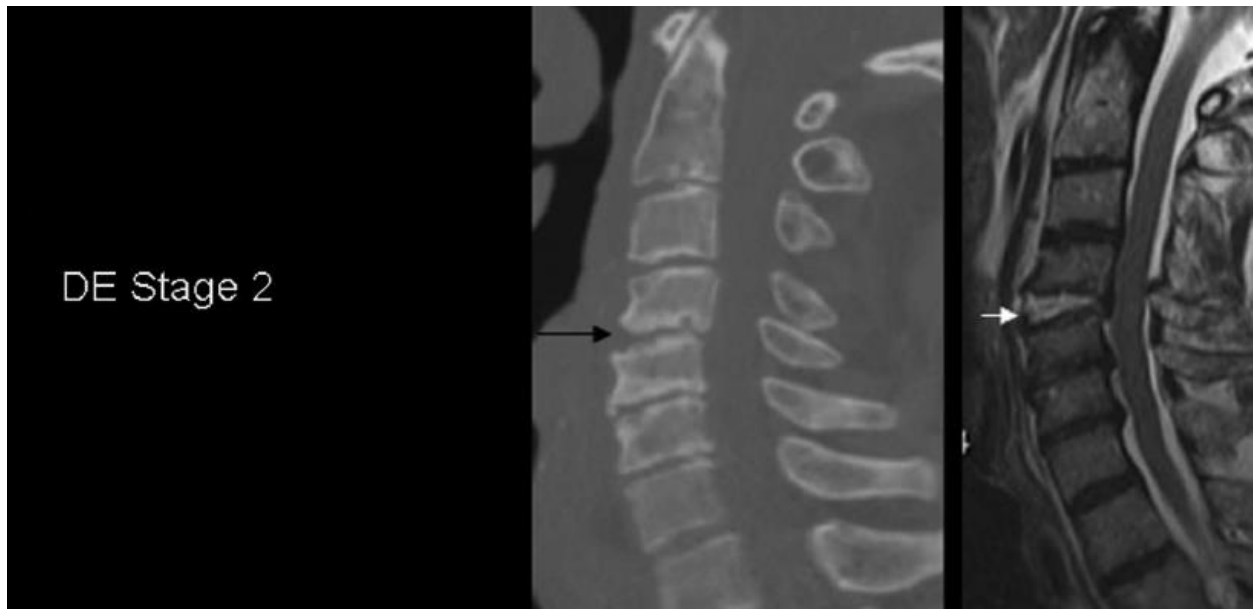


FIGURE-12 Sagittal reformatted views of cervical spine indicating distractive extension stage 2 of Allen Classification.

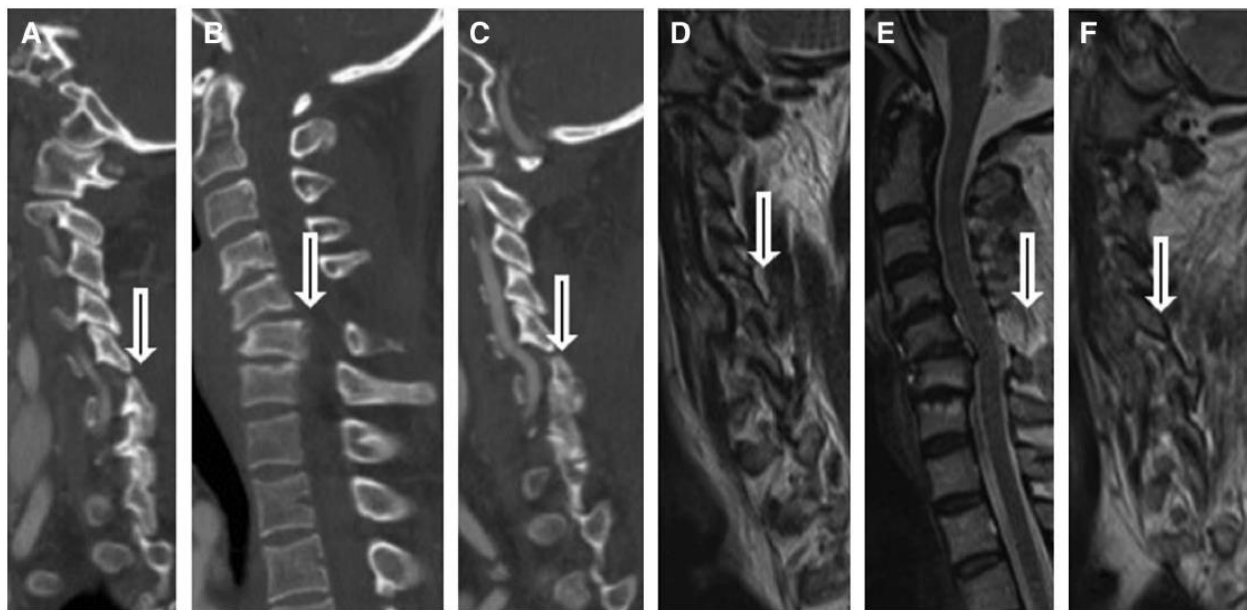


FIGURE-13 Sagittal reformatted views of cervical spine indicating distractive flexion stage 1 phylogeny of Allen et al Classification (A, B, C) associated with significant ligamentous injury (D, E, F).

Harris Classification:^{16,22}

Based on biomechanical, cadaveric, and pathological evidence that vector forces along the “central coordinating system” are fundamental determinants of cervical spine injuries, Harris and his colleagues introduced yet another mechanistic classification system for cervical spine fractures and dislocations in 1986.²² This classification was also derived from data from the literature, and from clinical and radiographic observations. Major vector forces were flexion, extension, rotation, vertical compression, and lateral bending. A combination of vector forces such as flexion-rotation, extension-rotation, and lateral bending may produce added varieties of injuries. It was believed that specific vector forces and the magnitude of causative force determine groups of injuries that could be used in a new classification.

(1)Flexion:

- a. Anterior subluxation (hyperflexion sprain): Flexion vector forces along the Z-axis produce bilateral disruption of posterior ligamentous complex, including the joint capsules. On radiographs, there is widening of the inter-spinous ligament. There is a 30 to 50% chance of delayed dislocation if not managed properly.
- b. Bilateral inter-facet dislocation: In this category, there is dislocation or locking of both facet joints. There may be evidence of translation of up to 50%. Anterior and posterior ligamentous complexes are disrupted, producing complete instability of the involved motion segment.
- c. Simple wedge (compression) fracture: In this class of injuries, the body of the involved vertebra assumes a wedge deformation. PLC may or may not be disrupted.

- d. Clay-shoveler (coal-shoveler) fracture: a vertical fracture through the spinous processes of C6, C7 and T1 is the result of forced flexion of the neck with intense tightening of inter-spinous and supraspinous ligaments.
- e. Flexion teardrop fracture: The degree of flexion and anatomical injury in this category is quite substantial. There is a triangular fracture of the body with encroachment into the spinal canal. Anterior ligamentous complex (ALC) and PLC are both disrupted and there is a flexion deformity of the cervical spine at that motion segment.

(2) Flexion-Rotation:

Unilateral inter-facet dislocation: A combination of major forces of flexion and rotation is the main pathogenetic mechanism in this category of cervical spine injury. This pattern of injury is also referred to as unilateral locked facet. There may be less than 50% translation of the bodies of the involved motion segment. The ligamentous complex is usually partially damaged.

Extension-Rotation Pillar fracture:

Extension and impaction of the articulating processes in Z-axis results in fracture of the articulating processes. There is no translation and the patient may have radicular symptoms because of impaction upon the neural foramen involved.

(3) Vertical Compression:

- a. Jefferson fracture of the atlas: In this class of upper cervical spine injuries, vertical compression along the Y-axis will fracture the C1 arch and lateral dislocation of C1 lateral masses.

b. Burst (bursting, dispersion, axial loading) fracture: Translation of vector forces along the Y-axis via the occipital condyles or sacrum when the cervical spine is in a neutral position will result in a burst fracture with possible retro-pulsion of fragmented bone into the spinal canal. There may be a bilaminar fracture of the posterior arch. In plain radiographs, a straight cervical spine will differentiate this injury from a tear drop fracture (CF stages 4 and 5), which is a flexion injury.

(4) Hyperextension:

- a. Hyperextension dislocation: Extreme vector forces in the Z-axis will disrupt the ALL and intervertebral disc and put tension on the PLL. There may be end plate avulsion fractures (in up to 60%) of the involved motion segment. Some translation of the vertebral bodies without fracture of the posterior arch is not unusual.
- b. Avulsion fracture of anterior arch of the atlas: Hyperextension vector force against the anterior tubercle of atlas via intact longus colli and the atlantoaxial ligament may cause a horizontal fracture of atlas.
- c. Extension teardrop fracture of the axis: Translation of hyperextension vector forces via an intact ALL can result in an avulsive triangular fracture of antero-inferior portion of C2. This phenomenon is especially prevalent in patients with cervical spondylosis and osteopenia.
- d. Fracture of the posterior arch of the atlas: Impaction of the posterior arch of the atlas between the occiput and the posterior arch of C2 during hyperextension is considered to be the pathogenic mechanism behind this fracture.
- e. Laminar fracture: Laminar fractures were considered as compressive extension injury stage 2.

- f. Traumatic spondylolisthesis (hangman's fracture): This is the classic bilateral fracture of the pars inter-articularis of C2 in extreme hyperextension.
- g. Hyperextension fracture-dislocation: Extreme hyperextension may cause fracture of the posterior arch through the lateral masses and facets, and in severe degrees, dislocation of 2 subjacent motion segments.

(5)Lateral Flexion:

Uncinate process fracture: This fracture occurs along the X-coordinate by extreme lateral flexion of the cervical spine.

In summary, Harris added to the classification systems already proposed by Holdsworth and Allen et al.^{18,21,23} However, much like the Allen classification system, this 1 is highly detailed with respect to presumed injury mechanism, yet has questionable utility in guiding treatment or predicting outcome. Similar to the Holdsworth and Allen systems, the Harris classification system, when subjected to a validation process by Vaccaro et al,²⁴ demonstrated an intra-class correlation coefficient of only 0.42. Nonetheless, the descriptive components of this system that describe the anatomic areas of failure (e.g. bilateral facet dislocation) have been widely adopted and are commonly used as a means of describing sub-axial cervical spine trauma.



FIGURE-14

Mildest form of flexion injury proposed by Harris. Sagittal angulation associated with increased interspinous ligament is conjunction with disruption of capsular ligaments.

Pedicle screw fixation:

Historical review of pedicle screw fixation:

Pedicle screw fixation of the cervical spine was pioneered in 1964 by Leconte,²⁵ who inserted screws into the C2 pedicles for treatment of traumatic spondylolisthesis of the axis. Leconte's work was followed by that of Saillant and Bleyria²⁶ in 1979.

In 1984, borne and colleagues²⁷ described using pedicle screw fixation for the treatment of pedicular fractures of C2. Recently, this technique has been used for caudal fixation for

occipitocervical plate fixation.²⁸ Pedicle screw fixation was not used in the lower cervical spine until 1995.

Abumi and colleagues,²⁹ followed by Jeanneret and colleagues,³⁰ were the first to introduce screws into the pedicles in the lower cervical spine to treat fractures and dislocations. As a result of successful outcomes in the treatment of various unstable cervical spine disorders, pedicle screw fixation in the cervical spine has been the subject of several studies involving anatomy, biomechanics, and clinical application.

Cervical pedicle screw fixation:

Surgical fixation in cervical spine is needed to correct or maintain spinal alignment (treat instability), to enhance fusion rates and to allow early mobilization.³¹ Instability in cervical spine can be caused by various conditions such as trauma, infection, neoplasm or posterior decompression procedures. Various techniques to achieve surgical fixation of cervical spine include spinous process wiring, triple wire technique, sub-laminar wiring, lateral mass plating, anterior vertebral body plating and trans-pedicular screw fixation.³² Type of pathology and surgeon experience determines the choice of fixation method. Situations with absent or deficient spinous process prevent the use of wiring techniques. A study has reported that amongst the seven anterior and posterior fixation techniques, trans-pedicular screw fixation was found to be overall most effective in terms of stiffness, for flexion, extension, torsion, and compression in posterior column and three column instabilities.³³ Also as compared to bicortical lateral mass screws, which is a preferred method of posterior cervical spine fixation, pedicle screws have been shown to have a higher pullout strength and lower risk of loosening during cyclic loading.³³ Panjabi et al in 1991 in their anatomic study of cervical vertebrae reported that trans-pedicular

screw fixation is possible in cervical spine.³⁴ In 1994 Abumi et al reported the use pedicle screws in 13 patients with sub-axial cervical trauma without complication. Subsequently many have reported morphometric parameters of cervical pedicle^{31,35,36,37,38} and also several biomechanical³⁹ and clinical studies have been published.^{40,41,42,43} However cervical pedicle screw insertion carries risk of catastrophic complications⁴⁴ and several cadaveric studies have reported high perforation rates.⁴⁵

Few morphometric studies have been reported for cervical pedicle in Indian population.^{46,47,48} More studies are needed to ascertain the feasibility of cervical pedicle screw fixation in Indian population. Most of the morphometric studies have reported that transverse pedicle diameter is less than the sagittal diameter, hence transverse diameter can be limiting factor with regard to screw diameter.

Technique of cervical pedicle screw placement of the C2 pedicle:

After sub-periosteal exposure of the posterior aspect of the upper cervical spine, dissection is extended lateral to the C2–C3 facet joint. The C2 lamina, pedicle, and inferior articular process are further clearly identified using a small curette. Roy-camille and colleagues⁴⁹ recommended that the entrance point for screw insertion be located in the upper medial quarter of the C2 articular mass because the vertebral artery is in front of the 2 lateral quarters and the 1 lower medial quarter. Smith and colleagues²⁸ believed that the starting point is 3 to 5 mm superior to the center of the C2–C3 facet joint. After tapping, the screw is directed 10° to 25° medially and 25° cranially, with screw lengths ranging from 20 to 22 mm. Xu and colleagues⁵⁰ recommended that the entrance point for screw placement be approximately 5 mm inferior to the superior border of the lamina and 7 mm lateral to the lateral border of the spinal canal. The screw is directed 33° medially and 20° superiorly. For fixation of pedicular fractures of C2, Borne and colleagues²⁷ recommended a precise location of the screw entry on the posterior aspect of the inferior articular process of C2, anatomical reduction of the fractured pedicles, and medial (20°) and cephalad (22°) screw orientation. In their series, they used screws 3.5 mm in diameter and 30 mm in length. Because of individual variation in the C2 pedicle dimension and location of the vertebral artery, C2 pedicle screw insertion must be determined on a case-by-case basis to avoid inadvertent injury to the vertebral artery. Correct identification of the posterior and medial borders of the C2 pedicle and placement of the screws as close as possible to the medio-superior cortex of the C2 pedicles allow surgeons to avoid penetrating the transverse foramen and damaging the vertebral artery.⁵¹

Pedicle screw placement of the C2 pedicle

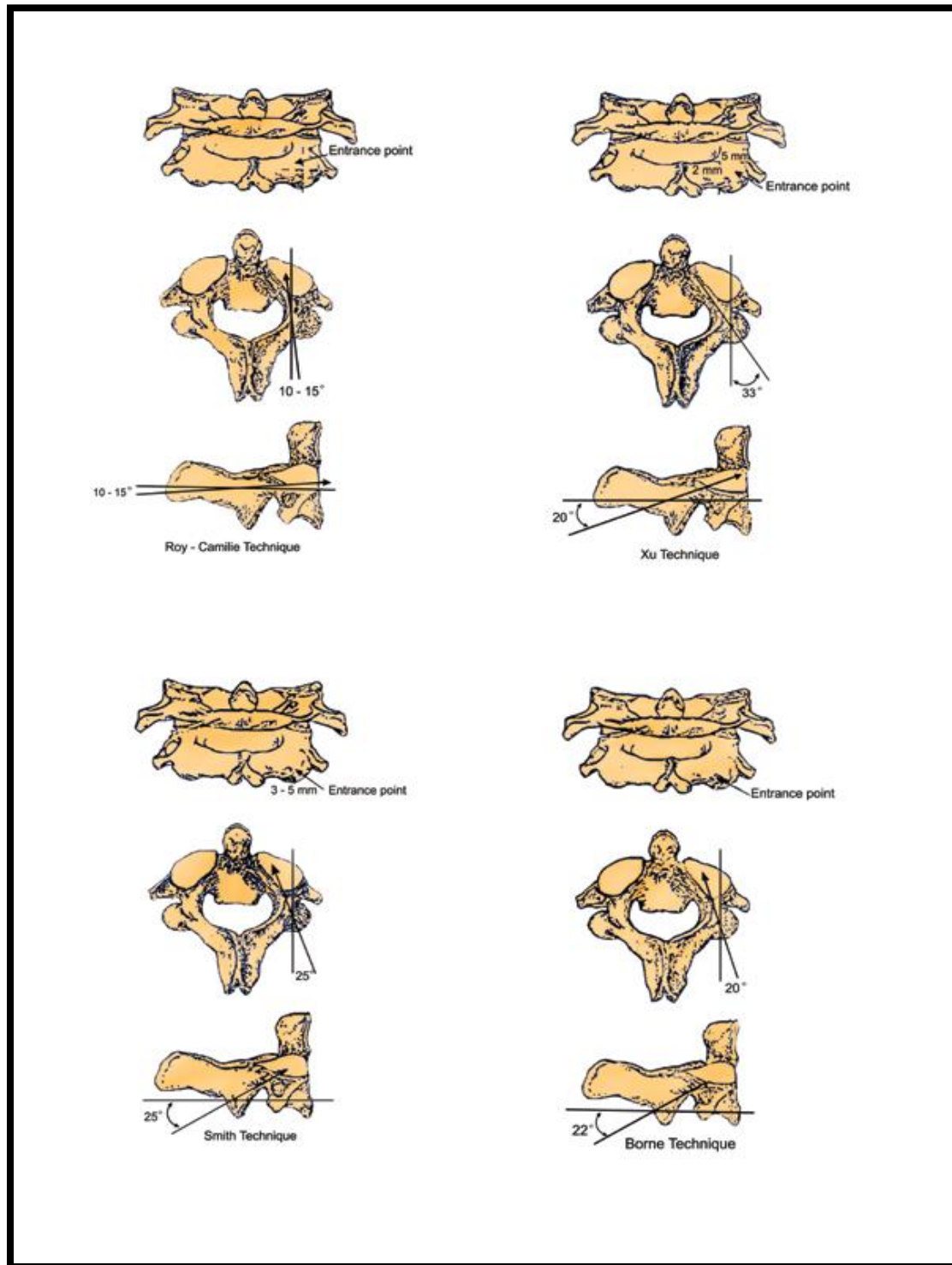


FIGURE-15

Technique of cervical pedicle screw placement of the lower cervical pedicle:

Pedicle screw insertion into the pedicles in the lower cervical spine is a technical challenge that requires a solid knowledge of the 3-dimensional anatomy of the cervical pedicle and experience with pedicle screw fixation in the thoracolumbar spine. Based on the technique described by Abumi and colleagues²⁹ and Abumi and Kaneda,⁵² pedicle screw fixation in the lower cervical spine is performed under fluoroscopy. After exposure of the lateral margin of the lateral masses at the levels to be instrumented, the entrance point for screw insertion is determined. This point is located just lateral to the midpoint of the lateral mass and slightly inferior to the inferior border of the superior facet. The dorsal cortex at the entrance point is penetrated with a burr, and the entrance hole is enlarged. A nerve probe or small curette is used to palpate the inner wall of the pedicle cavity, which is then tapped. Pedicle probing and tapping are monitored with lateral fluoroscopy. Screw direction is 25° to 45° medial in the transverse plane and parallel to the superior endplate of the vertebral body in the sagittal plane based on the measurements of preoperative computed tomography (CT) scans. Available screw diameters are 3.5, 4.0, and 4.5 mm, and lengths are 20, 22, 24, and 28 mm.

To avoid violation of the facet joint, Jeanneret and colleagues³⁰ recommended that the entrance point for screw insertion be in the middle of the articular mass and 3 mm beneath the superior facet, with the screw directed 45° medially in the transverse plane. A 4.0-mm cancellous screw can be inserted in the pedicle in the lower cervical spine. Maximal screw lengths are 26 mm at C3–C4, 28 mm at C5, 30 mm at C6, and 32 mm at C7. Based on anatomical studies, Xu and colleagues¹⁴ and Ebraheim and colleagues⁵⁵ suggested that the screw entrance point for screw insertion at the levels of c3–c6 is approximately 2 mm below the inferior edge of the superior facet and 5 to 6 mm medial to the lateral edge of the lateral mass. At C7, this point lies 1 mm

inferior to the midline of the transverse process and 2 to 3 mm medial to the lateral edge of the lateral mass. An and colleagues⁵³ documented that the screw entrance point at C7 is at the intersection of the transverse line through the middle of the transverse process and the vertical line through the middle of the facet joint.

Because of the small size of the lower cervical pedicle and the difficulty in determining the accurate starting point and direction for screw insertion, Miller and colleagues⁵⁴ and Albert and colleagues⁵⁵ both recommended partial laminectomy or laminoforaminotomy before initiation of screw insertion. Pedicle screw insertion guided by direct visualization of the medial, superior, and inferior walls of the pedicle in the lower cervical spine through a partial laminectomy decreases the incidence of screw penetration of the pedicle.

Pedicle screw placement of the lower cervical pedicle

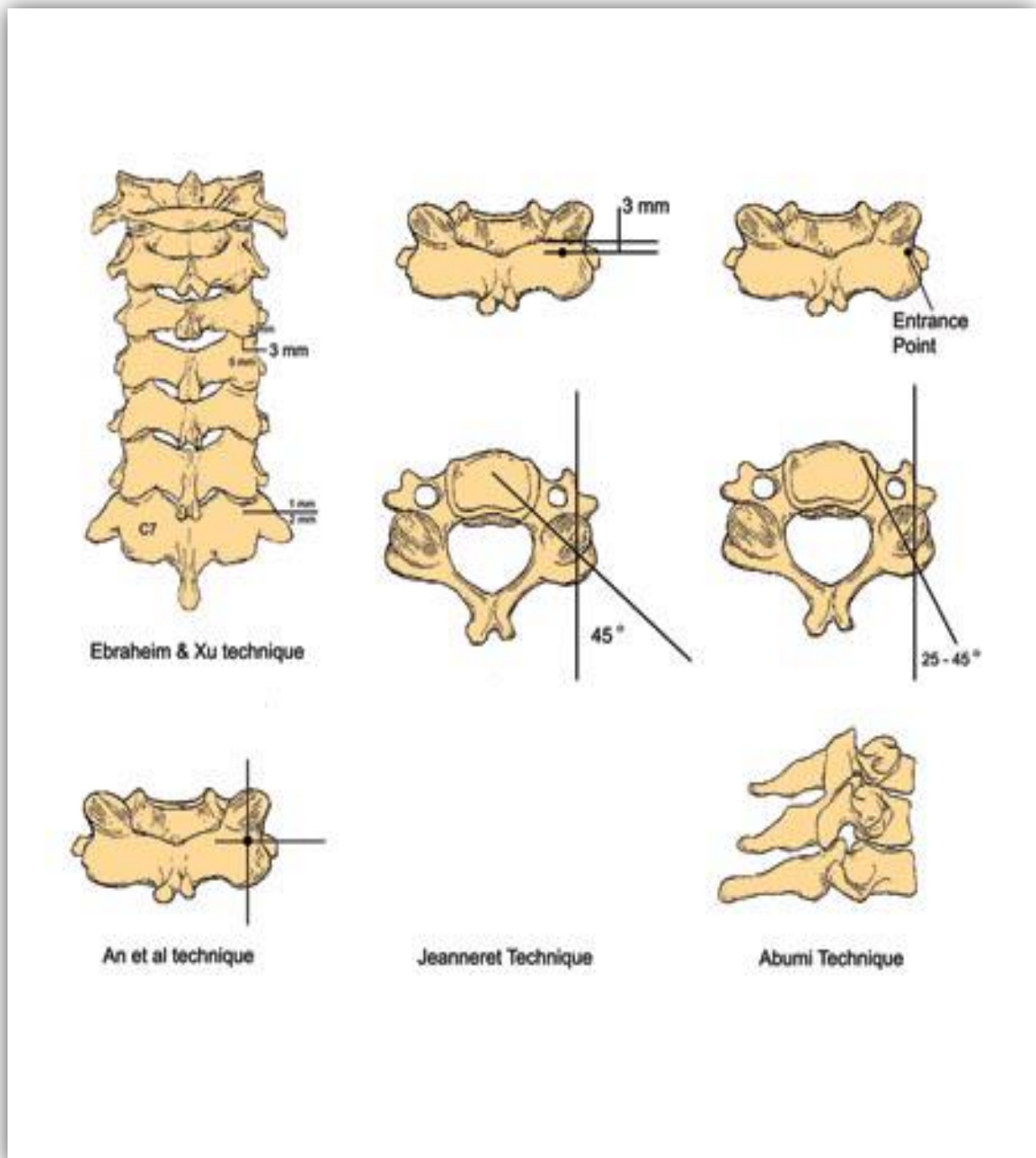


FIGURE-16

Indian studies of cervical pedicle screw fixation:

S.R.Mitra et al⁵⁶ (2015) studied the feasibility of pedicle screw instrumentation in sub-axial cervical spine in Indian population with regard to transverse pedicle diameter and observed that the mean transverse diameter on direct measurement and CT measurement were noted to be less as compared to the white population. The transverse pedicle diameter was less at all levels in females as compared to males. Transverse diameter was minimum at C3 and maximum at C7. They concluded that transverse pedicle diameter is less as compared to white population. Pedicle screw fixation may not be feasible at all levels in Indian population especially females with 3.5 mm screw option available currently. Hence smaller diameter screw option should be available. Also pre-operative multi planar CT morphometric evaluation of each level should be done to determine appropriate screw dimensions, trajectory and entry point.

Bijjawara Mahesh et al⁵⁷ (2014) studied a new technique for cervical pedicle screw placement with partial drilling of medial cortex and they concluded that the use of the technique by Abumi et al., more than half of the cervical pedicle screw perforations described was lateral. Use of a blunt pedicle probe usually directs the surgeon toward the lateral cortex as the medial cortex is thicker and stronger. With the new medial cortical pedicle screw technique described, lateral perforations were low. However, surgeons attempting this technique should be aware of the increase in medial perforations experienced by the authors with the new technique. The study gives an additional option of technique to be considered by surgeons already using cervical pedicle screw placements in selected patients. Further evaluation for reproducibility of the medial cortical pedicle screw technique by other surgeons and testing of biomechanical strength of the screws is required.

Suresh.Spillai⁵⁸ (2014) studied on the sub axial cervical pedicle screw fixation and they reported that the pedicle screw fixation in the lower and middle cervical spine has been considered very risky, but pedicle screw fixation has bio mechanically proven its superior stabilizing effect. A thorough knowledge of the local anatomy and the surgical techniques is a must before embarking on cervical pedicle screw fixation. Pre-operative evaluation of vertebral artery is a must, because if the dominant vertebral artery is injured, serious neurological complications can occur.

SushilPatkar⁵⁹ (2014) studied the anterior fixation of atlantoaxial joints, technique and pitfalls and they reported that both the atlantoaxial joints can be exposed adequately by a unilateral extra pharyngeal approach from the right side. The atlantoaxial dislocation can be introduced in to the joint. The odontoid process can be drilled and removed. The C1-C2 joint can be fixed either by (i) C1 lateral mass and C2 body screw plate bilaterally or (ii) bilateral anterior C2-C1 trans-articular screws.

Patwardhan A R et al⁶⁰ (2012) studied the computed tomography-based morphometric analysis of cervical pedicles in Indian population and observed that the mean transverse diameters of the cervical pedicles of C2 to C7 in males were 5.3 to 6.1 mm and mean transverse diameters of the cervical pedicles of C2 to C7 in females were 5.1 to 5.6 mm. Between 2.1% and 55.7% of pedicles in our male population and between 5.5% and 74.3% pedicles in our female population was smaller than 5.0 mm in transverse diameter and thus cannot have fixation with a 3.5 mm screw using this technique. They concluded that the transverse pedicle diameter of cervical pedicles in the Indian subjects is smaller compared to the western population. Although trans-pedicular screw fixation has stronger pullout strength compared to lateral mass fixation, its use must be considered carefully and individually. Preoperative CT evaluation is a must before trans-

pedicular fixation in the cervical spine, especially in the Indian female population. As an option 2.7-mm screws can be devised for the Indian population giving a wider safety margin.

Rajan VV et al⁶¹ (2010) studied the iso-c3d navigation assisted pedicle screw placement in deformities of the cervical and thoracic spine and observed that the CT scans of the cervical spine showed 90.8% perfectly placed screws with 7 (7%) grade i pedicle breaches, 2 (2%) grade ii pedicle breaches and one anterior cortex penetration (< 2mm). Five lateral pedicle breaches violated the vertebral artery foramen and three medial pedicle breaches penetrated the spinal canal; however, no patient had any neurovascular complications. In the thoracic spine there were 92.2% perfectly placed screws with only six (2%) grade ii pedicle breaches, eight (3%) grade i pedicle breaches and five screws (2%) penetrating the anterior or lateral cortex. No neurovascular complications were encountered. They concluded that the iso-c 3d based navigation improves the accuracy of pedicle screw placement in deformities of the cervical and thoracic spine. The low incidence of pedicle breach implies increased safety for the patient.

Worldwide studies of cervical pedicle screw fixation:

Kim, Moon-Kyu et al⁶² (2015) studied the hybrid technique of mini open surgery and use of a percutaneous cannula system for cervical pedicle screws placement and observed that there were 12 (24%) misplacements among 50 cervical pedicular screws used. The hybrid technique was applied clinically in 4 traumatic, 2 degenerative, and 2 failed back surgery lesions. Thirty cervical pedicle screws were inserted using the percutaneous cannula system and 10 were inserted using a cannula as a retractor. Misplacement occurred in 6.7% (n = 2) and 20% (n = 2) pedicles, respectively, and there were no symptomatic complications (total incidence, 10%). An additional incision for the cannula system can be made for 2-level cervical pedicle screw

insertions. They concluded that the use of the percutaneous cannula system facilitated a secure convergence angle for cervical pedicle screw insertion without extending muscle dissection or shifting cervical alignment because of muscle retraction. Moreover, this system can be used for cervical pedicle screw insertion in bull necked patients.

Mingzhi song et al⁶³ (2014) studied the four lateral mass screw fixation techniques in lower cervical spine following laminectomy and observed that the three-dimensional finite element model of the intact C3-C7 vertebrae was successfully established. This model consists of 503,911 elements and 93,390 nodes. During flexion, extension, lateral bending, and axial rotation modes, the intact model's angular inter segmental range of motion was in good agreement with the results reported from the literature. The post-operative model after the three-segment laminectomy and the reconstructive model after applying the four lateral mass screw fixation techniques were established based on the validated intact model. The stress distribution for the Magerl and Roy-Camille groups were more dispersive, and the maximum von mises stress levels were lower than the other two groups in various conditions. They concluded that the lateral mass screw fixation techniques of Magerl and Roy-Camille are safer methods for stabilizing the lower cervical spine. Therefore, these methods potentially have a lower risk of fixation fracture.

Jinshan tang et al⁶⁴ (2014) studied the position and complications of pedicle screw insertion with or without image-navigation techniques in the thoracolumbar spine and they reported that the accuracy of the position of grade i, ii, iii and iv screws and complication rate related to pedicle screw placement were significantly increased when navigation techniques were used in comparison to conventional techniques. Future research in this area should include

reconstruction CTs with well-planned methodology to limit bias and report on validated, patient-based outcome measures.

X. Qiang et al⁶⁵ (2014) studied the placement using funnel technique and topographic landmarks surgical technique and observed that the in five pedicles (5%), the procedure was aborted because of a small or nonexistent pedicle medullary canal. In group i (funnel technique), 82% of screws were placed in the pedicle correctly, seven pedicles (18%) had noncritical breaches, and two pedicles (4%) had critical perforations. In group ii (topographic landmarks surgical technique), 62.2% of screws were placed in the pedicle correctly, whereas 11 pedicles (24.4%) had noncritical perforations and 6 pedicles (13.3%) had critical perforations. Statistically significant differences were demonstrated between the two groups. They concluded that the funnel technique can enhance accuracy and further improving the safety of trans-pedicular screw placement comparing with topographic landmarks surgical technique.

Dae-Jean Jo et al⁶⁶ (2012) studied the cervical pedicle screw insertion using the technique with direct exposure of the pedicle by lamino-foraminotomy and observed that the correct position was found in 95 screws (91.3%); grade 0-75 screws, grade 1-20 screws and the incorrect position in 9 screws (8.7%); grade 2-6 screws, grade 3-3 screws. There was no neurovascular complication related with cervical pedicle screw insertion. They concluded that this technique (technique with direct exposure of the pedicle by lamino-foraminotomy) could be considered relatively safe and easy method to insert cervical pedicle screw.

J. Alex Thomas et al⁶⁷ (2010) studied of the alternate method for placement of C-1 screws and observed that the forty-nine screws were placed in C-1 lateral masses by using the new technique. Solid arthrodesis was achieved in all cases, with a mean follow-up period of 30 months. There were no cases of CSF leakage, new neurological deficit, injury to the C-2

ganglion, vertebral artery injury, or hardware failures. They concluded that the technique is a safe and effective way to fixate C-1 while avoiding the C-2 nerve/ ganglion and venous plexus. The results indicate that excellent clinical and radiographic outcomes can be achieved with this new technique.

AdebukoaOnibokun et al⁶⁸ (2009) studied the anatomic considerations for C2 pedicle screw placement and observed that the overall mean pedicle width was 5.8 ± 1.2 mm. The mean pedicle width in males (6.0 ± 1.3 mm) was greater than that in the female subjects (5.6 ± 1.1 mm). This difference was not found to be statistically significant. The overall mean pedicle transverse angle was 43.9 ± 3.9 degrees. The mean pedicle transverse angle (pta) in males was 43.2 ± 3.8 degrees, while that in females was 44.7 ± 3.7 degrees. They concluded that the preoperative planning is absolutely mandatory, particularly in determining not only screw trajectory, but in analyzing individual patient anatomy and reception to a C2 pedicle screw.

Failed Cervical Spine Fixation Due to Improper Pedicular Screw Size:

Given the technical difficulties of placing instrumentation in the spine, it is inevitable that complications sometimes arise from mal-positioning of hardware. The radiologist should systematically assess the integrity of neural and vascular structures throughout the spine, including the neural foramina, thecal sac, central cord and cauda equina, and foramen transversarium, as well as adjacent structures such as the major abdominal vessels, psoas musculature, posterior mediastinum, and prevertebral soft tissues.

Pedicle screws, in particular, deserve attention because of their frequent use and proximity to sensitive neural and vascular structures. Lonstein et al⁶⁹ reported an overall complication rate of

2.4% per screw in a retrospective review of clinical outcomes with placement of 4790 pedicle screws. The most common complication was nerve root irritation from medial angulation of the screw with resultant violation of the medial cortex of the pedicle.

Optimal screw placement is typically along the medial aspect of the pedicle. The instrumentation gains purchase from its proximity to cortical bone but should not disrupt it; the tip of the pedicle screw should approach but not breach the anterior cortex of the vertebral body. Loosening of pedicle screws often may be seen as a rim of lucency around the screw threads. Complications may arise from medial or lateral deviation of a screw or from its penetration of the anterior cortex of the vertebral body. Similar complications may arise from mal-positioning of anterior cervical plates and screws, which may penetrate the adjacent disk space, foramen transversarium, spinal cord, or nerve roots. Graft material in either case also may herniate anteriorly or posteriorly (depending on the approach used for placement) and cause neurologic compromise.

Although surgery at the wrong level is an uncommon occurrence, it may account for the persistence of clinical symptoms. The radiologist should consider potential surgical interventions and should provide surgically relevant information when reporting findings at preoperative imaging. In reporting cases of spinal stenosis, it is important to describe the structures that are causing canal compromise.

The acute onset of neurologic symptoms in the immediate postoperative setting should arouse clinical suspicion about the possible formation of a hematoma. Such occurrences require urgent surgical decompression.

Computed Tomography:

Historical review of computed tomography:

Medical imaging has experienced significant changes in both the technologic and clinical areas since the discovery of x-rays in **1895 by Wilhelmconrad Roentgen**, a German physicist. Innovations have become common in the radiology department, and today the introduction of new ideas and methods and refinement in existing techniques are apparent.

The first contrast examination was described by **Walter Dandy who in 1918** introduced ventriculography by injecting air directly into the ventricles.

In **1921, Sicard** described a radiopaque oily contrast substance that could be injected into the spinal canal and used to diagnose intra spinal lesions.

Egarmoniz, in **1927** described cerebral angiography. These developments represented considerable progress in the diagnosis of lesions of central nervous system.

In **1948, George More** described the use of radioactive isotopes to diagnose the location of the tumor. This was an important non-invasive approach in diagnosing brain neoplasms and other conditions.

In **1960's** the diagnostic procedures, particularly angiography, continued to improve through the use of selective and super selective approaches.

Image reconstruction from projections finally found practical application in medicine in the **1960's** through the work of investigators such as **Oldendroff, Kuhl, and Edwards**, who were studied problems in nuclear medicine.

in**1963, Allan Macleodcormack** also applied reconstruction techniques to nuclear medicine.

In1967, Dr. Godfrey New Boldhounsfield applied the reconstruction techniques to produce the world's first clinically useful CT scanner for imaging the brain.

In **1979, Hounsfield and Cormack** shared the Nobel prize in medicine and physiology, for their contributions to the development of CT.

Later different generation (a term used to refer to the method of scanning) of CT scanner were introduced mainly to improve the image quality and to reduce the scan time.

In the mid-**1980s**, another high speed CT scanner was introduced, which is referred as the Electron Beam CT (EBCT) scanner used for imaging cardio-vascular system. In **1989, Dr. Willikalender** introduced volume scanning by using spiral / helical CT scanners.

In spiral / helical CT scanners, a thin X-ray beam traces a path around the patient and scans a volume of the tissue. Recently, dual slice spiral / helical CT scanner and multi slice CT scanners were introduced which mainly increase the speed and volume of scan. Volume CT scanning has resulted in a wide range of applications such as CT fluorography, CT angiography, three-dimensional imaging, and virtual reality imaging.⁷⁰

Baker et al in 1980 reported that CT is the most accurate neuro-radiologic examination for the detection of intracranial lesions, and, if contrast enhancement is employed, CT will reveal upto 98% of such masses and specifically identify about 90%. Because of its relatively innocuous nature, CT should be the first test employed in the evaluation of patient's with suspected brain tumors.⁷¹

Segal et al in 1990 mentioned the use of contrast enhancement is indispensable in the evaluation of brain tumors and may help to distinguish an iso-dense lesion from the surrounding parenchyma or a hypodense lesion hidden within an area of edema.⁷²

Osborn in 1994 states that small round cell tumors such as Medulloblastoma are iso-dense or hyper-dense compared to brain parenchyma before contrast administration, whereas

Astrocytomas are almost hypodense. Thus Medulloblastoma can frequently be differentiated from cerebellar Astrocytomas with the use of CT scanning.⁷³

Richard b. Schwartz in 1995 observed that small Meningiomas are better visualized on CT than MR image. They also said that Craniopharyngiomas were easily detected by CT because of the presence of calcification.⁷⁴

David Sutton et al, in 1998, states that meningioma is the commonest benign intracranial tumours. Appearances of Meningiomas on CT are sufficient to permit specific diagnosis in over 95% of cases. And also mentioned that calcification is more common in dermoid, so better demonstrated by CT.⁷⁵

CT scan can detect over 90% brain tumors, small tumors (< 0.5 cm), tumors adjacent to bone such as pituitary Adenomas, Clival tumours and vestibular schwannomas, brainstem tumours, and low grade Astrocytomas maybe missed and are better detected by the more sensitive MRI.⁷⁶

Thus CT and MRI play a vital role in the diagnosis of brain lesions and should be employed as primary imaging modalities.

However, computed tomography remains, the most widely used form of neuroimaging for the diagnosis of brain tumours due to its wider availability and lower costs, although MR imaging is used with increasing frequency.⁷⁶

MDCT scan:

Computer navigation systems are powerful surgical tools in spinal instrumentation surgery. Advances in three-dimensional (3d) image reconstruction and computer science have, over the past several years, allowed for the application of such image-guided systems to clinical problem solving, and surgeons performing spine surgery have found procedures involving computer

navigation systems to be superior to conventional methods in terms of improved safety and accuracy of pedicle screw insertion.

Numerous clinical trials of CT-based spinal-navigation systems have been reported^{77,78,79,80,81,82,83,84,85,86} and fluoroscopy-based navigation systems have been recently applied to computer-aided spine surgery^{87,88}. Although fluoroscopy-based navigation systems do not require preoperative CT imaging or registration, CT-based navigation systems offer advantages of precise preoperative planning and 3d visualization of patient anatomy in the operating room. CT-based navigation systems were developed to avoid misplacement of pedicle screws, and all of these systems use some type of 3d localizer, involving optical^{89,90,91} magnetic⁹² or sonic techniques⁹³.

Current CT-based navigation systems typically include a measurement process for sampling patient-specific medical data, a decision-making process for generating the surgical plan, a registration process for aligning the surgical plan to the patient, and an action process for accurately achieving the goals specified in the plan.

Some authors have reported that computed tomography (CT)-guided cervical trans-foraminal steroid injection through a posterior approach is safe and effective and is more effective than a C-arm guided procedure with respect to reducing pain and improving functional status in instances of cervical disc herniation^{94,95}. C-arm fluoroscopy is relatively inexpensive and is easy to apply, but has disadvantages, this procedure depends solely on bony anatomical landmarks⁹⁶. CT fluoroscopically guided injection provides excellent anatomical resolution and more precise needle placement in the axial plane. Detection and avoidance of important vascular structures (i.e., jugular, vertebral, and carotid vessels) are thus enabled during needle advancement into the outer neural foramen, facilitating meticulous needle delivery to the posterior aspect of the neural

foramen^{97,98}. On the other hand, CT-guided procedures have been hampered by an inability to show the spread of contrast media in real time and by the need for expensive equipment. Furthermore, there have been no related studies of cost-effectiveness effect. Recently, high-resolution ultrasound has been used successfully to identify the targeted nerves, neighboring blood vessels, and anatomic planes, and to permit real-time guidance of needle insertion, without exposure to radiation hazards⁹⁹. However, anatomic structures obscured by bony surfaces cannot be detected by ultrasound.

Role of MDCT scan in cervical pedicle morphometry:

Morphometric measurements based on CT scans are more efficient in determining pedicle dimensions than manual caliper measurements.^{100,101,102} CT scans may be able to avoid possible deviations in disc height by post-mortem changes such as dehydration and altered tonus of the soft tissue.¹⁰³ previous studies targeted areas at the coronal or sagittal planes for spiral ct.^{104,103,105} although it can display the character of the vertebral anatomy, subjective selection error always appears due to deficiency of scan precision and choice of target area. Mimics software is compatible with data of various types of machines (e.g. CT or MRI) and 3-d reconstruction, region segmentation, output conversion, surface meshing, body meshing and processing, detailed data analysis for anthropometric templates, and osteotomy simulation can be viewed directly. The first step in screw placement for cervical pedicle fixation is to find an accurate entrance point. There are many measurements of cervical vertebrae and pedicles through different methods.^{100,101,106,107,102}

CT analysis of the cervical spine to provide accurate measurements on sagittal canal diameter (scd), right and left transverse foramens' sagittal (sfd) and transverse (tfd) diameters and distance between spinal canal and transverse foramens (dsc-tf) for each level of the cervical spine, from C1-C7. These data could serve as useful tools for preoperative planning, regarding the surgical approach and screw orientation to the cervical spine.¹⁰⁸

Indian studies of role of MDCT scan in cervical pedicle morphometry:

Ajay Kumarmahto and Saifomar¹⁰⁹ (2015) studied on the clinico-anatomical approach for instrumentation of the cervical spine and observed that the height of the vertebral bodies was observed to be larger at lower levels. Maximum anteroposterior length and transverse length were observed at C6 and C5, respectively. They concluded that the knowledge of both morphology and morphometry of typical cervical vertebrae is imperative for developing instrumentation related to the cervical spine. Ethnic variations have been reported in these dimensions.

Narendra Kumar Bhambri et al¹¹⁰ (2015) studied the morphometric analysis of diameter and relationship of vertebral artery with respect to transverse foramen in Indian population and observed that the largest vertebral artery diameter (al) was at level C7 on the right side (3.5 ± 0.8) and at the level of C5 on the left side (3.7 ± 0.4). Statistically significant difference between males and females were seen at levels C4, C5, and C7. The diameter of the vertebral artery was smaller in females than males. The l value was greater than other parameters (m, a, p) at the same level in all the measurements. The h value was greatest at C6 level and shortest at C5. They concluded that the CTA is necessary before pedicle screw fixation due to variation in

measurements at all levels. The highest potential risk of vertebral artery injury during cervical pedicle screw implantation may be at C5, then at C4, and safest at C7.

Partha Sarathi Banerjee et al¹¹¹ (2012) studied the morphometric analysis of the cervical spine of Indian population by using computerized tomography and they reported that the 15 important morphological parameters have been measured. These values have been tabulated and their mean, standard deviation and range of variation have been computed. It has been found that pedicle dimensions of Indian people are smaller at almost all vertebra levels as compared to Caucasian people. Pedicle axis length for Indian people are found to be smaller at C3, C4 and C5 levels than those for other Asian people including Chinese people, but it is bigger at C6 and C7 levels. Indian people have longer measurements of pedicle length + lateral mass on an average than their other Asian counterparts at C5, C6 and C7 levels, but shorter measurements at C3 and C4 levels. The results of the present work may help in better understanding of morphological parameters of cervical spine region of Indian population. It may be further useful in designing spinal implants which would be biomechanically compatible to the anatomy of Indian people.

S Rajasekaran et al¹¹² (2007) studied the intra-operative iso-c 3d navigation for pedicle screw instrumentation of Hangman's fracture and they reported that the successful treatment of an unstable Hangman's fracture with posterior pedicle screw fixation using iso-c 3d fluoroscopy-based computer navigation guidance. Postoperative computed tomographic images confirmed accurate placement of the pedicle screws. The navigation system is useful, especially in an unstable upper cervical spine injury where the likelihood of change in the inter-segmental relationship is maximal before and after positioning for surgery. The navigation system has the advantage of data acquisition after patient positioning, thus making safe pedicle fixation of the C1 and C2 vertebrae possible despite fractured posterior elements.

Worldwide studies of role of MDCT scan in cervical pedicle morphometry:

Munusamy T et al¹¹³ (2015) studied the computed tomographic morphometric analysis of cervical pedicles in a multi-ethnic Asian population and relevance to sub-axial cervical pedicle screw fixation and observed that smallest mean pedicle width (pw) was at C4 in males and C3 in females. Mean pw for males was significantly greater than females at all levels 8 % of our population had at least one pw < 4.00 mm. At C5, C6 and C7 there is zero percent incidence of pw < 4.00 mm. The mean pedicle height (ph) in males was significantly greater than females at all levels, but no statistically significant sex differences in mean pedicle transverse angle (pta) values were found. There were significant ethnic differences in mean pw of males at C4, C5 and C7 and mean ph of females at C3, C4 and C7. They concluded that the trans-pedicular screw fixation is generally feasible in their population except for 8 % with at least one pw < 4.00 mm. However, in view of significant sex and ethnic morphometric variability, pre-operative CT evaluation together with image-guided screw placement is highly advised to ensure safety and accuracy.

Pongsthorn Chanplakorn et al¹¹⁴ (2014) studied the morphometric evaluation of sub-axial cervical spine using multi-detector computerized tomography (MDCT) scan and observed that the mean outer pedicle width (opw) and inner pedicle width (ipw) significantly increased from C3 to C7 while the mean outer pedicle height (oph) and inner pedicle height (iph) of those showed non-significant difference between any measured levels. The medial-lateral cortical thickness was significantly smaller than the superior-inferior one. Pedicle transverse angle (pta) in the upper cervical spine was significantly wider than the lower ones. The pedicle sagittal angle (psa) changed from upward inclination at upper cervical spine to the downward inclination at lower cervical spine. They concluded that the cervical vertebra has relatively small and narrow

inner pedicle canal with thick outer pedicle cortex and also shows a variable in pedicle width and inconsistent transverse angle. To enhance the safety of cervical pedicle screw (cps) insertion, the entry point and trajectories should be determined individually by using preoperative MDCT scan and the inner pedicle width should be a key parameter to determine the screw dimensions.

Masashiuehara et al¹¹⁵ (2012) studied the computer-assisted C1-C2 trans-articular screw fixation "Magerl technique" for atlantoaxial instability and observed that the evaluation of screw insertion by CT revealed correct penetration to atlantoaxial joints, with a perforation rate of 2.6%. There was no complication, including vertebral artery tear, and all patients who were followed-up during one year or more after surgery achieved bony fusion. Some subjects who appeared inappropriate for surgery from CT images were assessed as eligible for surgery based on the evaluation results obtained using the navigation system. They concluded that the CT-based navigation system is an effective support device for Magerl's procedure.

Bazaldua c. J. J. Et al¹¹⁶ (2011) studied the morphometric study of cervical vertebrae C3-C7 in a population from northeastern Mexico and they reported that 150 cervical vertebrae (C3-C7) obtained from a northeastern Mexican population to determine the dimensions of the bodies, pedicles, laminae, spinous processes, and superior and inferior articular processes. They did not find significant differences in measurements taken on the left and right sides. The dimensions of the vertebral bodies were larger at lower levels. The pedicles of the C3 vertebra were larger in all dimensions compared to the other vertebrae. The largest height of the laminae was observed at C7 and the largest transverse length was observed at C5. The dimensions of the bodies, spinous processes, and laminae increased from C3-C7, whereas the dimensions of the pedicles and superior and inferior articular process height decreased toward the lower cervical levels.

Chern, Joshua J et al ¹¹⁷ (2009) studied the computed tomography morphometric analysis for axial and sub-axial translaminar screw placement in the pediatric cervical spine and observed that the mean laminar heights at C-2, C-3, C-4, C-5, C-6, and C-7, respectively, were 9.76 $\pm$ 2.22 mm, 8.22 $\pm$ 2.24 mm, 8.09 $\pm$ 2.38 mm, 8.51 $\pm$ 2.34 mm, 9.30 $\pm$ 2.54 mm, and 11.65 $\pm$ 2.65 mm. Mean laminar thickness at C-2, C-3, C-4, C-5, C-6, and C-7, respectively, were 5.07 $\pm$ 1.07 mm, 2.67 $\pm$ 0.79 mm, 2.18 $\pm$ 0.73 mm, 2.04 $\pm$ 0.60 mm, 2.52 $\pm$ 0.66 mm, and 3.84 $\pm$ 0.96 mm. In 50.7% of C-2 laminae, the anatomy could accept at least 1 translaminar screw (laminar thickness $\geq$ 4 mm). They concluded that the anatomy in 30.4% of patients younger than 16 years old could accept bilateral C-2 translaminar screws. However, the anatomy of the sub axial cervical spine only rarely could accept translaminar screws. The study establishes anatomical guidelines to allow for accurate and safe screw selection and insertion. Preoperative planning with thin-cut CT and sagittal reconstruction is essential for safe screw placement using this technique.

Zhu ruofu et al¹¹⁸ (2008) studied the CT evaluation of cervical pedicle in a Chinese population for surgical application of trans-pedicular screw placement and they reported that the dimensions of the pedicles (C3-C7) were determined in 60 patients from CT images of cervical spinal lesions. Measurements of pedicle height, width, pedicle axis length, effective length, and two angles of the pedicles, the distances from the projection point of the pedicle axis to the lateral edge of the lateral mass and to the inferior edge of the superior facet were measured. The smallest outer pedicle width was found at C3 among the female and C4 among the male. This measurement was significantly different between male and female patients in the outer pedicle width at C3 and C4. The mean values of the outer pedicle width ranged from 5.4 to 6.7 mm in males, and 4.4 to 6.3 mm in females. The projection point of the pedicle axis in the lateral-

superior area of the cervical lateral mass was the most important. There were significant correlations between the vertebral level and both pedicle angles. The smallest pedicle transverse angle was at C7 in males and females. The cervical spinal cord or vertebral artery may be at risk of injury if the angulation of the screw insert is over-medial or over-lateral in the transverse plane. Therefore, preoperative CT evaluation of pedicle transverse angle is very important. Considering the amount of variation among individuals, the data on CT measurements of pedicle in a Chinese population in conjunction with evaluation of the results of preoperative CT may enhance the safety of trans-pedicular screw fixation in the lower cervical spine.

MATERIAL AND METHOD

Study Design: A prospective intervention study,

Study Location: Department of Orthopaedics and Radio Diagnosis, R.L.Jalappa hospital, Sri Devaraj URS medical college.

Study duration: November of 2013 to July 2015.

Patient selection: Clinical evaluation of patients with characteristic injury patterns which are commonly include odontoid, teardrop, facet and hangman's fractures were selected for further treatment. CT-scans were performed with the patient supine and the neck at a neutral position.

Sample Size: 200 patients

Sample size calculation: 200 patients with clinical diagnosis of cervical spine pathology were selected. The target population from which we can randomly select our sample was considered to be 3000. We assumed to test our results at the 95% confidence level and prepared to accept a margin of error of $\pm 10\%$. The sample size actually obtained for this study was 200 patients. We plan to include 200 patients with 10 % drop out rate.

Inclusion criteria:

1. Age group above 18 yrs.
2. Subjects with cervical spine fractures, cervical spine pain indicating CT requirement viz. cervical myelopathy.

Exclusion criteria:

1. Patients with more than one pedicle fracture in the same level cervical spine were excluded from the study.
2. Patients with an evidence or history of previous cervical spine surgery, infections, neoplasms, trauma or congenital spinal anomalies

Study tools:

1. Predesigned Proforma (Annex 1)
2. Informed consent (Annex 2)
3. CT machine- 16 slice Siemens Somaton.

Clinical evaluation of patients

Current protocols for evaluation of suspected cervical spine injury included history, clinical examination and radiographic evaluation to predict the presence of instability, identify neurological deficits and guide the need for intervention. During the course of evaluation, patients was maintained in a supine position with rigid collar immobilization or other stable neutral immobilization, while standard Advanced Trauma Life Support protocols were performed. The immediate clinical examination of the spine should include inspection and palpation of the spine, as well as a complete neurological examination. In addition cranial nerve examination was performed.

Radiographic evaluation

Plain radiographs included lateral, AP and odontoid views .

Key radiographic features need to be assessed:

1. The presence of soft tissue swelling anterior to the vertebral bodies;
2. Loss of the normal smooth cervical lordosis with special attention to the normal lordotic lines
3. Disc space narrowing
4. Segmental kyphosis

The information from these evaluations provided indirect assessments of spinal stability. Stability of the spine has been defined by White and Panjabi as “the ability of the spine under physiologic loads to maintain an association between vertebral segments in such a way that there is neither damage nor subsequent irritation of the spinal cord or nerve roots and, in addition, there is no development of incapacitating deformity or pain due to structural changes.” Given this framework, they have provided a scoring system that has been widely adopted in predicting the presence of instability on cervical radiographs with evidence of segmental kyphosis greater than 11 degrees and antero-listhesis greater than 3.5 mm of one vertebral body on another as strong indicators of instability.

Methodology & Procedure:-

Eight important anatomic dimensions have been identified, which are significant from view-point of spinal surgery:

PL – L = Pedicle length (Left)

PL – R = Pedicle length (Right)

PDW – L = Pedicle width (Left)

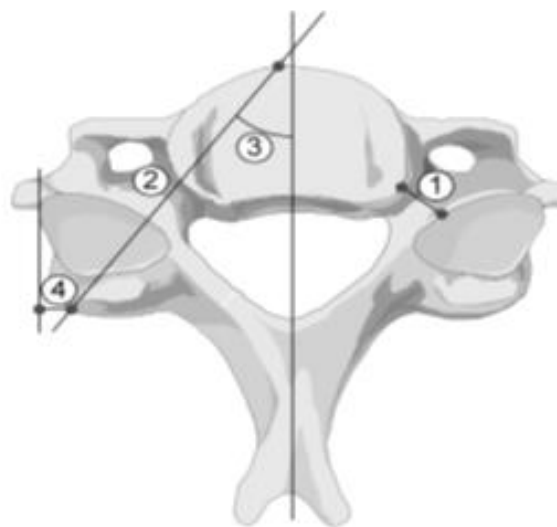
PDW – R = Pedicle width (Right)

PDH – L = Pedicle height (Left)

PDH – R = Pedicle height (Right)

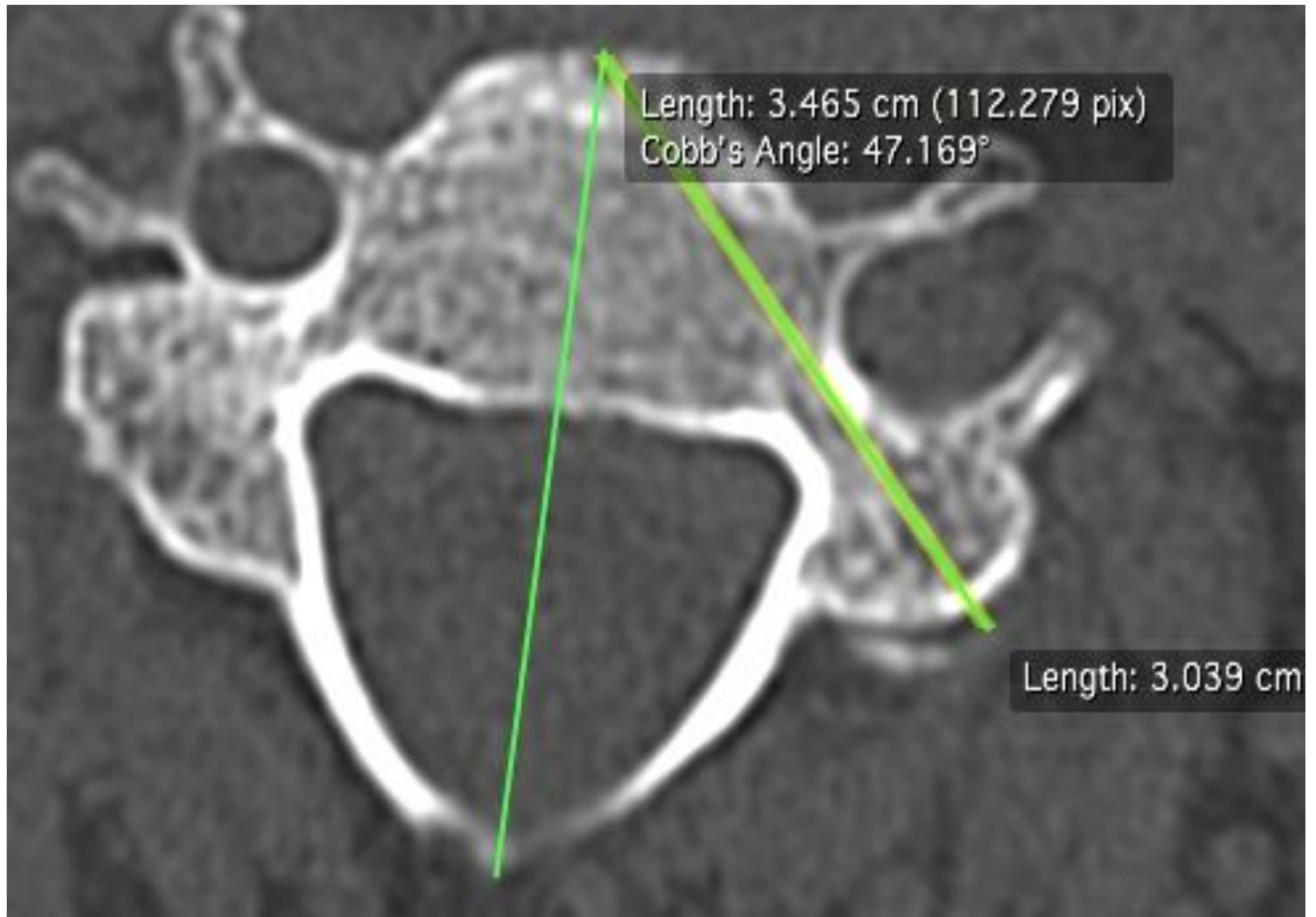
PTA – L = Pedicle transverse angle (Left)

PTA – R = Pedicle transverse angle (Right)



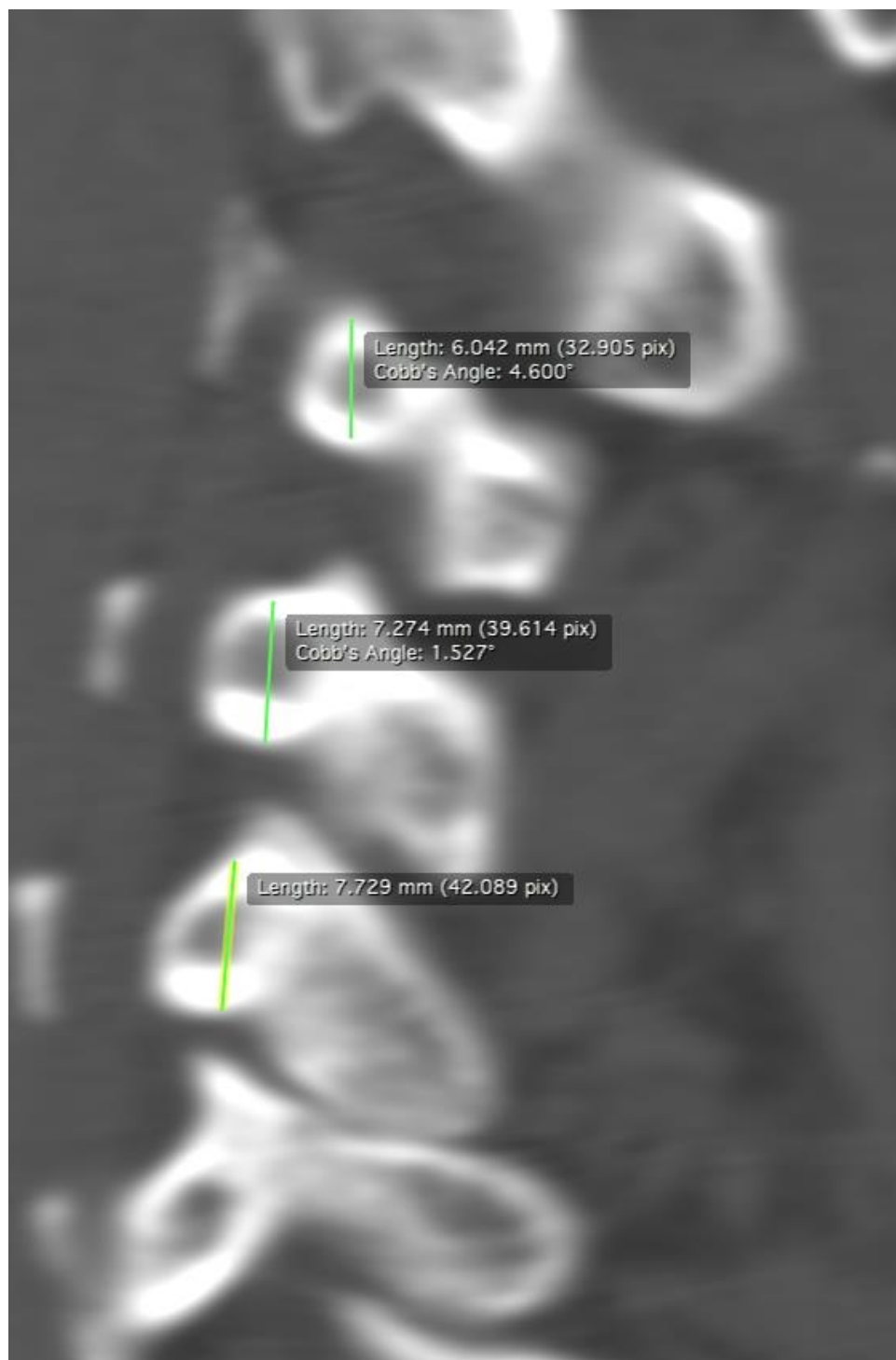
1.pedicle length,
2.pedicle
axis length
3. pedicle transverse angulation

FIGURE-17



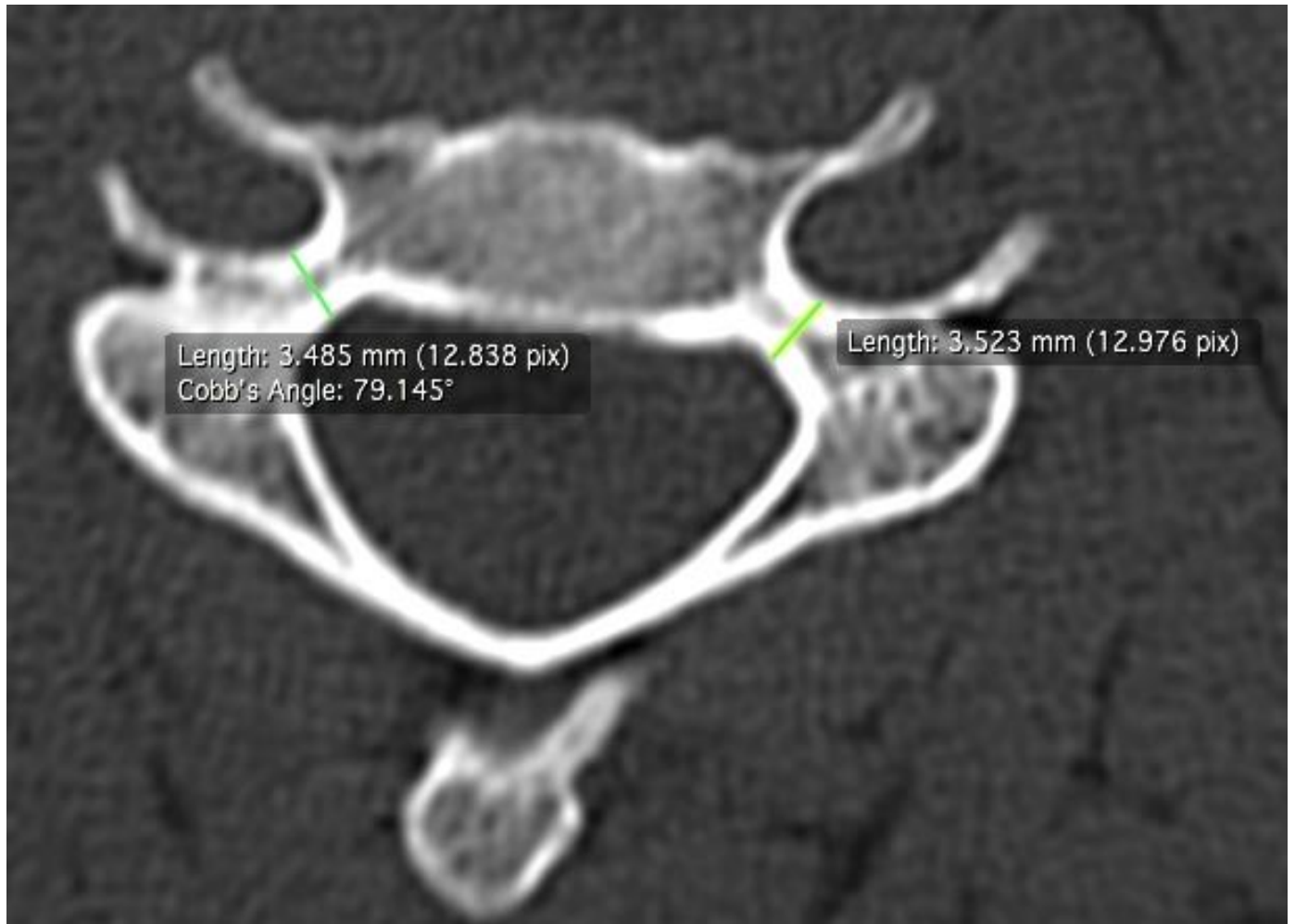
PEDICULAR LENGTH AND TRANSVERSE ANGULATION

FIGURE-18



PEDICULAR HEIGHT

FIGURE -19



PEDICULAR WIDTH

FIGURE-20

These parameters have been measured (for each of five cervical vertebrae, C3 to C7) from the CT scan data of the patients, by using MIMICS soft-ware. Degenerative problem is very rare at C1 and C2 level and it is prevalent at the lower cervical spine i.e. from C3 to C7 level.

CT PROTOCOL: The cervical CT scans were performed by using a CT scanner (Siemens 16slice CT machine). Axial CT images were obtained with 1-mm slice thickness. Reconstruction into sagittal and coronal planes was then performed to measure various cervical parameters as described by Reinhold et al.¹¹⁹ The vertical reconstructions along the plane of longitudinal pedicle axis (LPA) were obtained to measure the pedicle sagittal angle (PSA), the angle between the lower cervical endplate and the longitudinal pedicle axis. Then, the axial reconstructions of the plane perpendicular to the LPA at the pedicle isthmus were employed to measure the outer pedicle height (OPH) and inner pedicle height (IPH). The axial images at the level of pedicle were obtained for the measurement of the outer pedicle width (OPW), inner pedicle width (IPW) and the pedicle transverse angle (PTA), the angle between the sagittal plane and LPA. All of the paired cervical pedicle parameters were measured individually for the left and the right sides using the digital measurement software at the CT work station.



FIGURE-21

16slice Siemens CT machine

Statistical analysis

The data obtained were analyzed using SPSS software version 20.0 for Windows (SPSS, Chicago, IL). All the results were expressed in mean $\pm$ SD and Frequency (%). All these measurements were taken in millimeters and degrees. The mean and standard deviations for each side was calculated and student 't' test was used to determine the difference between right and left side. As there was no significant statistical difference between the parameters for right and left side; hence the data was pooled together¹²⁰. p value of <0.05 was considered as significant.

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Observation and results

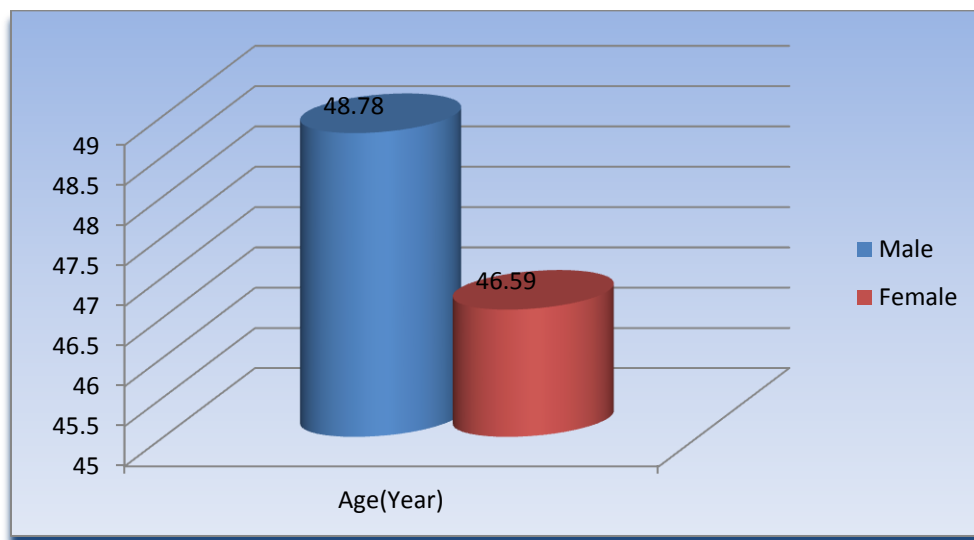
Table-1 Shows age and gender distribution of studied patients. 105 male patients of age ranging from 18-77 years, mean age 48.78 ± 9.4 years and 90 female patients of age ranging from 24-79 years, mean age 46.59 ± 9.1 years were inducted for study. The age variation between male and female patients was not statistically significant, $P=0.101$.

Table 1 Shows age and sex distribution of studied patients

Gender	Frequency	Mean Age (Range)	P-value
Males	105	48.78 ± 9.4 (18-77)	0.101
Females	90	46.59 ± 9.1 (24-79)	
Total	200	46.73 ± 9.2 (18-79)	

SD= standard deviation, age in year.

Chart no 1 bar graph shows age and sex distribution.



CT Findings:

Table -2 Shows pedicle length (PL) (in mm) of studied patients. CT Findings of spinal vertebrae C3 to C7, for length of both sides right & left as also for both categories of patients, male & female, were recorded. The mean left side length of C3 vertebra for male patients was 4.85 ± 0.4 mm range 2.75-5.98 mm, the corresponding measurement for female patients was 3.61 ± 0.5 mm range 2.12-5.16. Similarly the mean left side length of C4 vertebra for male patients was 4.96 ± 0.7 mm range 2.82-5.97 mm, the corresponding length for female patients was 3.72 ± 0.6 mm range 2.32-5.626. The mean length of left side of C5 vertebra for male patients was 5.16 ± 0.3 mm range 3.22-6.86 mm, the corresponding length for female patients was 4.14 ± 0.4 mm range 2.44-5.86. For C6 vertebra left side length of male patients was 5.37 ± 0.5 mm range 3.42-6.82 mm, the corresponding length for female patients was 4.18 ± 0.3 mm range 2.36-5.63 and left side length of C7 vertebra for male patients was 5.29 ± 0.3 mm range 3.44-6.98 mm, the corresponding measurement for female patients was 4.68 ± 0.4 mm range 2.56-6.26. Similarly mean right side length measurements of spinal vertebrae C3—C7 for male and female patients were 5.34 ± 0.3 mm, 3.76-6.86 mm, & 4.48 ± 0.4 mm, 2.24-5.68 mm for C3, 5.39 ± 0.2 , 3.55-6.44 mm, & 4.36 ± 0.3 mm, 3.55-6.44 for C4, 5.54 ± 0.3 mm, 3.66-6.46 mm, & 4.76 ± 0.3 mm, 2.56-5.87 for C5, 5.76 ± 0.5 mm, 3.86-6.84 mm, & 4.78 ± 0.4 mm, 2.63-5.46 mm for C6 and 5.49 ± 0.3 mm, 3.87-6.98 mm, & 4.69 ± 0.4 mm, 2.88-5.64 mm for C7 for male and female patients respectively.

Table 2 Shows pedicle length (PL) (in mm) of studied patients.

		Left		Right	
		Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
C3	Male	4.85 $\pm$ 0.4	2.75-5.98	5.34 $\pm$ 0.3	3.76-6.86
	Female	3.61 $\pm$ 0.5	2.12-5.16	4.48 $\pm$ 0.4	2.24-5.68
C4	Male	4.96 $\pm$ 0.7	2.82-5.97	5.39 $\pm$ 0.2	3.55-6.44
	Female	3.72 $\pm$ 0.6	2.32-5.62	4.36 $\pm$ 0.3	2.76-5.89
C5	Male	5.16 $\pm$ 0.3	3.22-6.86	5.54 $\pm$ 0.3	3.66-6.46
	Female	4.14 $\pm$ 0.4	2.44-5.86	4.76 $\pm$ 0.3	2.56-5.87
C6	Male	5.37 $\pm$ 0.5	3.42-6.82	5.76 $\pm$ 0.5	3.86-6.84
	Female	4.18 $\pm$ 0.3	2.36-5.63	4.78 $\pm$ 0.4	2.63-5.46
C7	Male	5.29 $\pm$ 0.3	3.44-6.98	5.49 $\pm$ 0.3	3.87-6.98
	Female	4.68 $\pm$ 0.4	2.56-6.26	4.69 $\pm$ 0.4	2.88-5.64

SD= standard deviation, mm= millimeter

Chart no 2 line graph shows nature of variation of pedicle length (PL).

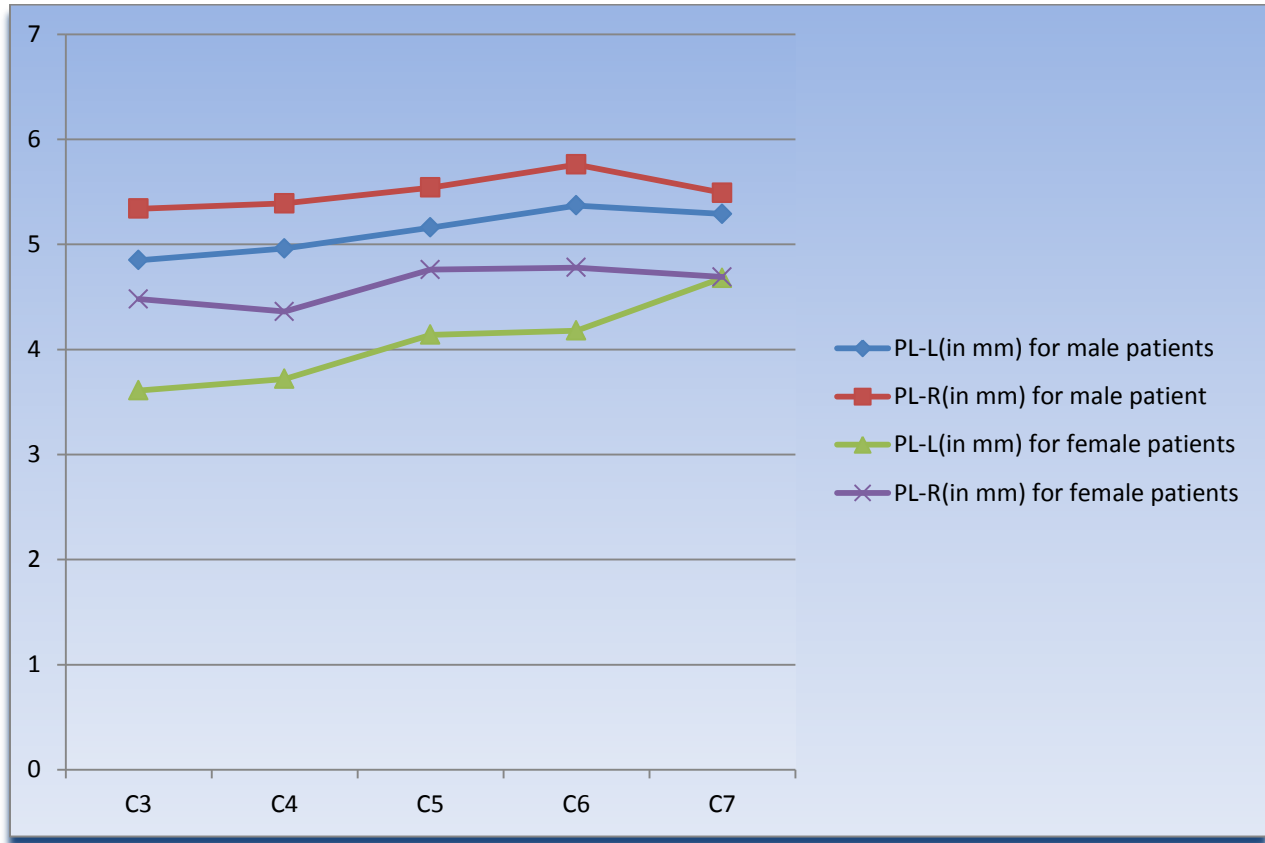


Table no 3 Shows nature of variation of pedicle width (PDW). CT Findings of spinal vertebrae C3 to C7, for pedicle width of both sides right & left as also for both genders of patients were recorded. The mean pedicle width of left side of C3 vertebra for male patients was 5.12 ± 0.5 mm range 3.16-7.18 mm, and the corresponding measurement for female patients was 4.14 ± 0.3 mm & 2.24-6.68. Similarly mean left side pedicle width of C4 vertebra for male patients was 5.18 ± 0.4 mm range 3.14-7.62 mm, the length for female patients was 4.17 ± 0.5 mm & 2.62-6.71 respectively. The mean left side pedicle width of C5 vertebra for male patients was 5.35 ± 0.6 mm range 3.46-7.36 mm, the corresponding pedicle width for female patients was 4.48 ± 0.5 mm & 2.84-6.68. For C6 vertebra left side pedicle width of male patients was 5.52 ± 0.4 mm range 3.54-8.63 mm, the corresponding pedicle width for female patients was 4.56 ± 0.5 mm & 2.38-6.94 respectively. And left side pedicle width for C7 vertebra for male patients was 5.91 ± 0.6 mm range 4.76-8.63 mm, the corresponding measurement of pedicle width for female patients was 5.28 ± 0.5 mm & 3.86-7.85. Similarly mean right side pedicle width measurements of spinal vertebrae C3—C7 for male and female patients were 4.82 ± 0.3 mm, 3.04-7.72 mm, & 4.23 ± 0.4 mm, 2.67-6.88 mm for C3, 4.88 ± 0.6 , 3.44-7.84 mm, & 4.27 ± 0.8 mm, 2.12-6.56 for C4, 5.15 ± 0.4 mm, 3.53-8.46 mm & 4.45 ± 0.5 mm, 2.23-7.51 for C5, 5.62 ± 0.7 mm, 3.63-7.68 mm, & 4.56 ± 0.6 mm, 2.32-7.32 mm for C6 and 5.83 ± 0.5 mm, 3.48-8.24 mm, & 5.38 ± 0.4 mm, 4.23-8.16 mm for C7 for male and female patients respectively.

Table no 3 Shows nature of variation of pedicle width (PDW).

		Left		Right	
		Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
C3	Male	5.12 $\pm$ 0.5	3.16-7.18	4.82 $\pm$ 0.3	3.04-7.72
	Female	4.14 $\pm$ 0.3	2.24-6.68	4.23 $\pm$ 0.4	2.67-6.88
C4	Male	5.18 $\pm$ 0.4	3.14-7.62	4.88 $\pm$ 0.6	3.44-7.84
	Female	4.17 $\pm$ 0.5	2.62-6.71	4.27 $\pm$ 0.8	2.12-6.56
C5	Male	5.35 $\pm$ 0.6	3.46-7.36	5.15 $\pm$ 0.4	3.53-8.46
	Female	4.48 $\pm$ 0.5	2.84-6.68	4.45 $\pm$ 0.5	2.23-7.51
C6	Male	5.52 $\pm$ 0.4	3.54-8.63	5.62 $\pm$ 0.7	3.63-7.68
	Female	4.56 $\pm$ 0.5	2.38-6.94	4.56 $\pm$ 0.6	2.32-7.32
C7	Male	5.91 $\pm$ 0.6	4.76-8.63	5.83 $\pm$ 0.5	3.48-8.24
	Female	5.28 $\pm$ 0.5	3.86-7.85	5.38 $\pm$ 0.4	4.23-8.16

Chart no. 3 line graph shows nature of variation of pedicle width (PDW).

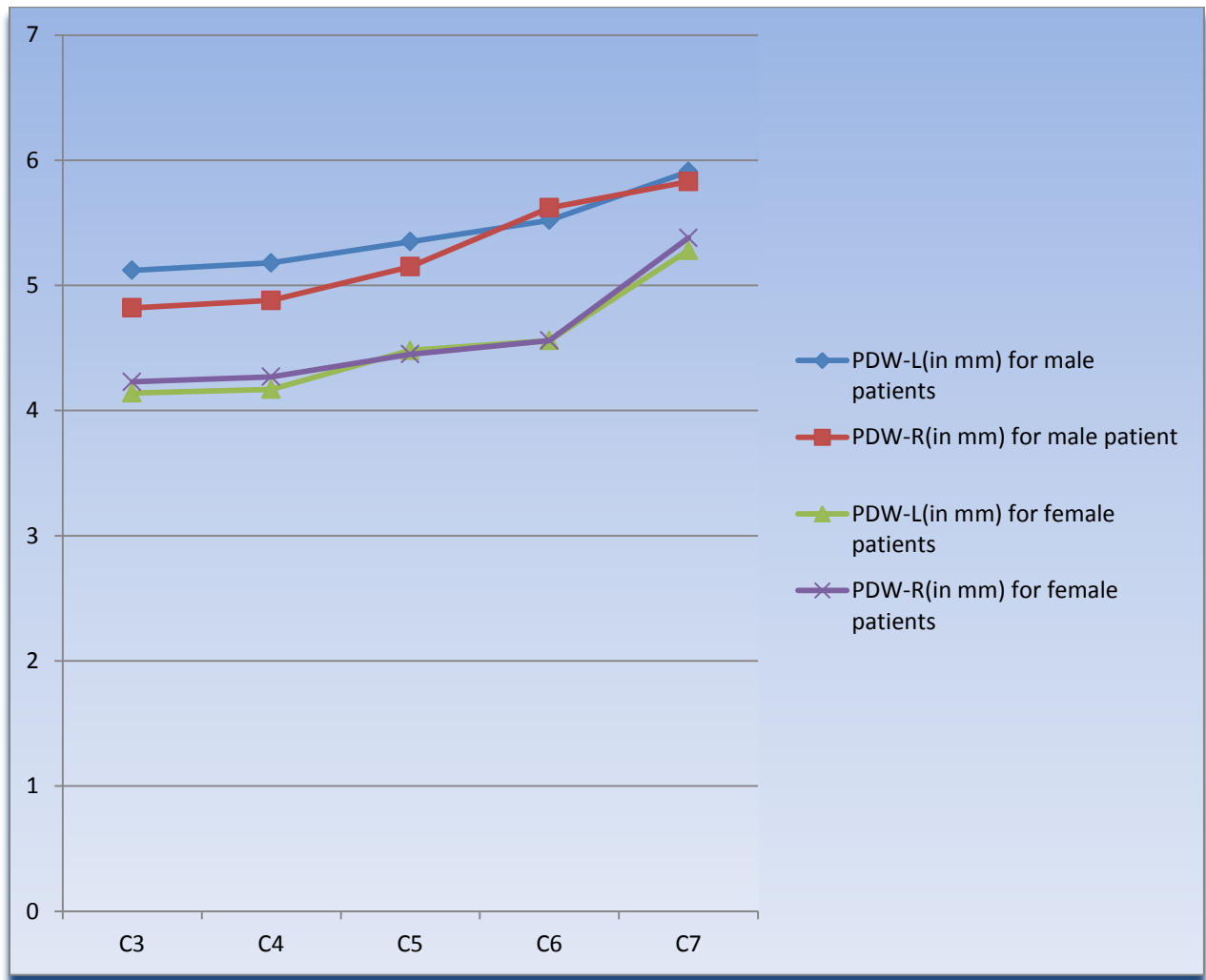


Table no 4 Shows nature of variation of pedicle height (PDH). The mean left side pedicle height of C3 vertebra for male patients was 6.81 ± 0.5 mm range 4.76-8.23mm, and the corresponding measurement for female patients was 6.44 ± 0.3 mm & 4.36-8.18. Similarly mean left side pedicle height of C4 vertebra for male patients was 6.92 ± 0.5 mm range 4.76-9.26 mm, and the corresponding pedicle height for female patients was 5.93 ± 0.4 mm & 4.12-8.24. The mean left side pedicle height of C5 vertebra for male patients was 7.07 ± 0.3 mm range 5.04-9.56mm, the corresponding pedicle height for female patients was 6.72 ± 0.4 mm & 4.56-8.85. For C6 vertebra left side pedicle height of male patients was 6.84 ± 0.4 mm range 4.82-9.24 mm and ,the corresponding pedicle height for female patients was 5.76 ± 0.3 mm & 3.98-8.16 and left side pedicle height of C7 vertebra for male patients was 6.94 ± 0.2 mm range 4.56-8.36 mm, the corresponding measurement of pedicle height for female patients was 5.89 ± 0.4 mm & 4.43-8.42. Similarly mean right side pedicle height measurements of spinal vertebrae C3—C7 for male and female patients was 6.46 ± 0.4 mm, 4.23-8.56mm ,& 6.18 ± 0.5 mm, 4.06-8.28mm for C3 , 6.72 ± 0.4 , 4.27-8.48mm, & 5.26 ± 0.7 mm, 4.12-8.27 for C4, 6.81 ± 0.5 mm,, 4.67-8.69,mm& 5.54 ± 0.3 mm, 4.15-8.42 for C5, 6.81 ± 0.5 mm, 4.67-8.96mm,& 5.48 ± 0.6 mm, 4.05-8.66mm for C6 and 6.92 ± 0.7 mm, 4.77-8.96mm,& 5.86 ± 0.4 mm, 4.21-8.43mm for C7 vertebra for male and female patients respectively.

Table no 4 Shows nature of variation of pedicle height (PDH).

		Left		Right	
		Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
C3	Male	6.81 $\pm$ 0.5	4.76-8.23	6.46 $\pm$ 0.4	4.23-8.56
	Female	6.44 $\pm$ 0.3	4.36-8.18	6.18 $\pm$ 0.5	4.06-8.28
C4	Male	6.92 $\pm$ 0.5	4.76-9.26	6.72 $\pm$ 0.4	4.27-8.48
	Female	5.93 $\pm$ 0.4	4.12-8.24	5.26 $\pm$ 0.7	4.12-8.27
C5	Male	7.07 $\pm$ 0.3	5.04-9.56	6.81 $\pm$ 0.5	4.67-8.69
	Female	6.72 $\pm$ 0.4	4.56-8.85	5.54 $\pm$ 0.3	4.15-8.42
C6	Male	6.84 $\pm$ 0.4	4.82-9.24	6.81 $\pm$ 0.5	4.67-8.96
	Female	5.76 $\pm$ 0.3	3.98-8.16	5.48 $\pm$ 0.6	4.05-8.66
C7	Male	6.94 $\pm$ 0.2	4.56-8.36	6.92 $\pm$ 0.7	4.77-8.96
	Female	5.89 $\pm$ 0.4	4.43-8.42	5.86 $\pm$ 0.4	4.21-8.43

Chart no. 4 line graph shows nature of variation of pedicle height (PDH).

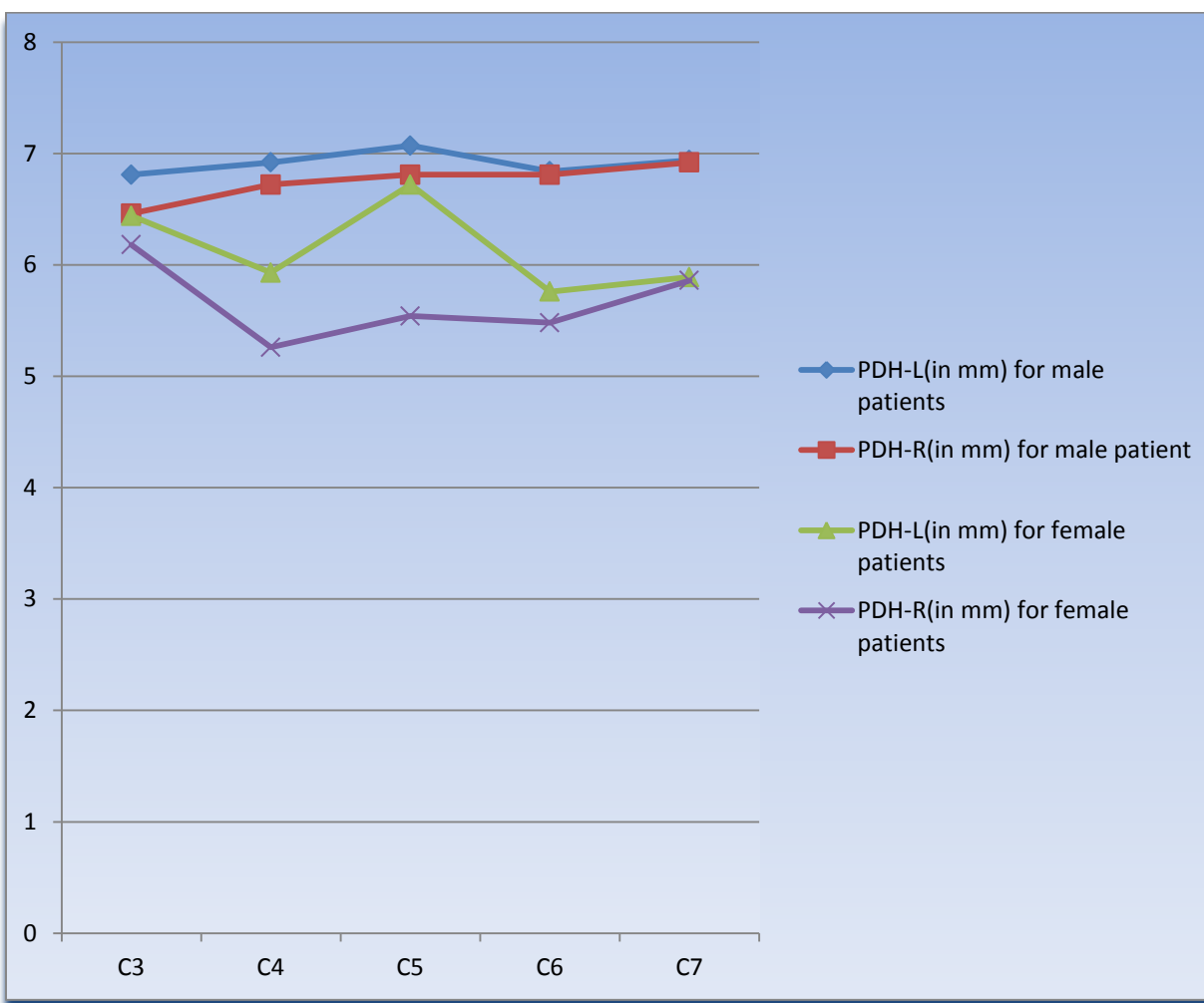


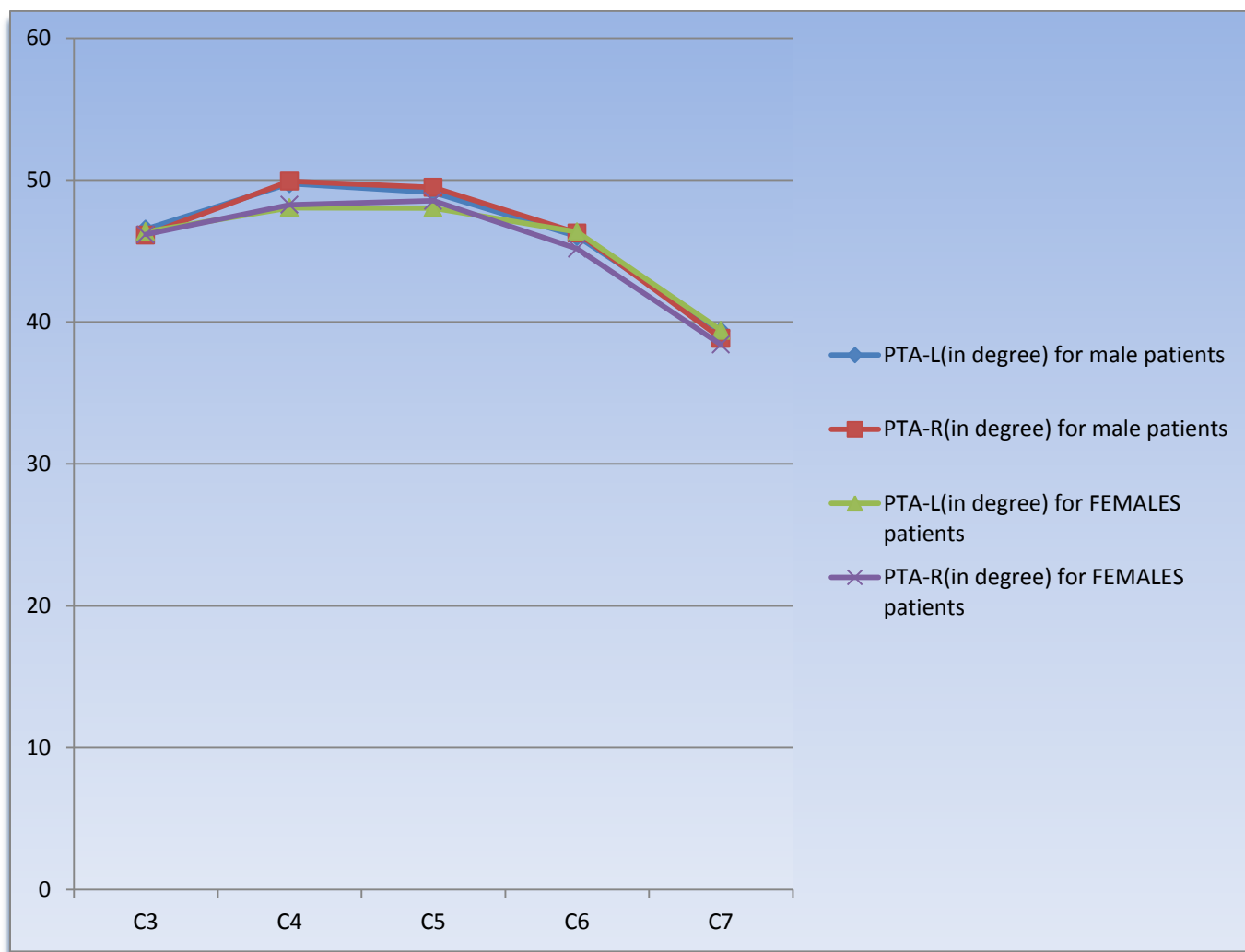
Table 5 Shows pedicle transverse angle (PTA) (in degree) of studied patients. Shows nature of variation of pedicle height (PDH). The mean left side pedicle transverse angle of C3 vertebra for male patients was 46.54 ± 3.61 range 38.67-56.62, and the corresponding measurement for female patients was 46.37 ± 3.16 & 41.85-53.91. Similarly mean left side pedicle transverse angle of C4 vertebra for male patients was 49.74 ± 3.82 mm range 40.12-59.11, and the corresponding pedicle transverse angle for female patients was 48.05 ± 3.16 & 43.31-55.98. The mean left side pedicle transverse angle of C5 vertebra for male patients was 49.13 ± 4.09 range 36.8-60.28, the corresponding pedicle transverse angle for female patients was 48.03 ± 3.78 & 43.77-57.67. For C6 vertebra left side pedicle transverse angle of male patients was 46.02 ± 4.21 range 37.4-57.1 and, the corresponding pedicle transverse angle for female patients was 46.34 ± 3.17 & 41.97-53.5 and left side pedicle transverse angle of C7 vertebra for male patients was 49.13 ± 4.09 range 29.7-50.24, the corresponding measurement of pedicle transverse angle for female patients was 48.03 ± 3.78 & 32.23-46.23. Similarly mean right side pedicle transverse angle measurements of spinal vertebrae C3—C7 for male and female patients was 46.13 ± 3.65 , 34.64-57.93, & 46.17 ± 3.35 , 42.97-55.15 for C3, 49.92 ± 4.0 , 39.78-60.73, & 48.26 ± 4.36 , 43.68-57.85 for C4, 49.48 ± 4.29 , 37.82-63.05 & 48.54 ± 3.37 , 43.73-54.4 for C5, and 46.27 ± 4.34 , 34.64-57.93, & 45.16 ± 3.96 , 33.44-52.71 for C6 and 38.86 ± 4.84 , 28.93-51.0, & 38.41 ± 4.97 , 31.6-49.05 for C7 vertebra for male and female patients respectively.

Table 5 Shows pedicle transverse angle (PTA) (in degree) of studied patients.

		Left		Right	
		Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
C3	Male	46.54 $\pm$ 3.61	38.67-56.62	46.13 $\pm$ 3.65	37.13-55.72
	Female	46.37 $\pm$ 3.16	41.85-53.91	46.17 $\pm$ 3.35	42.97-55.15
C4	Male	49.74 $\pm$ 3.82	40.12-59.11	49.92 $\pm$ 4.0	39.78-60.73
	Female	48.05 $\pm$ 3.16	43.31-55.98	48.26 $\pm$ 4.36	43.68-57.85
C5	Male	49.13 $\pm$ 4.09	36.8-60.28	49.48 $\pm$ 4.29	37.82-63.05
	Female	48.03 $\pm$ 3.78	43.77-57.67	48.54 $\pm$ 3.37	43.73-54.4
C6	Male	46.02 $\pm$ 4.21	37.4-57.1	46.27 $\pm$ 4.34	34.64-57.93
	Female	46.34 $\pm$ 3.17	41.97-53.5	45.16 $\pm$ 3.96	33.44-52.71
C7	Male	39.36 $\pm$ 4.81	29.7-50.24	38.86 $\pm$ 4.84	28.93-51.0
	Female	39.42 $\pm$ 4.36	32.23-46.23	38.41 $\pm$ 4.97	31.6-49.05

SD= standard deviation,

Chart no 5 line graph shows nature of variation of pedicle transverse angle (PTA).



DISCUSSION

Sub-axial cervical spine instability can be caused by various conditions, such as trauma, neoplasm, infection or posterior cervical decompression procedures. In many conditions, the cervical spine stabilization is needed to maintain spinal alignment.¹²¹ Although other surgical techniques such as clamp and hook plating, lateral mass screw fixation or interspinous wiring have been shown effective in stabilizing the cervical spinal column, from the mechanical perspective, the cervical trans-pedicular screw (CPS) fixation provides a stronger construction than the others and less likely to failure.¹²²

To date, CPS is one of the most advanced procedures for treatment of the cervical instability, and many recent studies have demonstrated the excellent efficacy of its application on the cervical spine surgery.^{123,124} Moreover, the advanced intra-operative imaging techniques, such as the navigation-guided spine surgery or three-dimensional image-based navigation systems, can provide a greater accuracy and safety during the CPS insertion which results in the popularity of CPS fixation among cervical spine surgeons.^{125,126}

However, CPS insertion is a technically demanding procedure, as it carries a risk of catastrophic damage to the surrounding neurovascular structures.¹²⁷ The small size of cervical pedicles and variability in the pedicle morphometry demand a careful assessment of the entry point and the angle of placement of the screws. High percentage of pedicle wall violations has been observed in experimental model¹²⁸ and even in clinical studies despite the use of intra-operative image guide navigation.^{125,126}

Therefore, a quantitative understanding of cervical pedicle morphology at different spinal levels would minimize the risk and improve the successful surgical outcome. Several studies have already been documented regarding the external dimensions and angular parameters of the

pedicles.¹³⁵ **Error! Bookmark not defined.** To best of our knowledge, there are only a few studies documenting the internal architecture of the cervical pedicle, especially the narrowest part of the cervical pedicle or isthmus¹⁴⁶ which is the crucial part to determine the trajectories and size of the pedicle screw.

A prospective intervention study carried out at department of Orthopaedics and Radio-diagnosis, of Sri R.L.Jalappa hospital with the objectives to assess the morphometry of the sub-axial cervical with objectives to assess the morphometry of the sub-axial cervical spine pedicles through computer tomography and to determine the frequency of neurovascular injuries in patients who undergo pedicular mass fixation.

Demographic data

Demographic data of present study i.e age comparison between male and female patients and gender distribution were not statistically significant. ($p>0.05$) Few studies were similar to our findings as reported by Chanplakorn et al¹²⁹, Rao RD et al¹³⁰, Banerjee PS et al¹³¹ and Chen C et al¹³². Pedicle morphometry has previously been evaluated in cadaver spines or patients who underwent surgical intervention with use of physical measurement devices^{133,134,135,136} or medical imaging modalities^{137,138,139,140}. Sample populations included older specimens or patients^{135,136,139,138}, limited sample size^{137,135,141}, or unidentified age and sex^{137,133,135,139}. Despite these differences in measurement technique and study population, our results are consistent with previous data.

The morphometry of the subaxial cervical spine pedicles through computer tomography.

As shown in table 1, the mean values of pedicle lengths have been found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right side.

Table 2 of present study shows the variation of mean values of pedicle widths through vertebrae levels from C3 to C7. Progressively increasing trend is noticed here too, which continues upto C7. Like pedicle length values, pedicle widths also are found to be smaller for women than for men, at all vertebrae levels, but the difference between left and right side is very little for both men and women.

The variation of mean values of pedicle height is shown in table 3. A little fluctuating nature is observed for women though the values are smaller than those for men. For this parameter, very little difference is observed between left and right side values for men. But, for women, some appreciable difference is noted.

Tables 6, 7 and 8 show the comparative measures of mean pedicle length, width and height of Indian males and females with those already reported in previous studies all of which dealt with European and American people as reported in below tables. From these three tables, it can be seen that the pedicle dimensions of Indian people are smaller at almost all vertebra levels as compared to Caucasian people. Since pedicle dimensions are important for trans-pedicular screw fixation and similar surgeries, this smaller size of pedicle in Indian population needs to be taken into account while planning such a surgical procedure.

Table 6. Comparison of present and previous measurements of pedicle length of cervical vertebrae

Author (Year)		Pedicle length (mean, in mm)				
		C3 level	C4 level	C5 level	C6 level	C7 level
Bozbuga et al. ¹⁴² (2004)		5.3	5.4	5.4	5.8	NA
Kayalioglu et al. ¹⁴³ (2007)		6.15	6.14	5.51	5.67	NA
Banerjee	Left side	4.89	4.87	5.09	5.42	6.19
PS et al ¹³¹	Right side	4.71	4.76	4.98	5.34	6.03
Present study	Left side	4.23	4.34	4.65	4.7	5.07
	Right side	4.91	4.87	5.15	5.27	5.09

Table 7. Comparison of present and previous measurements of pedicle height of cervical vertebrae

Author Name (Year)		Pedicle height (mean, in mm)				
		C3 level	C4 level	C5 level	C6 level	C7 level
Panjabi et al ¹³⁵ (1991)		7.4	7.4	7.0	7.3	NA
Xu, Kang et al. ¹⁴⁴ (1999)		6.4	6.5	6.1	6.0	NA
Ugur et al. ¹⁴⁵ (2000)		6.3	6.5	6.4	6.6	NA
Panjabi et al. ¹⁴⁶ (2000)		6.7	7.1	6.3	6.2	NA
Bozbuga et al. ¹⁴² (2004)		6.9	6.7	7.7	6.9	NA
Kayalioglu et al. ¹⁴³ (2007)		5.93	6.24	6.29	6.23	NA
Banerjee	Left side	6.66	6.69	6.95	6.43	6.75
PS et al ¹³¹ (2012)	Right side	6.15	6.35	6.59	6.41	6.71
Present study	Left side	6.62	6.42	6.89	6.3	6.42
	Right side	6.32	5.99	6.17	6.14	6.39

Table 8. Comparison of present and previous measurements of pedicle width of cervical vertebrae

Author Name (Year)		Pedicle width (mean, in mm)				
		C3 level	C4 level	C5 level	C6 level	C7 level
Panjabi et al ¹³⁵ (1991)		5.6	5.4	5.6	6.0	NA
Ugur et al. ¹⁴⁵ (2000) ¹³		4.9	5.2	5.3	5.7	NA
Panjabi et al ¹⁴⁶ . (2000) ¹²		4.3	4.4	4.9	5.1	NA
Bozbuga et al. ¹⁴² (2004) ⁸		4.5	4.4	4.7	4.7	NA
Kayalioglu et al. ¹⁴³ (2007)		4.16	4.57	5.03	5.28	NA
Reinhold M et al (2007) ¹⁴⁷		5.7	5.6	6.2	6.7	7.9
Rao RD et al ¹³⁰ (2008)		5.3	5.5	5.75	6.1	7.05
Liu J et al. Error! Bookmark not defined. (2010)		5.26	5.33	5.68	5.91	6.63
Banerjee PS et al ¹³¹ (2012)	Left side	4.89	4.87	5.09	5.42	6.19
	Right side	4.71	4.76	4.98	5.34	6.03
Chanplakorn et al. ¹²⁹ (2014)	Left side	4.72	4.87	5.28	5.51	6.60
	Right side	4.81	4.85	5.28	5.50	6.54
Present study	Left side	4.63	4.67	4.91	5.04	5.59
	Right side	4.52	4.57	4.8	5.09	5.60

In CT comparison also we note that mean transverse pedicle width in our study is less as compared to those reported in western population. Our measurements are in agreement with other studies in Indian population as reported by Banerjee PS et al.¹³¹, Patwardhan AR et al.¹⁴⁸ and Gupta R et al¹⁴⁹.

Transverse pedicle width in our study are smaller than those reported in other study done by Reinhold M et al (2007)^{150,151} in their study used 3.5 mm screws at all levels and reported high percentage of pedicle violations.

Table 9. Comparison of present and previous measurements of pedicle transverse angle (PTA) of cervical vertebrae

Author Name (Year)			pedicle transverse angle (mean, in degree)				
			C3 level	C4 level	C5 level	C6 level	C7 level
Liu et al ^{Error! Bookmark not defined.} (2010)	Male		46.34	47.62	46.24	43.36	37.65
	Female		45.44	46.35	46.59	43.22	36.91
Banerjee PS et al ¹³¹ (2012)	Male	Left	47.56	50.77	50.16	47	40.26
		Right	47.3	50.89	50.46	47.25	39.89
	Female	Left	47.39	49.03	49.01	47.31	40.52
		Right	47.14	49.24	49.57	46.13	39.39
Chanplakorn et al. ¹²⁹ (2014)	Male	Left	42.02	43.48	42.86	41.35	38.27
		Right	42.21	43.56	43.05	41.54	38.62
	Female	Left	42.91	44.59	44.59	42.51	39.13
		Right	43.32	44.91	45.05	42.89	39.45
Present study	Male	Left	46.54	49.74	49.13	46.02	39.36
		Right	46.13	49.92	49.48	46.27	38.86
	Female	Left	46.37	48.05	48.03	46.34	39.42
		Right	46.17	48.26	48.54	45.16	38.41

The calculated mean values, standard deviations and also ranges of variation of one morphological parameter viz. PTA (for male population) is tabulated and compared with those of two previous reports as reported by Ruofu Z et al and Liu J et al.¹⁵² **Error! Bookmark not defined.** Angular measurements of the pedicle axis in the transverse provide a quantitative description of the direction of pedicle screw insertion. In a previous study, Abumi et al. recommended that the transverse angulation should be medially inclined from 25° to 45°.¹⁵³ However, in a more recent study, Sakamoto et al. recommended screw insertion angles of approximately 50° from C3 to C6 in order to orient the screw coaxial with the pedicle axis and to reduce the risk of vertebral artery injury.¹⁵⁴ We found that transverse and sagittal plane angulations were significantly dependent on spinal level. Transverse angulation was approximately 45° at C3 through C5 and decreased caudally to approximately 33° at C7 for both sexes.

The variation in case of PTA among the gender has been demonstrated in this present study (Table 9). Males had wide angle than females but not in significant amount. However, we found that the PTA variation among C3 to C7 demonstrated the same pattern among the left and right pedicles as they had wide angle in the upper subaxial cervical spine, C3 to C5, and became slightly narrow in the lower cervical region at C6 and C7. Our results revealed the characteristic trend, which were comparable to the previous studies as reported in table 4.^{131, 129}

We assume that this result may be caused by measurement error representing the variation in pedicular axis drawing due to the relatively large dimension of the C7 internal pedicle height (IPH) and the variation among the shape of C7 vertebral endplate which may be distorted in a step of image reconstruction.

We identified larger pedicle sizes in men for all four linear dimensions and different angular measurements between men and women. The mean pedicle width and height were approx. 10% greater in men than in women. This finding is consistent with the results of a study involving the Japanese population that demonstrated pedicle width and height to be 5.3% and 19.2% greater in men.¹⁵⁵

Considering these facts and findings from our study, it can be inferred that pedicle screw fixation may not be feasible in Indian population at all levels for a particular patient especially in females. Although we did not measure the cortical thickness of pedicle wall, we noted the medial wall to be thicker than the lateral wall.

Multiple authors have reported that medial wall is thicker than the lateral wall and hence pedicle guide probe should be directed towards the medial wall for safe placement of pedicle screw.¹²⁹

Many studies have concluded that preoperative evaluation of each level with multiplanar CT is essential if pedicle screw instrumentation is planned in cervical spine as reported by Ludwig SC et al.¹⁵⁶, Rao RD et al.¹³⁰, Chanplakorn et al.¹²⁹ and Reinhold M et al.¹⁴⁷.

In our study the transverse diameter was minimum at C3 for both males and females. It increased from C3 to C7. According to the literature 3.5 mm screw may not be suitable and could have violated most of the pedicles from C3-C6 in our study. Hence a smaller size screw should be considered in Indian population.

CONCLUSION

Through this study we found that there is less significance in the demographic profile. There was a progressive increase in the lengths, widths and height of the pedicles from C3-C7 vertebra. pedicle transverse angle (PTA), which are supposed to determine the direction of screw advancement, it is found from the present study that the angle is varying from 28.93° to 63.73° with mean value of 47.50° for Indian males, while the corresponding values are from 31.6° to 57.85° with mean value of 46.17° for Indian females. The pedicle dimensions of Indian population are smaller in all the parameters at all levels. Though the literature describes the use of 3.5 mm cervical pedicular screws Indian population will require a smaller size

SUMMARY

- Demographic profile of studied patients was not significant.
- The mean values of pedicle lengths have been found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right side.
- Present study shows the variation of mean values of pedicle widths through vertebrae levels from C3 to C7. The same progressively increasing trend is noticed here, which continues upto C7. Like pedicle length values, the pedicle widths also are found to be smaller for women than for men, at all vertebrae levels, but the difference between left side and right side is very little for both men and women.
- It can be seen that the pedicle dimensions of Indian people are smaller at almost all vertebra levels.
- Regarding inclinations of pedicles or pedicle transverse angle (PTA), which are supposed to determine the direction of screw advancement, it is found from the present study that the angle is varying from 28.93° to 63.73° with mean value of 47.50° for Indian males, while the corresponding values are from 31.6° to 57.85° with mean value of 46.17° for Indian females.
- Hence a smaller size screw should be considered in Indian population.

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ANNEXURE-I

PROFORMA

**COMPUTERIZED TOMOGRAPHIC MORPHOMETRIC ANALYSIS OF SUBAXIAL
CERVICAL SPINE PEDICLES IN SOUTH INDIAN POPULATION**

NAME OF THE PATIENT:

HOSPITAL NO:

AGE:

SEX:

ADDRESS:

CONTACT NO:

DATE OF SCAN:

CASE HISTORY

CHIEF COMPLAINTS:

CLINICAL EXAMINATION

NEUROLOGICAL EXAMINATION FINDINGS:

XRAY FINDING

REASON FOR UNDERGOING CT-SCAN OF CERVICAL SPINE:

FINDINGS OF THE CT –SCAN

DOES THE PATIENT REQUIRE SURGICAL INTERVENTION YES/NO

SURGICAL INTERVENTION UNDERTAKEN YES/NO

IF YES

DATE OF SURGERY:

SURGICAL PROCEDURE PERFORMED:

DETAILS OF THE INPLANT USED:

INTRA-OPERATIVE COMPLICATION

POST OPERATIVE REHABILITATION

POST OPERATIVE EVALUATION

CLINICAL:

RADIOLOGICAL:

ANNEXURE-II

CONSENT FORM

I/WE THE PATIENT/THE PATIENT ATTENDENTS HERE BY GIVE CONSCENT TO INCLUDE THE RESULTS FROM THE ABOVE INVESTIGATION AFTER UNDERSTANDING THE PROCEDURE OF THE STUDY.

SIGNATURE:

RELATION WITH THE PATIENT/SELF

CONSENT FORM FOR SURGERY

I/WE THE PATIENT/THE PATIENT ATTENDENTS HAVE BEEN EXPLAINED ABOUT THE PATIENTS CONDITION AND THE NECESSACITY FOR SURGICAL INTERVENTION.I/WE HAVE UNDERSTOOD THE SAME AND HERE BY GIVE FULL CONCENT FOR THE SURGICAL INTERVENTION AND TO INCLUDE THE FINDINGS IN THE ABOVE MENTIONED STUDY.

SIGNATURE:

RELATION WITH THE PATIENT/SELF

Morphometric data

PATIENT NAME:

AGE: CT SCAN NO:

C3 Pedicle	Right	Left
Height		
Width		
Length		
Transverse angulation		

C4 Pedicle	Right	Left
Height		
Width		
Length		
Transverse angulation		

C5 Pedicle	Right	Left
Height		
Width		
Length		
Transverse angulation		

C6 Pedicle	Right	Left
Height		
Width		
Length		
Transverse angulation		

C7 Pedicle	Right	Left
Height		
Width		
Length		
Transverse angulation		

Signature of the candidate

ANNEXURE-III

KEY TO MASTER CHART

M - Male

F – Female

PL – L = Pedicle length (Left)

PL – R = Pedicle length (Right)

PDW – L = Pedicle width (Left)

PDW – R = Pedicle width (Right)

PDH – L = Pedicle height (Left)

PDH – R = Pedicle height (Right)

PTA – L = Pedicle transverse angle (Left)

PTA – R = Pedicle transverse angle (Right)

S.No	NAME	Gender	Age	Left pedicle length (PL)					Right pedicle length (PL)					Left pedicle width					Right pedicle width					Left pedicle height					Right pedicle height					Left pedicle transverse angle					Right pedicle transverse angle				
				C3	C4	C5	C6	C7	C3	C4	C5	C6	C7	C3	C4	C5	C6	C7	C3	C4	C5	C6	C7	C3	C4	C5	C6	C7	C3	C4	C5	C6	C7	C3	C4	C5	C6	C7					
1	BABU	Male	20	4	5	3.6	5	6	3.8	5	5.4	5.37	5	3.6	4.9	3.8	5	5.4	5.4	5.12	5.3	5.86	5	3.6	4.9	3.8	5	5.4	5.4	5.12	5.3	5.86	5	40.6	45.6	48	52	30.5	40	45.6	48	52	30.5
2	CHANDRAN	Male	45	5	4	6	6	5	5.6	6	6	6	6.2	6	2.9	5.6	6	6	5.12	5.6	5.99	5.9	3.2	6	2.9	5.6	6	6	5.12	5.6	5.99	5.9	3.2	41.5	50.3	42	43.6	36.2	51	50.3	42	43.6	36.2
3	ERAMMA	Female	46	4	3.5	5	4.2	2.6	3	4	5	5	5.86	5	3.7	3	4	5	3	3.12	6.2	5.6	5.86	8	3.7	3	4	5	3	3.12	6.2	5.6	5.86	50	56.5	45	42.6	49.6	52	56.5	45	42.6	49.6
4	RAMAMMA	Female	48	3	3	3.2	2.8	4.6	5.6	4.3	4.2	5	5.9	3.2	6.7	5.6	4.3	4.2	3	4	5.16	5.6	4.4	3.2	6.7	5.6	4.3	4.2	3	4	5.16	5.6	4.4	51.5	55.2	46	45.7	50	51.3	55.2	46	45.7	50
5	SHOBA.B.V	Female	62	3.5	2.8	5.86	5.4	4.5	2.6	5.8	2.6	5.3	5.6	5.86	4.7	2.6	5.8	2.6	5.2	4.2	6	2.8	4.6	7	4.7	2.6	5.8	2.6	5.2	4.2	6	2.8	4.6	56.2	59.3	45	43.6	50.23	56.3	59.3	45	43.6	38.14
6	MALLIKA	Female	47	4.5	4	4.4	4.9	3.6	5	5.6	3	2.6	5.6	4.4	5	5	5.6	3	6	5	6	6	3	4.4	5	5	5.6	3	6	5	6	6	3	52.2	53.6	48	42.1	45.8	59.1	53.6	48	42.1	46
7	NARAYANA REDDY	Male	57	6	6	5.1	2.9	6	6.5	5.3	4.9	3.5	2.9	5.1	5.2	6.5	5.3	4.9	5	3	6	6.1	6.3	5.1	5.2	6.5	5.3	4.9	5	3	6	6.1	6.3	51.3	42	42	52	36	40.3	42	42	52	36
8	MALLESH	Male	48	3	3.5	5.2	3.7	4.5	6	2.8	4.6	5.6	5.2	5.2	4.2	6	2.8	4.6	4.8	5.9	5	2.6	5.6	5.5	4.2	6	2.8	4.6	4.8	5.9	5	2.6	5.6	40.6	45	53	41.9	32	45.6	45	53	41.9	32
9	ANAND	Male	48	5.3	6	6	6.7	5.6	6	6	3	4	5.9	6	5	6	6	3	3.7	5.9	3.6	3	3.4	6	5	6	6	3	3.7	5.9	3.6	3	3.4	53.9	41	56	38	35	52.6	41	56	38	35
10	GANESH	Male	46	5.5	6	5	4.7	4	6	6.1	6.3	5	6	5	3	6	6.1	6.3	3.4	3	5.02	4	5.9	5	3	6	6.1	6.3	3.4	3	5.02	4	5.9	52.3	49	45	57	36.9	53.8	49	45	57	36
11	ANKITHA	Female	45	5	4	4.8	5	6	5	2.6	5.6	4.6	3	4.8	5.9	5	2.6	5.6	5	5.8	5	4.3	2.3	4.8	5.9	5	2.6	5.6	5	5.8	5	4.3	2.3	46.5	40	59	35	39	59.1	40	59	35	39
12	MOHAN	Male	24	2	2.8	3.7	5.2	5	3.6	3	3.4	6	2.5	3.7	5.9	3.6	3	3.4	5.5	5.4	3.2	4.5	5	8	5.9	3.6	3	3.4	5.5	5.4	3.2	4.5	5	41.2	51	60	32	32.5	42	51	60	32	32.5
13	MUNIYAMMA	Female	35	3	5	3.4	4.2	5.7	5.02	4	5.9	5.1	5.2	3.4	3	5.02	4	5.9	4	5.6	4.1	6	4.3	3.4	3	5.02	4	5.9	4	5.6	4.1	6	4.3	39.3	52	52	52	31.6	48	52	52	31.6	48
14	RRAMAMMA	Female	57	5	3.5	5	5	6	5	4.3	2.3	5.6	4.6	5	5.8	5	4.3	2.3	3	5	4	6	4.3	6.4	5.8	5	4.3	2.3	3	5	4	6	4.3	38.7	51.3	53	38	36.5	55.2	51.3	53	38	36.5
15	JAYAMMA	Female	24	3	5	5.5	3	6.2	3.2	4.5	5	4.3	4.9	5.5	5.4	3.2	4.5	5	3.4	3	5.3	4.2	5.3	8.2	5.4	3.2	4.5	5	3.4	3	5.3	4.2	5.3	53.6	56.3	60	50	46.5	59.3	56.3	60	50	46.5
16	MANJUNATH	Male	29	4	6.6	4	5.9	5	4.1	6	4.3	4.12	4	4	5.6	4.1	6	4.3	5.9	4	4.5	5	4.5	4	5.6	4.1	6	4.3	5.9	4	4.5	5	4.5	43.8	59.1	56.3	41.2	41.5	53.6	59.1	56.3	41.2	41.5
17	DILSHAD KHAN	Male	24	3	5	3	5.9	6	4	6	4.3	5.36	3.9	3	5	4	6	4.3	5.9	5	4.9	5.6	5.1	4.9	5	4	6	4.3	5.9	5	4.9	5.6	5.1	52.9	40.3	58.6	43.5	48.6	42	40.3	58.6	43.5	48.6
18	PRAJITHA	Female	35	2.6	5.63	3.4	3	4	5.3	4.2	5.3	5.1	5.6	3.4	3	5.3	4.2	5.3	5.2	4.9	5.9	4.2	5.3	5.3	3	5.3	4.2	5.3	5.2	4.9	5.9	4.2	5.3	40.6	45.6	54.8	49.8	50	45	45.6	54.8	49.8	50
19	UMESH	Male	45	5	4.8	5.9	5.8	5.8	4.5	5	4.5	5.12	6.8	5.9	4	4.5	5	4.5	5	5.2	4.9	2.3	5.2	5.9	4	4.5	5	4.5	5	5.2	4.9	2.3	5.2	38	52.6	60.05	53.8	41.5	41	52.6	60.05	53.8	41.5
20	VISHWANATH	Male	59	4	4.2	5.9	5.4	5.6	4.9	5.6	5.1	5.42	6.3	5.9	5	4.9	5.6	5.1	5.5	4	2.8	4.8	5	5.9	5	4.9	5.6	5.1	5.5	4	2.8	4.8	5	56.3	53.8	51.3	56	29	49	53.8	51.3	56	29
21	SURESH KUMAR	Male	37	3	6	5.2	5.6	5	5.9	4.2	5.3	5.12	5.9	5.2	4.9	5.9	4.2	5.3	6.2	3.5	4	4.8	5.23	5.2	4.9	5.9	4.2	5.3	6.2	3.5	4	4.8	5.23	53.8	59.1	54.2	57	29.5	40	59.1	54.2	57	29.5
22	KUMARI	Female	60	2.3	2.8	5	5	6	4.9	2.3	5.2	5	5.8	5	5.2	4.9	2.3	5.2	5.9	3	6.4	3.9	5	5	5.2	4.9	2.3	5.2	5.9	3	6.4	3.9	5	42	42	40.6	57.1	30	51	42	40.6	57.1	30
23	ANJAMMA	Female	62	3.5	5	5.5	3	5	2.8	4.8	5	5	5	5.5	4	2.8	4.8	5	2.9	3.8	5.6	5	3	5.5	4	2.8	4.8	5	2.9	3.8	5.6	5	3	38	48	36.5	55	32	52	48	36.5	55	32
24	VAMSI	Male	40	6	4	6.2	4	6.7	4	4.8	5.23	5.4	4	6.2	3.5	4	4.8	5.23	5.2	4.2	6	2.8	4.6	3.2	3.5	4	4.8	5.23	5.2	4.2	6	2.8	4.6	51.5	55.2	46	45.7	52.8	51.3	55.2	46	45.7	45
25	BALARAJU	Male	57	5	3	5.9	5	5.7	6.4	3.9	5	5	5	5.9	3	6.4	3.9	5	6	5	6	6	3	6.4	3	6.4	3.9	5	6	5	6	6	3	56.2	59.3	45	43.6	50.23	56.3	59.3	45	43.6	38.2
26	KRISHNAMMA	Female	41	2.3	2.8	2.9	4.9	4	5.6	5	3	4.2	5.4	2.9	3.8	5.6	5	3	5	3	6	6.1	6.3	4.8	3.8	5.6	5	3	5	3	6	6.1	6.3	52.2	53.6	48	42.1	46	59.1	53.6	48	42.1	46
27	KRISHNA REDDY	Male	65	3	4.6	5	5.2	4	5	5.2	5.3	5	5.3	5	5	5	5.2	5.3	4.8	5.9	5	2.6	5.6	5	5	5	5.2	5.3	4.8	5.9	5	2.6	5.6	51.3	42	42	52	36	40.3	42	42	52	36
28	SRIRAMREDDY	Male	79	4	6	4.9	4	6	5	5.3	5.16	5	5.1	4.9	4.9	5	5.3	5.16	3.7	5.9	3.6	3	3.4	4.9	4.9	5	5.3	5.16	3.7	5.9	3.6	3	3.4	40.6	45	53	41.9	31.8	51	45	53	41.9	

S.No	NAME	Gender	Age	Left pedicle length (PL)				Right pedicle length (PL)				Left pedicle width				Right pedicle width				Left pedicle height				Right pedicle height				Left pedicle transverse angle				Right pedicle transverse angle												
70	GOWRAMMA	Female	65	4	2.8	3	2.44	5	2.56	5	5.6	4.2	4.3	3.6	3.8	4	5.7	4.9	2.9	3.8	5.6	5	3	3.6	3.8	4	5.7	4.9	2.9	3.8	5.6	5	3	52.3	49	45	57	36	42	49	45	57	36	
71	BASAMMA	Female	79	3	4	4.5	4.9	4.6	2.9	4	5.7	4.9	2.9	6	5	3.2	5.8	2.8	5	5	5	5.2	5.3	6	5	3.2	5.8	2.8	5	5	5	5.2	5.3	46.5	40	59	35	39	48	45.6	48	52	30.5	
72	FARIDHA	Female	35	3.5	5	5	2.8	4.5	5.63	3.2	5.8	2.8	3.9	5	4.9	5.8	3.5	4	4.9	4.9	5	5.3	5.16	5	4.9	5.8	3.5	4	4.9	4.9	5	5.3	5.16	41.2	51	60	32	32.5	55.2	50.3	42	43.6	36.2	
73	VENKATESHAPPA	Male	77	4.2	6	5	6	4	5	5.8	3.5	4	6.9	3.2	5.8	5	4.2	4.5	5.2	5.8	5	5.9	5.6	3.2	5.8	5	4.2	4.5	5.2	5.8	5	5.9	5.6	39.3	52	52	52	31.6	59.3	56.5	45	42.6	49.6	
74	RADHA	Female	30	4	4	5	4.2	3.6	5.2	5	4.2	4.5	5	5.86	5.4	6.2	6.8	5	4.2	5.4	3	4.8	6.2	5.86	5.4	6.2	6.8	5	4.2	5.4	3	4.8	6.2	38.7	51.3	53	38	36.5	42	55.2	46	45.7	50	
75	NANDISH GOWDA	Male	24	4.9	6.5	6	6.9	5.9	5	6.2	6.8	5	5.2	4.4	2.7	4.9	2.6	5.3	3.7	2.7	5.3	4.2	5.3	4.4	2.7	4.9	2.6	5.3	3.7	2.7	5.3	4.2	5.3	53.6	56.3	60	50	46.5	53	59.3	45	43.6	50.23	
76	KOWSAR TAJ	Female	29	2.6	5	4.8	5	2.5	5.9	4.9	2.6	5.3	5	5.1	6	4.5	5.8	5.2	5.6	6	4.5	5	4.5	5.1	6	4.5	5.8	5.2	5.6	6	4.5	5	4.5	43.8	59.1	56.3	41.2	41.5	56	53.6	48	42.1	46	
77	TEJASWINI	Female	24	4.2	2.7	4.9	3.4	5	5.3	4.5	5.8	5.2	4.2	5.2	4	2.9	5.8	5.2	4.8	4	4.9	5.6	5.1	5.2	4	2.9	5.8	5.2	4.8	4	4.9	5.6	5.1	52.9	40.3	58.6	43.5	48.6	45	42	42	52	36	
78	NAVEENA	Female	35	4.2	5.62	3.4	5	2.5	5	2.9	5.8	5.2	5.6	6	4.5	4	5.6	4.6	5.7	4.5	5.9	4.2	5.3	6	4.5	4	5.6	4.6	5.7	4.5	5.9	4.2	5.3	40.6	45.6	54.8	49.8	50	35	45	53	41.9	32	
79	BHAVYA	Female	45	5	2.7	5	4.2	4.5	5.1	4	5.6	4.6	5	5	5.6	3.9	5.6	5.36	3.6	5.6	4.9	2.3	5.2	5	5.6	3.9	5.6	5.36	3.6	5.6	4.9	2.3	5.2	38	52.6	60.05	53.8	41.5	60	41	56	38	35	
80	MARUTHI	Male	59	4	3	5	3	4	6.8	3.9	5.6	5.36	3	4.8	4.2	5.7	5.2	4.13	4.2	4.2	2.8	4.8	5	4.8	4.2	5.7	5.2	4.13	4.2	4.2	2.8	4.8	5	56.3	53.8	51.3	56	29	52	49	45	57	36	
81	SHILPA	Female	37	3	5.1	5.5	2.44	4	5.6	4.3	5.4	3.9	2.44	3.7	3.4	5.2	5.2	5	5.9	3.4	4	4.8	5.23	7.5	3.4	5.2	5.2	5	5.9	3.4	4	4.8	5.23	53.8	59.1	54.2	57	29.5	53	40	59	35	39	
82	MARAMMA	Female	60	2.7	2.32	3	4.9	6	4.3	4.2	4	5.4	4.9	3.4	5	6	6	5.12	5.7	5	6.4	3.9	5	8	5	6	6	5.12	5.7	5	6.4	3.9	5	42	42	40.6	57.1	30	60	51	60	32	32.5	
83	BHARATH	Male	62	6	2.8	6.5	3.7	2	5.9	3.6	5.8	5	2.9	5	5	6	3.6	5.42	6.1	5	5.6	5	3	8	5	6	3.6	5.42	6.1	5	5.6	5	3	38	48	36.5	55	32	41.3	52	52	52	31.6	
84	NARAMMA	Female	40	5	4	5	2.36	2.9	5	5	5.2	5.8	5.2	5.5	6.5	5	5.6	4.2	4.4	6.5	5	5.2	5.3	5.5	6.5	5	5.6	4.2	4.4	6.5	5	5.2	5.3	51.5	55.2	46	45.7	61	58.6	51.3	53	38	36.5	
85	VEERAMMA	Female	57	2.6	4	3	4.8	4.8	5	3	5.6	5.6	5.6	4	5.6	4	5.7	4.9	4.2	5.6	5	5.3	5.16	6.8	5.6	4	5.7	4.9	4.2	5.6	5	5.3	5.16	56.2	59.3	45	43.6	50.23	54.8	56.3	60	50	46.5	
86	JHANSI	Female	41	3	4.2	2.44	5	2.6	5.1	2.6	5.8	5.4	5.6	3	5.2	3.2	5.8	2.8	5.2	5	5.9	5.6	6	5.2	3.2	5.8	2.8	5.2	5	5.9	5.6	52.2	53.6	48	42.1	46	47	59.1	56.3	41.2	41.5			
87	RAVI RAJ	Male	65	4	5	5.4	3.2	3	6.2	6.3	5.6	4	4	3.4	5.8	5.8	3.5	4	5.4	5.8	3	4.8	6.2	5.1	5.8	3.5	4	5.4	5.8	3	4.8	6.2	51.3	42	42	52	36	46	40.3	58.6	43.5	48.6		
88	SESHAMMA	Female	79	5	4	4.9	2.87	6	5.02	5	5	5	5	5	5.9	4.7	5	4.2	4.5	2.9	4.7	2.44	5	5.3	5.9	4.7	5	4.2	4.5	2.9	4.7	2.44	5	5.3	40.6	45	53	41.9	32	39	45.6	54.8	49.8	50
89	BHUSHAN	Male	35	5	3.2	5	4.2	5.6	6	5	6.14	5.6	4.2	5.9	5	6.2	6.8	5	5.2	4.9	5.4	5.12	5.3	5.9	5	6.2	6.8	5	5.2	4.9	5.4	5.12	5.3	53.9	41	56	38	35	38	52.6	60.05	53.8	41.5	
90	KORAMMA	Female	77	4.3	3.1	5.2	5.4	6.2	5	5.6	4	5.2	5.62	5.2	4.9	4.9	2.6	5.3	3.4	2.9	5.12	5.6	5.99	5.2	4.9	4.9	2.6	5.3	3.4	2.9	5.12	5.6	5.99	52.3	49	45	57	36	41	53.8	51.3	56	29	
91	SHUKANYA	Female	30	5	3.5	4.2	4.9	5.5	3.2	4	4	5.6	6.9	5	5.8	4.5	5.8	5.2	5	3.7	5	3.12	6.2	5	5.8	4.5	5.8	5.2	5	3.7	5	3.12	6.2	46.5	40	59	35	39	42	59.1	54.2	57	29.5	
92	PREETHI	Female	25	4	3	3.7	2.9	4.6	2.56	4.3	3	5.8	5	5.5	5.4	2.9	5.8	5.2	5.2	5.8	5	5.9	5.6	5.5	5.4	2.9	5.8	5.2	5.2	5.8	5	5.9	5.6	41.2	51	60	32	32.5	56.3	42	40.6	57.1	30	
93	PAVAN REDDY	Male	57	2.5	4.5	4.9	4.5	5.6	2.7	3.7	5.3	5.8	4.8	6.2	2.7	4	5.6	4.6	4.2	5.4	3	4.8	6.2	6.2	2.7	4	5.6	4.6	4.2	5.4	3	4.8	6.2	39.3	52	52	52	31.6	59.1	48	36.5	55	32	
94	MAHESH	Male	47	5.2	3.6	4.6	5	6	4.5	3.6	6.3	5	5.2	5.9	6	3.9	5.6	5.36	3.7	2.7	5.3	4.2	5.3	5.9	6	3.9	5.6	5.36	3.7	2.7	5.3	4.2	5.3	38.7	51.3	53	38	36.5	40.3	55.2	46	45.7	52.8	
95	PRASAD	Male	20	4.6	5.6	5.8	6	6	6	5.8	5.96	4.9	3.4	2.9	4	4.3	5.4	3.9	5.6	6	4.5	5	4.5	7.6	4	4.3	5.4	3.9	5.6	6	4.5	5	4.5	53.6	56.3	60	50	46.5	51	59.3	45	43.6	50.23	
96	REDDAMMA	Female	27	2.3	5	3.9	5.5	6	4	3.6	5.2	5.9	5	5	4.5	4.2	4	5.4	4.8	4	4.9	5.6	5.1	7	4.5	4.2	4	5.4	4.8	4	4.9	5.6	5.1	43.8	59.1	56.3	41.2	41.5	52	53.6	48	42.1	46	
97	RAKESH	Male	25	4.3	6.2	5.6	5.9	4	4	6.3	5.4	4.8	4.9	5.6	3.6	5.8	5	5.7	4.5	5.9	4.2	5.3	7	5.6	3.6	5.8	5	5.7	4.5	5.9	4.2	5.3	52.9	40.3	58.6	43.5	48.6	51.3	42	42	52	36		
98	SESHAMMA	Female	36	4.5	4.2	5	4.2	3.6	5.9	5	5	4.2	5.1	5.2	4.2	5.3	4.2	5.3	3.6	5.6	4.9	2.3	5.2	5.2	4.2	5.3	4.2	5.3	3.6	5.6	4.9	2.3	5.2	41.2	51	60	32	32.5	56.3	45	53	41.9	32	
99	NOOR TAJ	Female	25	4	5	3	2.3	2.6	5.36	5.1	4.9	2.3	5	4.2	3.4	4.5	5	4.5	4.2	4.2	2.8	4.8	5	4.2	3.4	4.5	5	4.5	4.2	4.2	2.8	4.8	5	39.3	52	52	52	31.6	59.1	41	56	38	35	
100	NAGESH	Male	57	4	4	4.4	4.5	6.2	6.1	5.1	3.6	4.5	4.3	3.7	5	4.9	5.6	5.1	5.9	3.4	4	4.8	5.23	3.7	5	4.9	5.6	5.1	5.9	3.4	4	4.8	5.23	38.7	51.3	53	38	36.5	40.3	49	45	57	36	
101	BEGHAM TAJ	Female	47	2.3	3.2	4.2	2.3	5	5.8	5.6	3	4	2.56	5.6	5	5.9	4.2	5.3	5.7	5	6.4	3.9	5	5.6	5	5.9	4.2	5.3	5.7	5	6.4	3.9	5	53.6	56.3	60	50	46.5	45.6	40	59	35	39	
102	MOHAMAD	Male	20	5	3.1	2.8	5	3	5.6	4.3	5	5	2.9	4.8	6.5	4.9	2.3	5.2	6.1	5	5.6	5	3	4.8	6.5	4.9	2.3	5.2	6.1	5	5.6	5	3	43.8	59.1	56.3	41.2	41.5	52.6	51	60	32	32.5	
103	BASHEERA	Female	27	2.1	3.5	5.4	5	2.5	5.3	4.2	4.2	4	4	5.9	5.7	5.6	2.8	4.8	5	4.4	6.5	5	5.2	5.3	5.7	5.6	2.8	4.8	5	4.4	6.5	5	5.2	5.3	52.9	40.3	58.6	43.5	48.6	53.8	52	52	52	31.6
104	HARITHA	Female	25	2.3	3	3	4.9	2.3	4.5	3	3.6	5	3	5.36	3.6	5.2	4	4.8	5.23	4.2	5.6	5	5.3	5.16	3.6	5.2	4	4.8	5.23	4.2	5.6	5	5.3	5.16	40.6	45.6	54.8	49.8	50	59.1	51.3	53	38	36.5
105	BABA JAN	Male	36	3	5	4	5.9	4	4	5.9	6.5	6	6	4.2	5.8</																													

S.No	NAME	Gender	Age	Left pedicle length (PL)					Right pedicle length (PL)					Left pedicle width					Right pedicle width					Left pedicle height					Right pedicle height					Left pedicle transverse angle					Right pedicle transverse angle				
140	KANAKAMMA	Female	31	3	2.8	5.6	5.2	4.5	2.9	4.5	5	5	3	4.5	5	5.12	5.6	5.99	3.6	5.6	4.9	2.3	5.2	4.5	5	5.12	5.6	5.99	3.6	5.6	4.9	2.3	5.2	38.7	51.3	53	38	36.5	53.6	49	45	57	36
141	JAYALAKSHMI	Female	37	2.3	4	4.8	3.4	3.6	5.63	5	4.5	4	5	5	5.2	5	3.12	6.2	4.2	4.2	2.8	4.8	5	5	5.2	5	3.12	6.2	4.2	4.2	2.8	4.8	5	53.6	56.3	60	50	46.5	43.8	40	59	35	39
142	LINGAMMA	Female	60	5	4	5	5	2.6	5.9	4	4	4	5	5	4.2	3	4	5.16	5.9	3.4	4	4.8	5.23	5	4.2	3	4	5.16	5.9	3.4	4	4.8	5.23	43.8	59.1	56.3	41.2	41.5	52.9	51	60	32	32.5
143	BASHEER	Male	62	2.9	5	5.2	5.7	5	4	6	5.1	5.7	5.3	5	5	5.3	4.2	5.3	5.7	5	6.4	3.9	5	5	5	5.3	4.2	5.3	5.7	5	6.4	3.9	5	41.2	51	60	32	32.5	40.6	52	52	31.6	
144	BYRAMMA	Female	40	5	4	2.44	4.8	5.6	5.4	5.6	5.9	4.8	5.3	5.9	5.4	4.5	5	4.5	6.1	5	5.6	5	3	5.9	5.4	4.5	5	4.5	6.1	5	5.6	5	3	39.3	52	52	52	31.6	38	51.3	53	38	36.5
145	ASHWIN	Male	57	4	4.5	6.2	6	6	5	3.4	4.3	6.52	6.9	2.9	4	4.9	5.6	5.1	4.4	6.5	5	5.2	5.3	2.9	4	4.9	5.6	5.1	4.4	6.5	5	5.2	5.3	38.7	51.3	53	38	36.5	56.3	56.3	60	50	46.5
146	GAJENDRA	Male	41	5	4.6	5	3	4	3.7	5.3	4.7	4.12	4.2	5	5	5.9	4.2	5.3	4.2	5.6	5	5.3	5.16	5	5	5.9	4.2	5.3	4.2	5.6	5	5.3	5.16	53.6	56.3	60	50	46.5	53.8	59.1	56.3	41.2	41.5
147	JAYAPPA	Male	65	5	4.3	6	4.9	6	5	6	4.5	4.17	5	4.9	5	4.9	2.3	5.2	2.8	5.2	5	5.9	5.6	4.9	5	4.9	2.3	5.2	2.8	5.2	5	5.9	5.6	43.8	59.1	56.3	41.2	41.5	42	40.3	58.6	43.5	48.6
148	SRINIVAS	Male	79	6	6.9	4	6	6	6	6.5	6	4.32	6	5.2	2.7	2.8	4.8	5	5.4	5.8	3	4.8	6.2	5.2	2.7	2.8	4.8	5	5.4	5.8	3	4.8	6.2	52.9	40.3	58.6	43.5	48.6	38	45.6	54.8	49.8	50
149	CHAITRA	Female	35	2.7	3.2	4.5	3	4.6	5.2	3.2	5.2	4.9	5.2	4.2	6	4	4.8	5.23	2.9	4.7	2.44	5	5.3	4.2	6	4	4.8	5.23	2.9	4.7	2.44	5	5.3	40.6	45.6	54.8	49.8	50	51.5	52.6	60.05	53.8	41.5
150	AYESH	Male	77	5.96	5.2	4	3	4.99	5.1	6	4.2	5.42	6	3.7	4	6.4	3.9	5	5.2	4.9	5.4	5.12	5.3	3.7	4	6.4	3.9	5	5.2	4.9	5.4	5.12	5.3	38	52.6	60.05	53.8	41.5	56.2	53.8	51.3	56	29
151	MEENAMMA	Female	30	4	3.1	5	4.8	4.5	3.4	2.56	5	2.9	4.6	5.6	4.5	5.6	5	3	3.4	2.9	5.12	5.6	5.99	5.6	4.5	5.6	5	3	3.4	2.9	5.12	5.6	5.99	56.3	53.8	51.3	56	29	52.2	59.1	54.2	57	29.5
152	RAJENDRA	Male	24	5.9	6.23	6	5.8	6.4	5.9	5.7	4.6	4.12	5	4.8	5.6	5	5.2	5.3	5.7	4.5	5.9	4.2	5.3	4.8	5.6	5	5.2	5.3	5.7	4.5	5.9	4.2	5.3	53.8	59.1	54.2	57	29.5	51.3	42	40.6	57.1	30
153	CHANDRAMMA	Female	29	5	5	4.8	5	6	2.3	5.02	5	5.4	5.23	5.7	4.2	5	5.3	5.16	3.6	5.6	4.9	2.3	5.2	5.7	4.2	5	5.3	5.16	3.6	5.6	4.9	2.3	5.2	42	42	40.6	57.1	30	40.6	48	36.5	55	32
154	VEDAVATHI	Female	24	3	4	3	5.2	5	4.8	5	5	5.4	5	3.6	3.4	5	5.9	5.6	5.2	4.2	6	2.8	4.6	3.6	3.4	5	5.9	5.6	5.2	4.2	6	2.8	4.6	38	48	36.5	55	32	53.9	55.2	46	45.7	61
155	RATHAN KUMAR	Male	35	5	5.8	6	5.6	6.2	4	5	6.3	5	6	4.2	5	3	4.8	6.2	6	5	6	6	3	4.2	5	3	4.8	6.2	6	5	6	6	3	51.5	55.2	46	45.7	39	52.3	59.3	45	43.6	50.23
156	PRAVEEN	Male	45	4.23	4.9	5.6	6	5.8	6	5.8	4.5	5	6.5	5.9	5	5.3	4.2	5.3	5	3	6	6.1	6.3	5.9	5	5.3	4.2	5.3	5	3	6	6.1	6.3	56.2	59.3	45	43.6	50.23	46.5	53.6	48	42.1	46
157	SURESH KUMAR	Male	59	4.2	4	6	6.9	5.7	6	5	4.1		6.3	5.7	6.5	4.5	5	4.5	4.8	5.9	5	2.6	5.6	5.7	6.5	4.5	5	4.5	4.8	5.9	5	2.6	5.6	52.2	53.6	48	42.1	46	41.2	42	42	52	36
158	MUTHU RAJ	Male	37	5.5	5	5	5.4	5.7	6.7	4.8	5.2	5.12	4.9	6.1	5.6	4.9	5.6	5.1	3.7	5.9	3.6	3	3.4	6.1	5.6	4.9	5.6	5.1	3.7	5.9	3.6	3	3.4	51.3	42	42	52	36	39.3	45	53	41.9	32
159	SHASHI KALA	Female	60	5	5.8	3.7	5.2	4.5	2.8	5	5.4	4.8	5.4	5.7	5.2	5.9	4.2	5.3	3.4	3	5.02	4	5.9	5.7	5.2	5.9	4.2	5.3	3.4	3	5.02	4	5.9	41.2	51	60	32	32.5	38.7	41	56	38	35
160	SUSHMITHA	Female	62	4.2	5.1	5.6	3.4	4	4.2	5.1	5.3	5.3	5	6.1	5.8	4.9	2.3	5.2	5	5.8	5	4.3	2.3	6.1	5.8	4.9	2.3	5.2	5	5.8	5	4.3	2.3	39.3	52	52	52	31.6	53.6	49	45	57	36
161	MUNISWAMY	Male	40	4.85	3.99	5	5.6	5.6	4	5.7	4.1	4	5.9	4.4	4.7	2.8	4.8	5	5.5	5.4	3.2	4.5	5	4.4	4.7	2.8	4.8	5	5.5	5.4	3.2	4.5	5	38.7	51.3	53	38	36.5	43.8	40	59	35	39
162	MADHUSUDAN	Male	57	4.9	6	5.6	5.9	5.8	5	5.8	4.3	5.12	6	4.2	4.9	4	4.8	5.23	4	5.6	4.1	6	4.3	4.2	4.9	4	4.8	5.23	4	5.6	4.1	6	4.3	53.6	56.3	60	50	46.5	52.9	51	60	32	32.5
163	VIDHYA SREE	Female	41	3.4	4.2	3.2	3.7	5.6	5.36	3.2	5	3	5.6	2.8	2.9	6.4	3.9	5	3	5	4	6	4.3	2.8	2.9	6.4	3.9	5	3	5	4	6	4.3	43.8	59.1	56.3	41.2	41.5	41.2	52	52	31.6	
164	NANJAMMA	Female	65	2.9	5	5.86	3	6	5.4	5	4	5	4	5.4	3.7	5.6	5	3	3.4	3	5.3	4.2	5.3	5.4	3.7	5.6	5	3	3.4	3	5.3	4.2	5.3	52.9	40.3	58.6	43.5	48.6	39.3	51.3	53	38	36.5
165	SHANKER	Male	25	6	3	5.6	6.9	5	5	6	5.6	5.2	5.6	2.9	4.2	5	5.2	5.3	5.9	4	4.5	5	4.5	2.9	4.2	5	5.2	5.3	5.9	4	4.5	5	4.5	40.6	45.6	54.8	49.8	50	38.7	56.3	60	50	46.5
166	LAVANYA	Female	57	3.6	4	4.9	5.5	6.2	5	2.9	4	5	5.5	5.2	5	5	5.3	5.16	5.9	5	4.9	5.6	5.1	5.2	5	5	5.3	5.16	5.9	5	4.9	5.6	5.1	38	52.6	60.05	53.8	41.5	53.6	59.1	56.3	41.2	41.5
167	MADHAN REDDY	Male	47	4	3.9	5	6	4.3	3.8	5.9	4	4.2	4	3.4	5.4	5	5.9	5.6	5.2	4.9	5.9	4.2	5.3	3.4	5.4	5	5.9	5.6	5.2	4.9	5.9	4.2	5.3	56.3	53.8	51.3	56	29	43.8	40.3	58.6	43.5	48.6
168	SHIVA SHANKAR	Male	20	5	4.6	6	5.9	5.9	5.4	6	6.3	4	6	5	4	3	4.8	6.2	5	5.2	4.9	2.3	5.2	5	4	3	4.8	6.2	5	5.2	4.9	2.3	5.2	53.8	59.1	54.2							