Introduction

Verbiest first described neurogenic intermittent claudication, which is a characteristic feature of lumbar spinal stenosis. It is characterized by pain, altered sensation and weakness in the lower extremity during standing and walking, and relieved on resting or sitting. Standing narrows the neural foraminal and canal area resulting in impingement, whereas flexing as seen in sitting increases the area relieving impingement ***(Siddiqui et al., 2006).***

Decompressive surgery has been required in patients who fail to respond to conservative therapy ***(Verbiest, 1954).***

Decompressive surgery typically involves excision of the ligamentum flavum and partial removal of the laminae. Medial facetectomies and foraminotomies are often performed as well depending on the cause of the stenosis, and fusion with or without instrumentation may be necessary for concomitant segmental instability. The goal of decompressive surgery is to remove the source of neurologic compression, thus, hopefully, relieving the neurogenic intermittent claudication ***(Joshua et al., 2005).***

Additional posterior fusion has been indicated in cases where the motion segment is believed to be unstable. In case that secondary instability is expected to develop after decompression of the posterior column, even a preventive fusion may be indicated although there is no preoperative instability ***(Etebar and Cahffl, 1999).***

Therefore, in severe spinal stenosis with or without segmental instability, many surgeons tend to perform decompression with fusion.

However, posterior fusion is not an ideal treatment modality for spinal stenosis with segmental instability also many studies have reported that this procedure can develop the so-called, the adjacent segmental syndrome ***(Etebar and Cahill, 1999).***

If surgeons perform fusion surgery due to a concern about potential instability, too many fusions may be done unnecessarily. Therefore, there should be strict indications when one considers fusion in lumbar spinal stenosis ***(Lee, 1988).***

The interspinous implants such as Coflex have been designed to treat lumbar neurogenic claudication secondary to spinal stenosis. These newly developed devices are composed of spacer made of titanium placed between two adjacent lumbar spinous processes ***(Swanson et al., 2003).***

Of these devices, Coflex should be implanted after the decompression and removal of the interspinous ligaments and resection of their bony attachment. This implant is placed in the interspinous space with the patient in a slightly flexed position. By preventing extension, it relieves the symptoms of lumbar spinal stenosis. However, it cannot be used as a substitute for a rigid fusion in cases of marked instability ***(Kong et al., 2007).***

It is hypothesized that interspinous implantation would result in a similar clinical outcome to the posterior lumbar interbody fusion (PLIF) when it is used in patients suffering from spinal stenosis with mild segmental instability and that this surgical method would be superior to PLIF without significantly affecting the degeneration at the adjacent motion segments ***(Tsai et al., 2006).***

Aim of the Work

Evaluation of interspinous spacers in the management of degenerative lumbar spinal canal stenosis.

Anatomy of the Lumbar Spine

Osseous Structures:

There are five lumbar vertebrae, followed by the sacrum making up the lumbosacral spine (Fig. 1 A and B). Each lumbar vertebra has 2 parts, the vertebral body and neural arch. The vertebral body; lies anteriorly, and its dimensions gradually increase from cephalad to caudal, and it is designed to bear weight. When viewed from above, the superior surface of vertebral body is wider transversely and is kidney shape. The discal surface of an adult vertebral body demonstrates on its periphery a ring of cortical bone. This ring, the epiphysial ring, acts as a growth zone in the young and in the adult as an anchoring ring for annular fibers. The hyaline cartilage plate lies within the confines of this ring. The neural arch; lies posterior to the vertebral body and consists of a pair of pedicles emerging from the posterolateral surface of the upper portion of vertebral body. These join with paired laminae, which are located further posteriorly, and are designed to protect the neural elements ***(Kuroki et al., 2004).***

The portion of the lamina between the superior and inferior articular processes and just below the level of the pedicle is the isthmus or pars interarticularis. This is a common site for stress fractures. From the junction of two laminae, a spinous process arises posteriorly. It is almost horizontal, quadrangular, and thickened along its posterior and inferior borders ***(Panjabi et al., 1993).***

Articulations

The articulations include the intervertebral disc anteriorly and a pair of facet or zygapophyseal joints posteriorly, reinforced by muscles and ligaments.

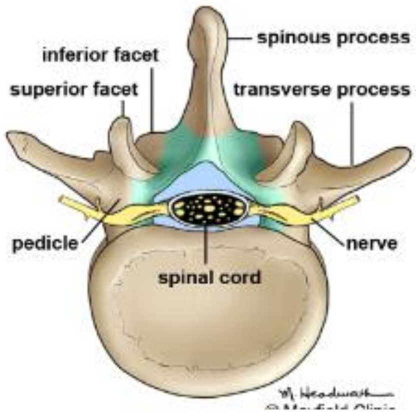

Figure (1): Osseous structures of the lumbar spine, ***(Hines 2013).***

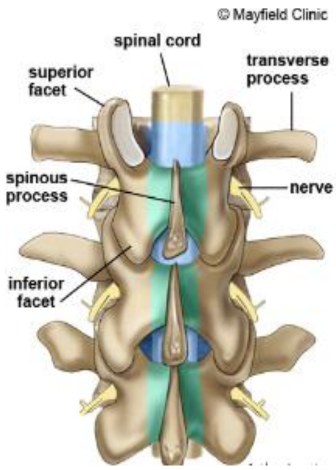

Figure (2): Seven bony processes arise from the vertebral arch to form the facet joints, spinous and transverse processes for muscle attachment.

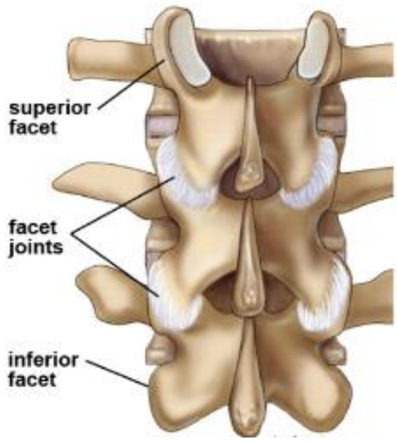

Figure (3): The superior and inferior facets connect each vertebra together. There are four facet joints associated with each vertebra.

(Hines, 2013)

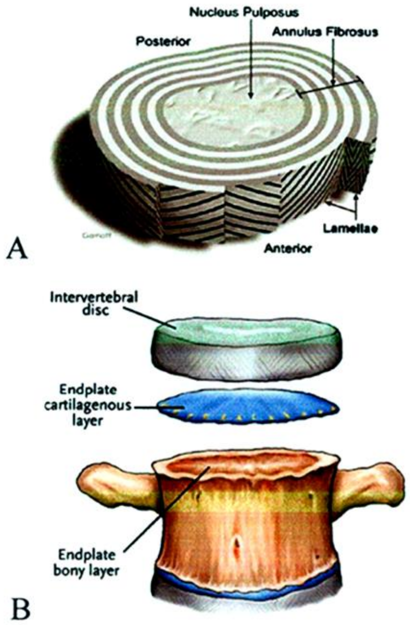

Figure (4): (A and B): The intervertebral disc ***(Devereaux, 2007).***

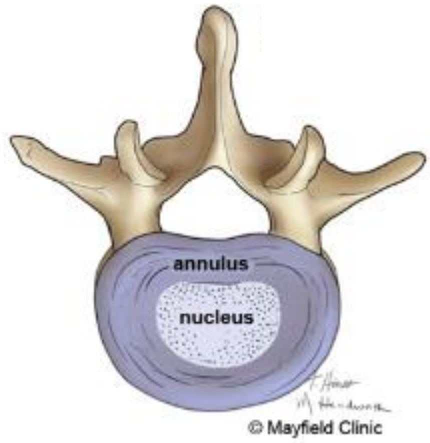

Figure (5): Intervertebral discs are made of a gel-filled center called the nucleus and a tough fibrous outer ring called the annulus ***(Hines, 2013).***

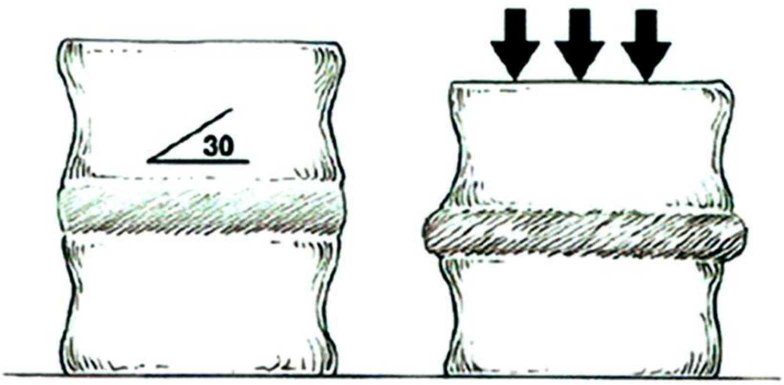

Figure (6): The annulus fibrosus is composed of layers of collagen fibers. The collagen fibers are oriented at 30° relative to the endplate. The orientation alternates with each successive layer ***(Belkoff, 2007).***

The Intervertebral Disc

Function: intervertebral discs stabilize the spine and maintain its alignment by anchoring adjacent vertebral bodies to each other. They also allow flexion, extension, and lateral bending motions between vertebrae that give the spine its flexibility, and they absorb energy and distribute loads applied to the spine ***(Chung et al., 2003).***

Structure: the disc tissue is best described as a specialized form of fibro-cartilage. The intervertebral disc is composed of three elements (Fig. 5); the central portion of the disc contains the nucleus pulposus, surrounded by the annulus fibrosus, and the cartilaginous end plates adjacent to the surfaces of the vertebral bodies ***(Martin et al., 2002).***

1) **The Annulus;** it forms the circumferential rim of the disc.The annulus has a multilayer lamellar architecture made of collagen fibers. Within each layer, the collagen is oriented at approximately 30° to the horizontal. Each successive layer is oriented at 30° to the horizontal in the opposite direction, leading to a "crisscross" type pattern. This composition allows the annulus, and in particular the outer annulus, which has the highest tensile modulus, to resist torsional, axial, and tensile loads (Fig. 6) ***(Rhee et al., 2006).***

   The fibers of the annulus can be divided into three main groups; the outer most fibers attaching between the vertebral bodies and the under surface of the epiphyseal ring; the middle fibers passing from the epiphyseal ring on one vertebral body to the epiphyseal ring of the vertebral body below; and the inner most fibers passing from one cartilaginous end plate to the other. The outer and middle fibers of the annulus are most numerous anteriorly and laterally but are deficient posteriorly, where most of the fibers are attached to the cartilage plate ***(Wong and Transfeldt, 2007).***

A thinner posterior annulus fibrosus and a more vertical arrangement of the fibers could account for increased incidence of posterior or posterolateral disc herniation as compared with anterior herniation ***(Ebraheim, 2004).***

The anterior longitudinal ligament (ALL) and posterior longitudinal ligament (PLL) further strengthen the disc space. The ALL attaches more strongly to the vertebral body edges than to the annulus. The PLL is not as strong as the ALL, it strongly attaches to the annulus fibrosus, and is frequently torn in cases of free fragment disc herniation ***(Martin et al., 2002).***

2) **The cartilaginous end plate** is located between the vertebral body and the disc; it functions as a growth plate and transfuses nutrients from the vertebral body to the disc ***(Ebraheim et al., 2004).***

3) **The Nucleus Pulposus** is centrally located and comprises approximately 50% of the total disc cross-sectional area in the

lumbar spine. It is composed of type II collagen strands that lie in a mucoprotein gel containing various hydrophilic proteoglycans that imbibe water. The water content of the disc varies with the age of the disc and in the normal disc ranges from 70 to 90% ***(Panagiotacopulos et al., 1987).***

The nucleus pulposus provides resistance to axial compression and is the principal determinant of disc height. The nucleus also contains a cellular component of both fibroblast like and chondrocyte like cells. These cells maintain the matrix in which they exist, and they also receive metabolic nutrients that diffuse through the matrix ***(Rhee et al., 2006).***

Collagens and proteoglycans are the primary structural components of the intervertebral disc macromolecular framework. Proteoglycan is a hydrophilic, negatively charged branched chain molecule composed of a protein attached to an oligosaccharide. They are also known as glycosaminoglycans and include structures such as chondroitin and collagen. The negative charge on the branched chains and the hydrophilic nature of proteoglycan internally pressurize the disc generating large hydrostatic pressure within the disc by drawing water via osmosis into the nucleus pulposus. Proteoglycans, through their interactions with water, give the tissues stiffness, resistance to compression, and viscoelasticity ***(Gumina et al., 1999).***

Unfortunately, proteoglycan and water content in the disc tend to decrease with age. Additionally the amount of hydration within the disc is inversely proportional to applied stress, suggesting that applied spinal loads lead to a loss of hydration and proteoglycan in the disc. Interestingly, proteoglycan, and water content, has also been shown to be low throughout the entire spine in patients with degenerated discs ***(Martin et al., 2002).***

Vascularity of the Disc:

The disc is an avascular structure with a low metabolic rate and receives most of its nutrition by diffusion, which is facilitated by spinal motion. The majority of disc nutrition is supplied via the capillary beds of the cartilaginous end plate. These capillary beds receive blood flow from the distal branches of the interosseous arteries supplying the vertebral body. Vascular and lymphatic tissue is present in the annulus of patients who are as old as age 20 years; however, lymphatics and blood vessels are not present in the nucleus pulposus at any age ***(Martin et al., 2002).***

Nerve supply of the Disc:

A meningeal branch of the spinal nerve, better known as the recurrent sinuvertebral nerve (Fig. 7), innervates the area around the disc space. This nerve exits from the dorsal root ganglion and enters the foramen, where it then divides into, a major ascending and lesser descending branch. The outer annular regions are innervated, but the inner regions and nucleus pulposus are not innervated. The ALL also receives afferent innervations from branches that originate in the dorsal root ganglion and from the segmental ventral ramus and sympathetic trunk. The PLL is richly innervated by nociceptive fibers from the major ascending branch of the sinuvertebral nerve ***(Martin et al., 2002).*** Degenerated human lumbar discs have been shown to contain more nerve tissue and to be more vascular than normal discs ***(Coppes et al., 1997).***

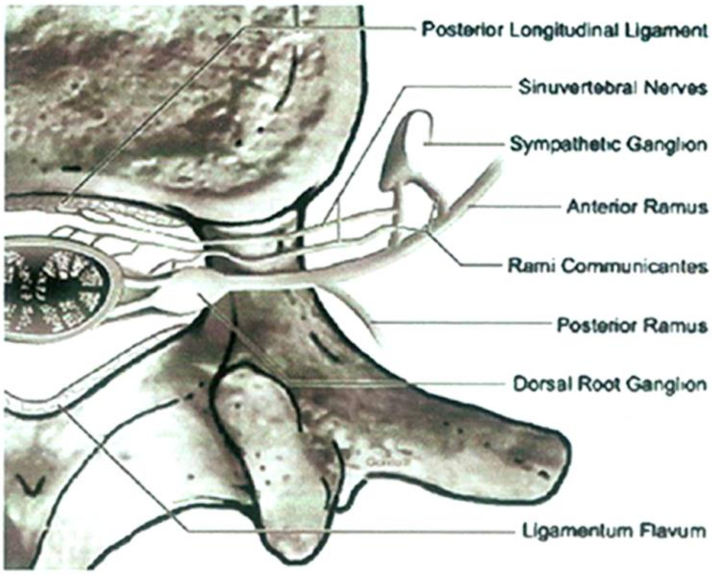

Figure (7): The Sinuvertebral nerve ***(Devereaux, 2007)***

Lumbar Facet Joints

Zygapophyseal joints are synovial joints that consist of the adjacent inferior and superior articular processes and the articular capsule. The articular surfaces are covered by hyaline cartilage, which allows sliding motion occurring in the posterior arch of the spinal column. The articular capsules are thin, and have an inner synovial and an outer fibrous membrane covered by the ligamentum flavum. In lumber region, the superior articular surface is concave and faces posteromedially, and the inferior articular surface is convex and faces anterolaterally. The facet joints lie posterolateral to the lumbar spinal canal and posterior to the intervertebral canals. These joints are sagittaly oriented in the upper lumbar spine, rotating toward the coronal plane at the lumbosacral junction and serve to limit the amount of forward shear translation and axial rotation of the motion segment ***(Watson and Giles, 1999).***

Muscles and Ligaments of the Lumbar spine

Ligaments; there are several ligaments that play an important role in stabilization of the spines as one unit (Fig. 8). These include:

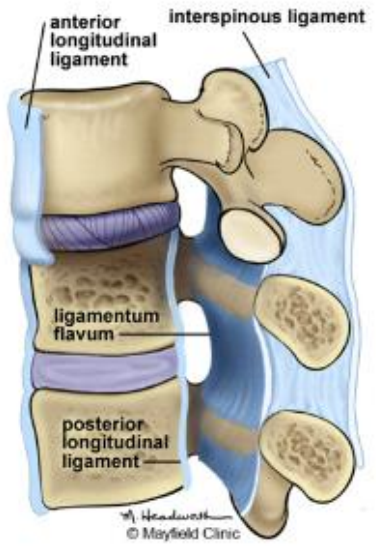

Figure (8): The ligamentum flavum along with the anterior and posterior longitudinal ligaments enable flexion and extension of the spine while keeping the vertebrae in alignment ***(Hines, 2013).***

1) **The ALL;** is a strong band that attaches to the whole anterior aspect of the vertebral bodies and intervertebral discs from the skull down to the upper part of sacrum. It is thicker anteromedially and thinner laterally. Limitation of extension of the spinal column is the main function of the anterior longitudinal ligament ***(Ebraheim et al., 2004).***

2) **The PLL;** attaches to the posterior aspect of the vertebral bodies and discs, from the occipital bone to the sacrum. In the lumbar region it is narrow over the middle of the vertebrae and broad over the discs. In the region of the intervertebral foramen, the posterior longitudinal ligament extends laterally and fuses with the lateral extensions of the anterior longitudinal ligament. The role of the posterior longitudinal ligament is to stabilize the spinal column during flexion ***(Ebraheim et al., 2004).***

3) **The ligamentum flavum;** is present in between the laminae of adjacent vertebrae and fuses with each other in the midline. It is mainly composed of yellow elastic fibers, which run in vertical direction. The attachments of the ligamentum flavum extend from the middle portion of the anterior surface of the upper laminae to the upper portion of the posterior surface of the lower laminae, covering whole interlaminar space. Laterally, the ligamentum flavum fuses with the capsule of the facet joint ***(Olszewski et al., 1996).***

Besides their role as restraints against hyperflexion of the lumbar spine, their main function is to provide a smooth covering for the posterior and posterolateral wall of the spinal canal in all postures of the spine ***(Giles, 1999).***

4) **The interspinous and supraspinous ligaments** are the posterior ligaments of the spinal column, which connect the spinous processes with each other ***(Ebraheim et al., 1997).***

5) **The intertransverse ligaments** are membranous structures located between the transverse processes, typically in the lumbar region. The intertransverse "ligament" (ITL) was just anterior to the intertransverse muscles and had a distinct horizontal and vertical leaf and its development ranged from a thin membranous to a thick ligamentous structure ***(Schlesinger et al., 1992).***

6) Transforaminal ligaments:

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).***

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