INTRODUCTION

The uses of pedicle screws for spinal stabilization have become increasingly popular worldwide. Pedicle screw system engages all three columns of the spine and can resist motion in all planes. Several studies suggest that pedicle screw fixation is a safe and effective treatment for many spinal disorders ***(Prafulla, 2005)***.

Lumbar fusion has undergone significant evolution since Cloward first introduced the original posterior lumbar interbody fusion procedure more than 50yrs ago. Many surgeons now prefer the transforaminal lumbar interbody fusion (TLIF) procedure in the management of a variety of spinal disorders that require lumbar fusion ***(Rosenberg and Mummaneni, 2001)***.

This procedure involves the application of pedicular screws together with an interbody cage to perform the fusion process, and it offers some distinct advantages including unilateral exposure, decreased neural retraction, and a more lateral angle of approach that facilitates revision surgery ***(Ames et al., 2005)***.

TLIF is a surgical method of spinal fusion that allows the benefits of anterior column stabilization and 360 degree fusion, while reducing the surgical and neurologic morbidity associated with traditional methods of posterior and anterior lumbar interbody fusion and allows, as part of the dissection, a far lateral access to the neural foramina to decompress both the traversing and exiting upper nerve root without neural manipulation and subsequently avoids nerve retraction injuries ***(Rosenberg and Mummaneni, 2001)***.

One of the greatest advantages of TLIF is the working zone within the disc space; unlike the bilateral standard posterior lateral interbody fusion techniques, the working zone for the unilateral technique begins at the lateral aspect of the dural sac and moves further lateral into the foramina. Exposure of the nerve elements is the key to this technique and gaining exposure from the pedicle above to the pedicle below. This working zone protects the neural structures from over distraction with minimal retraction of the dura and the surgeon is able to gain complete access to the disc space to perform the necessary discectomy, curettage, and distraction, as well as placement of instrumentation and eventual fusion constructs ***(Lowe et al., 2002)***.

A critical component of the fusion process is the interbody spacer or cage. The fusion cages are designed to restore normal disc height, improve construct stiffness and thus reduce posterior instrumentation failure. The TLIF cages can share significant amount of load even with the posterior fixation ***(Polly et al., 2000)***.

A number of structural designs of lumbar fusion cages have been developed, the banana shaped cages and the straight designs are the popular types of the TLIF cages ***(Tan et al., 2005)***.

Nowadays, several studies points to TLIF as a safe and effective method of spinal fusion, providing high fusion rates, good clinical outcomes with few complication ***(Ames et al., 2005)***.

AIM OF THE WORK

The aim of this work is to evaluate clinical and radiological short outcome of using transforaminal lumbar interbody fusion surgery as a modality of treatment of degenerative spondylolithesis and degenerative disc disease of the lumbar spine.

ANATOMY

The functional spinal unit is made up of an intervertebral disc, the adjacent superior and inferior vertebra, the interconnecting right and left facet joint, and the surrounding ligamentous tissue. The two adjacent vertebrae are linked by three joints the intervertebral joint, and the right and left facet joints (Fig. 1). This joint complex allows three-dimensional movements: flexion-extension, axial rotation, and lateral bending ***(Yong-Hing and Kirkady, 1990)***.

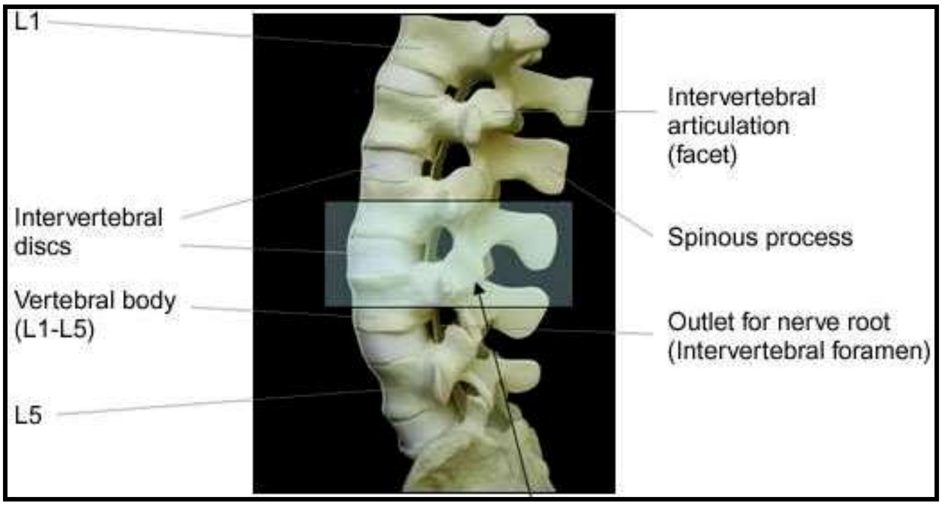

Fig. (1): Functional Spinal Unit (FSU)
http://operaciones-ortopedia.blogspot.com/2010/03/lumbar-spine.html.

In the center of this functional spinal unit lies the intervertebral foramen which serves as the doorway between the spinal canal and periphery *(Russel et al., 2002)*.

When looking outward through the inter-vertebral foramen from the spinal canal, the foramen takes on the appearance of an oval, round, or inverted teardrop-shaped window (Fig. 2) *(Smith et al., 1993)*.

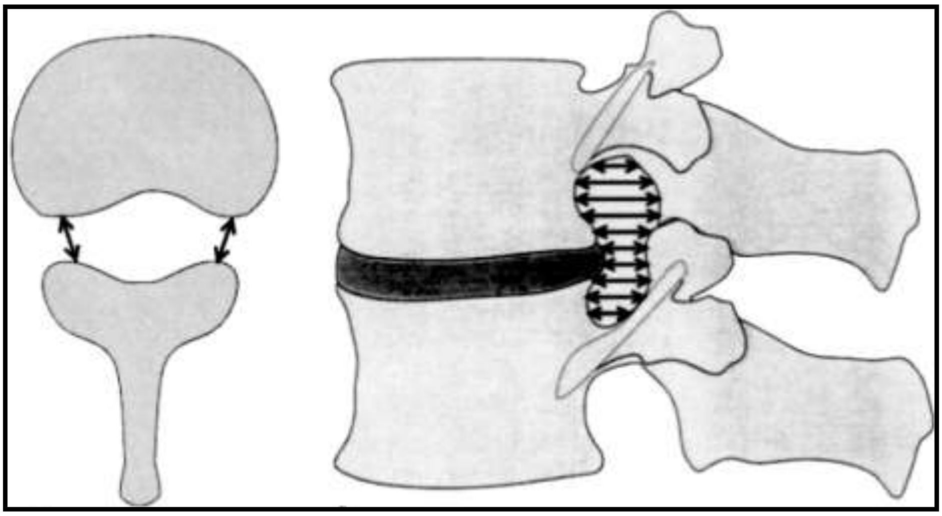

Fig. (2): The Shape and boundaries of the Intervertebral Foramen *(Crock, 1981)*.

The roof of the intervertebral foramen is the inferior aspect of the vertebral notch of the pedicle of the superior vertebra, the ligamentum flavum at its outer free edge, and posteriorly lays the pars interarticularis and the zygapophysial joint. The floor of the nerve root canal is the superior vertebral notch of the pedicle of the inferior vertebra, postero-inferior margin of the superior vertebral body, the intervertebral disc, and the postero-superior margin of the inferior vertebral body ***(Russel et al., 2002)***.

Multiple structures are involved in bounding the anterior aspect of the foramen. They include the posterior aspect of the adjacent vertebral bodies, the intervertebral disc, lateral expansion of the posterior longitudinal ligament, and the anterior longitudinal venous sinus. Posteriorly, the foramen is bounded by the superior and inferior articular process of the facet joint at the same level as the foramen, and the lateral prolongation of the ligamentum flavum. The medial canal border contains the dural sleeve. The lateral boundary is a fascial sheet and overlying psoas muscle ***(Russel et al., 2002)***. Its height and cross-sectional area vary from 11 to 19mm and from 40 to 160mm^2, respectively ***(Stephens et al., 1991)***.

However, the vertical height of the IVFs decreases as age increases. This might be due to subtle disc narrowing or slight vertical narrowing of the vertebral bodies with age ***(Gregory et al., 2003)***.

The superior anteroposterior dimension (SAP) increases in size as age increases and the inferior anteroposterior (IAP) measurement does not change with age. Therefore, the shape of the IVFs changes as age increased (Fig. 3) ***(Gregory et al., 2003)***.

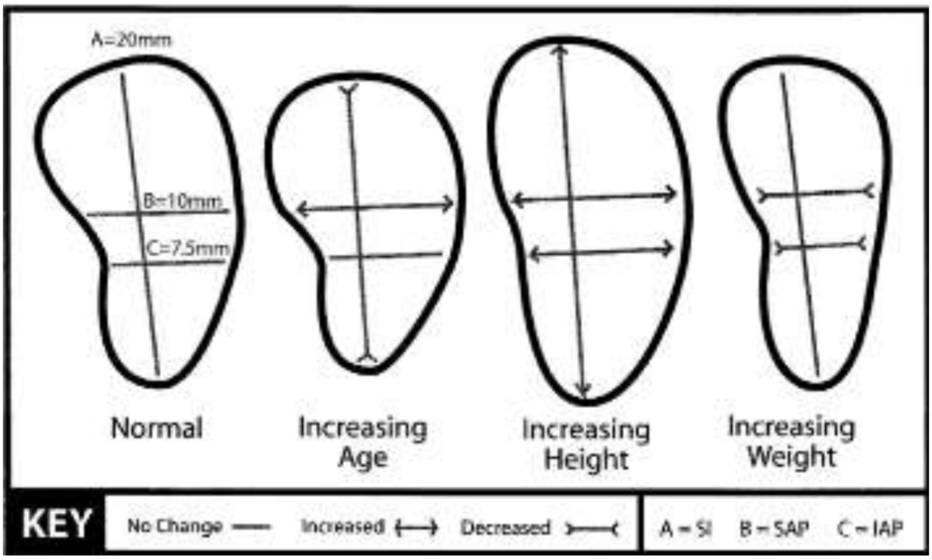

Fig. (3): Illustration demonstrating changes in IVF dimensions with increasing age, height, and weight ***(Stephens et al., 1991)***.

As might be expected, IVF height increased with overall body height. Interestingly, the SAP and IAP measurements also increased as overall body height increased ***(Stephens et al., 1991)***.

Therefore, the IVFs became longer (from top to bottom) and wider (from anterior to posterior) as body height increased (Fig. 3). Since oval IVF shapes are less likely to be associated with foraminal stenosis and radiculopathy than auricular-shaped IVFs, so this long, oval configuration might be considered healthy ***(Stephens et al., 1991)***.

Both antero-posterior (SAP and IAP) dimensions of the IVF were found to decrease as body weight increased. The result of this would be a more auricular-shaped IVF (Fig 3).

Since auricular-shaped IVFs have been related to stenosis, perhaps increased weight would predispose the IVFs to stenosis. This assumption could be considered a priori but also requires further investigation. The decrease in the SAP and IAP dimensions would presumably be the result of slight imbrications of facet surfaces with increased weight ***(Stephens et al., 1991)***.

The lumbar intervertebral foramina (IVFs) form a series of canalized tunnels through which the lumbar spinal nerve root emerges from the spinal canal. These structures are familiar to spinal surgeons, yet surprisingly little is known about the precise anatomy of this region, particularly the ligamentous structure associated with the lumbar IVFs (***Cramer et al., 2002)***.

The ligamentous structures in the lumbar IVFs, called the transforaminal ligaments (TFLs), were originally considered anomalous; however, more recently, TFLs have been referred to as normal structures ***(Bakkum and Mestan,1994)***.

Even though ligamentous structures associated with the IVFs of the human lumbar spine have been noted as early as the 19th century, it was not until 1969 that ***Golub and Silverman*** conducted the first serious study of these structures describing the TFL, since then, many more detailed studies have been conducted, and TFLs are now considered normal structures (Fig. 4) ***(Jun-Hong et al., 2005)***.

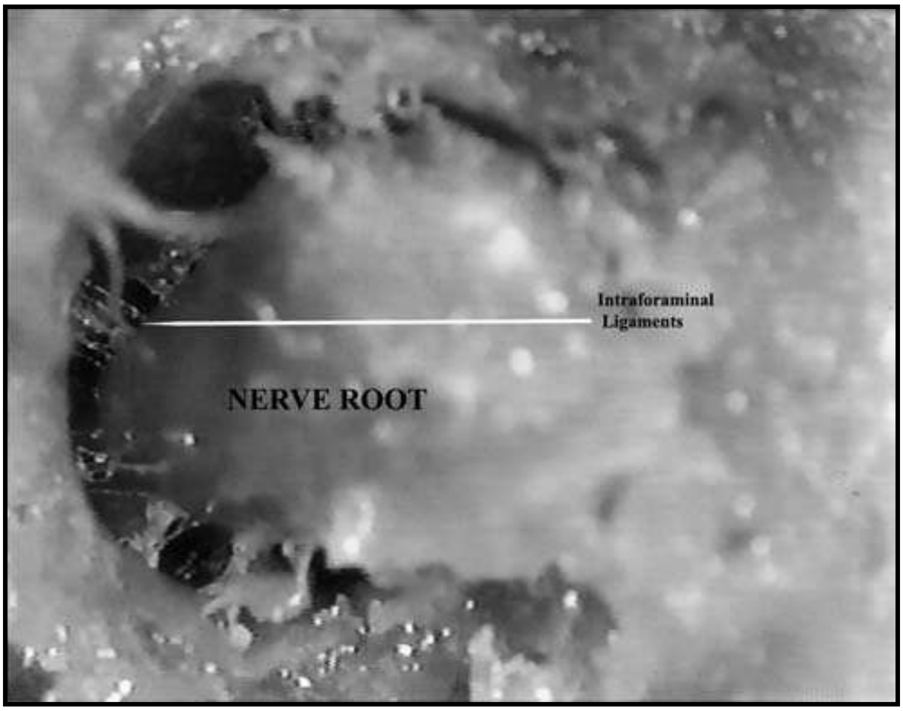

Fig. (4): Intraforaminal ligaments and nerve root shown in parasagittal anatomical section ***(Akdemir, 2010)***.

Although TFLs have been well documented in the human lumbar spine, TFLs were also reported to be found in the human lower thoracic spine similar to those found in the lumbar spine. In addition, a preliminary study has shown that there are also TFLs in the human cervical spine ***(Bakkum and Berthiaume,1994)***.

Several authors have suggested that TFLs play a potential role in some cases of nerve root entrapment and back pain ***(Transfeldt et al., 1993)***.

Normally these structures divide the IVF into compartments that transmit the neural and vascular structures that pass through the IVF, and it was noted that these ligaments grossly diminished the space available to the emerging anterior primary division of the spinal nerve ***(Olsewski et al., 1991)***.

Some investigators think that the TFL has a "guillotine" effect on the anterior primary division of the spinal nerve, therefore, it is possible that disc herniation or other degenerative changes could cause neurological symptoms in the IVF with TFL, whereas a lesion of the same size would not impinge on the neural structures if the TFL is absent ***(Jun-Hong et al., 2005)***.

Six types of foraminal ligaments were found; these are anatomically designated as the superior and inferior corporotransverse ligaments, and the superior, middle, inferior and posterior transforaminal ligaments (Fig. 5) ***(Hun et al., 2001)***.

The superior corporotransverse ligament is the most frequently seen in the spine, followed by the inferior corporotransverse ligament in frequency ***(Hun et al., 2001)***.

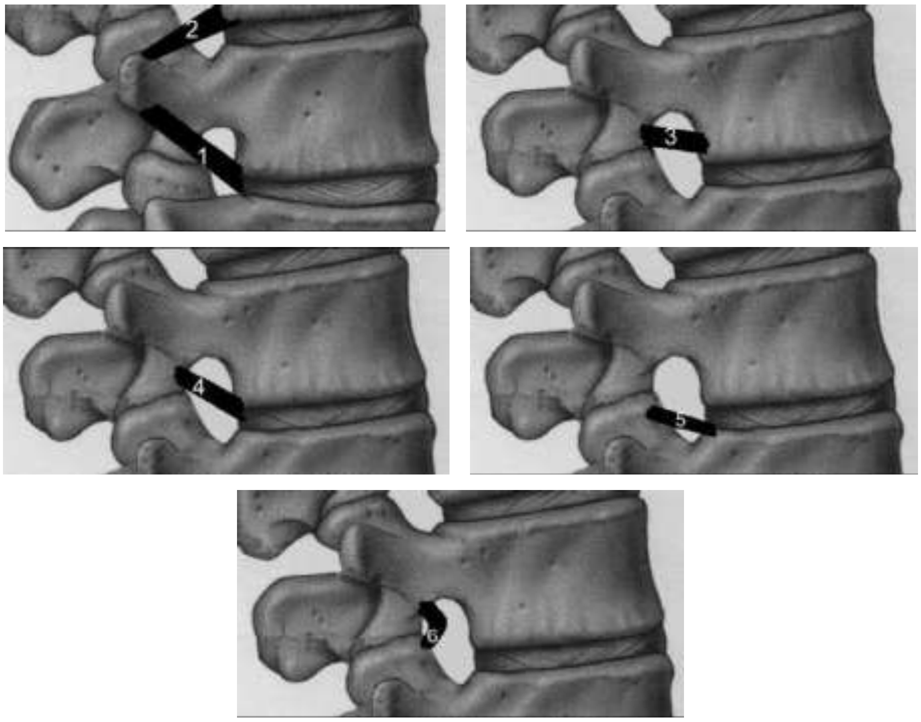

Fig. (5): (1) superior corporotransverse ligament. (2) Inferior corporotransverse ligament. (3) Superior transforaminal ligament. (4) Mid-transforaminal ligament. (5) Inferior trans-foraminal ligament. (6) Posterior transforaminal ligament ***(Hun et al., 2001)***.

Using MRI, if a trained radiologist identifies a TFL, there is an 87% chance that one is present; and if a trained radiologist does not identify a TFL in an intervertebral foramen, there remains a 51% chance that one is present ***(Cramer et al., 2002)***.

In IVFs where there is at least one identifiable TFL present, the superior-to-inferior dimension of the compartment transmitting the ventral ramus of the spinal nerve is diminished an average of 31.5%. If the size of the IVF is further diminished by degenerative changes of the intervertebral disc and zygapophysial joints, the TFLs could irritate or entrap the exiting spinal nerve or its anterior primary division (ventral ramus) and cause back and lower extremity pain ***(Macnab et al., 1990)***.

Therefore, being able to identify with confidence the presence of these ligaments may be of future benefit in the diagnosis of some cases of low back pain and radicular pain. The development of effective diagnostic imaging techniques for TFLs would also allow for the development of future research studies evaluating the relationship of TFLs to the presence of low back pain and radiating lower extremity pain.

Improved imaging techniques might also help to evaluate the role of TFLs in foraminal stenosis and improve the diagnosis of this condition ***(Nowicki and Haughton, 1992)***.

The critical dimensions of foraminal stenosis are 4mm or less for the posterior disc height, and 12mm or less for the foraminal height. The dimensions of the intervertebral foramen, however, change constantly during daily activity. Therefore, symptoms in patients with spinal stenosis are aggravated or relieved by the posture of their lumbar spine ***(Hasegawa et al., 1995)***.

It was also reported that all diameters of the lumbar foramina decreased as the spine moved from flexion to extension, with the cross-sectional area of the foramen increased 12% during flexion, and decreased 15% during extension ***(Inufusa et al., 1996)***.

Using an open-configuration magnetic resonance (MR) system with the individuals in an upright position, studies found a 23.2% decrease in the cross-sectional foraminal area from upright neutral to upright extended position and a 19.2% increase from upright neutral to upright flexed position ***(Schmid et al., 1999)***.

Considering anatomic relationships of a spinal nerve with its surrounding tissues in the inter-vertebral foramen during flexion, extension, lateral bending, and axial rotation, nerve root compression could be aggravated or relieved not only during flexion-extension but also during lateral bending and axial rotation of the lumbar spine; also, dynamic foraminal stenosis is more common in segments with disc degeneration ***(Nowicki et al., 1996)***.

Although disc degeneration is believed to associate with hypermobility of the motion segment, the exact kinematic of spinal motion segment with disc degeneration still has not been clarified ***(Panjabi et al., 1994)***.

Vascular Supply of the Nerve Root:

The vasculature of nerve roots has gone relatively unexplored until the latter half of the twentieth century.

Around that time, the diagnosis of lumbar spinal stenosis was postulated leading to an increased focus on the vascular anatomy of the lumbar nerve roots. Since then a number of morphologic studies have been able to establish the presence of a dual arterial blood supply to the nerve roots ***(Gilchrist et al., 2002).***