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Nonfusion Techniques for Degenerative Lumbar Diseases Treatment

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1. Introduction

Conservative treatment is the “gold standard” treatment for low back pain, in spine degenerative conditions. However, in cases where there is a failure in conservative measures, surgical treatment becomes an option (Roh et al, 2005). These procedures traditionally included decompression of spinal elements, correction of deformity and arthrodesis of the diseased spinal segment but, in some conditions, they both may be used in a combined manner (Schwarzenbach et al, 2005).

The technique of fusion with the use of only bone graft was first reported by Hibbs and Albee in 1911 (*apud* in Huang et al, 2005), for prevention of progression of Pott disease. Pioneers in using metallic instrumentation for stabilization, associated with bony fusions, were Harrington (1976) for scoliosis surgery, Roy Camille (1979) and Steffe (1986) with screw-plate system, Magerl (1984) with external fixation for fracture treatment, and Dick (1985), with the internal fixator (*apud* in Schwarzenbach et al, 2005). Since then, lumbar fusion became the “gold standard” surgical treatment for a wide range of painful conditions. The primary goal of lumbar stabilization is to treat pain from disc or facet, in the unstable spinal unit. In these cases pain emerges apparently under load (Christiansen et al, 2004).

However, no surgical treatment is perfect. Christiansen and coworkers (2004) obtained positive results in approximately 70% of cases of fusion surgery. An important complication, in the medium-term follow-up, is degeneration of the disc, adjacent to a fusion segment (Rham and Hall, 1996), known as adjacent disc degeneration (ADD). In this study, ADD occurred in 30% of cases, five years after fusion. Articular hypermobility in the segment above fusion segment was reported by Luk and collaborators (1987) in 50% of cases, of which 30% had also stenosis of the spinal canal.

Another post-operative complication, related to fusion, is pseudoarthrosis, compromising the final result of the surgery (Kornblum et al, 2004). In order to achieve good results in fusion, consolidation of the bony fusion is critical (Butterman et al, 1998). However, a study of Muholand and Sengupta (2002) noted that bony consolidation, with achieved fusion segment, does not represent necessarily a clinical success.

Rham and Hall (1996), in their study, also demonstrated that, in pseudoarthrosis, micromovements in the facet joint preserves hypermobility in the adjacent segments, acting

like a "protective factor for the development of the adjacent segment degeneration". This finding was also described in 2004 by Ghiselli and collaborators.

With all these evidences, nonfusion techniques arise, aiming the prevention of ADD, and the fact that this new technology does not require bone graft, since these techniques don't depend on bony consolidation.

1.1 The lumbar stability

In 1990, White and Panjabi defined instability of the spine as "the loss of the spine's ability to maintain its patterns of displacement under physiologic loads so there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain".

The importance of lumbar stability was originally established by Kruton (1944). Morgan and King (1957) reported that instability was a primary cause of low back pain. The degenerative process of the lumbar spine was better understood after studies of Kirkaldy-Willis and coworkers (1978), and the development of the disease was described later by Kirkaldy-Willis and Farfan (1982), using a concept of three phases: 1) temporal dysfunction, 2) unstable phase, and 3) restabilization. In the last phases, 2 and 3, patients often have stenosis, or deformities, like degenerative scoliosis, often requiring surgery for stabilization, decompression and/or correction of the deformity. (**Figure 1**)

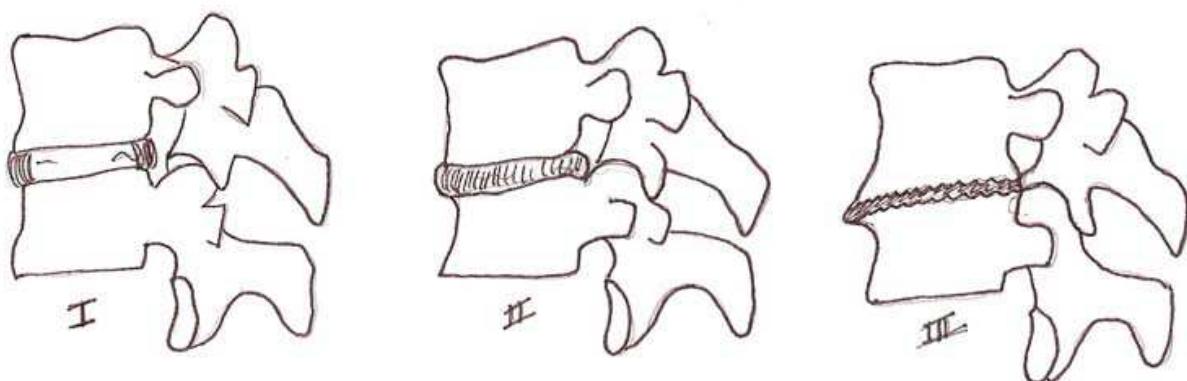


Fig. 1. The degenerative cascade described by Kirkaldy-Willis and Farfan (1982). At the third phase, the disc lost height and facet hypertrophy promotes segment stabilization, but also narrowing the neural foramen and the vertebral canal (stenosis)

The intervertebral disc plays the most important role in spine stabilization (Roh et al, 2005). Disc degeneration is a physiological process with aging. The extracellular matrix structure changes, mainly in proteoglycans concentration at the *nucleus pulposus*, leading to disc dehydration causing, because of that, morphological changes in the disc (Biyany et al, 2004). With these changes, biomechanical function of the disc is altered, and the load in this dysfunctional disc starts to injure other structures, such as the endplates, the facet joints and the fibrous annulus (Bernick et al, 1991). Additionally, these degenerative changes can cause a number of effects in the spine and nerve roots. Protrusion or disc herniation can cause radicular compression, central stenosis and considering that there are nociceptors located there, it will, as well, lead to low back pain (Roh et al, 2005).

The basic functions of the spine are: to provide stability, giving mobility to the body, to protect the spinal cord, and to control neural information in order to move the upper and lower limbs (Harms and Tabasso, 1999). For this reason, this architecture has passive elements (bones, joints and ligaments) and active elements (muscles).

Therefore, the spinal stabilizing system consists of three subsystems: spinal column, muscles surrounding the spine, and motor control unit. The spine carries load, and provides information about position, motion and loads of the spinal column (proprioception). With this information, the control unit turns it into action by the muscles (active elements), which must provide dynamic changes in the spinal column, altering the spinal posture and loads (Panjabi, 1992).

1.2 Biomechanics of the degenerated spine

Biomechanics of the spine is not simple, because it involves complex movements of flexion, lateral inclination and rotation, and the combination of all these movements. As the spine has a huge amount of spinal units, which provide the movements, its center of rotation is not static. As movement changes, the center of rotation changes as well, and so does the loading on the spine structures, having different points of axial load in the same functional unit, with focus in the intervertebral disc and facet joints (Lumsden et al, 1968). This mobility is possible due to the possibility of intervertebral disc deformation, but is limited by the disc architecture, vertebral body, and the structures in the posterior arch (Harms and Tabasso, 1999).

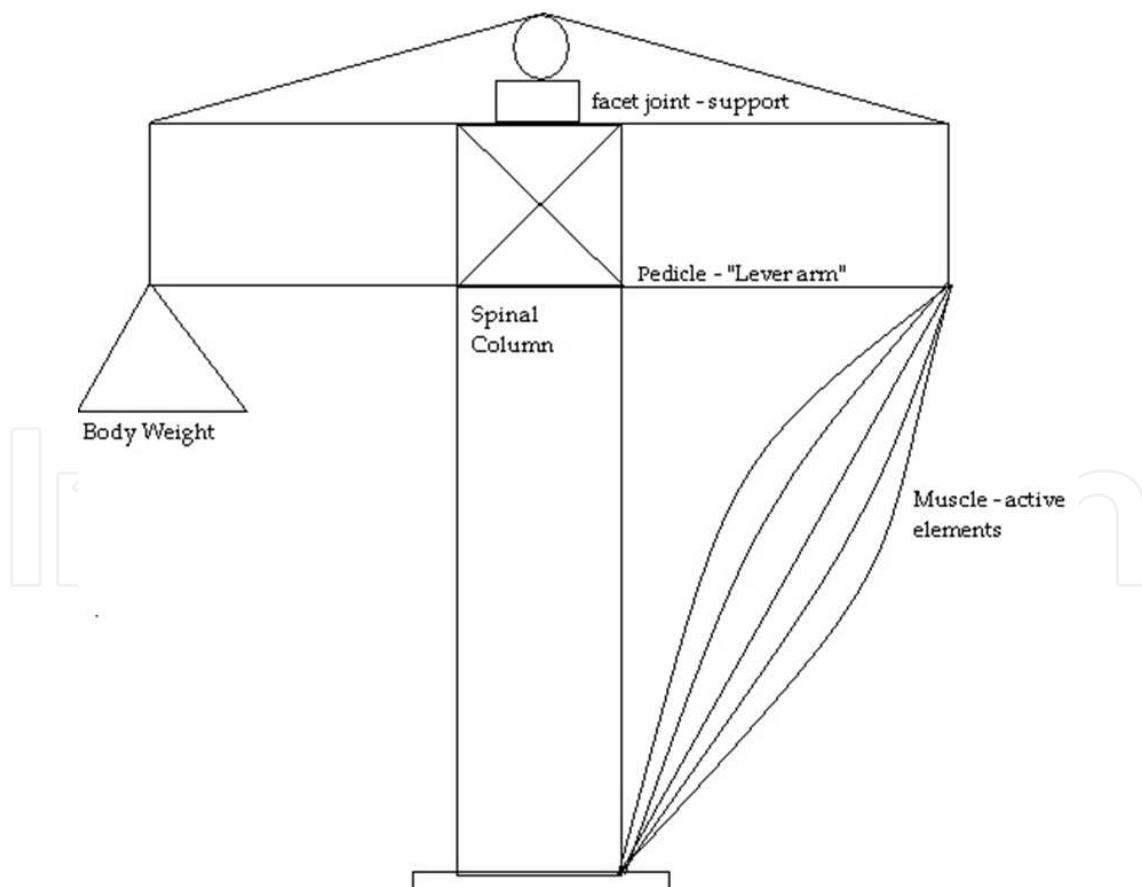


Fig. 2. The “crane”, of the lumbar stability. To be stable, all the elements, active and passive, must be intact. (Adapted from Harms and Tabasso, 1999)

For better understanding, we can imagine the spine as a crane (**Figure 2**). In standing position, the body center of gravity is located anterior to the spine, anterior to the vertebral bodies and intervertebral discs. Thus, an axial load is distributed as an axial compressive load in the anterior column, holding 80% of the axial load, and the remaining 20% as a shear force in the posterior column (Harms and Tabasso, 1999). So, the anterior column receives loads primarily by compression forces, and the posterior column also resists stretching, torque and tilt. Due to these characteristics, the anterior column acts like a distraction device, and the posterior column as a tension band (Harms and Tabasso, 1999). The tensile forces in the posterior columns are actively made by the muscles, and supported by the facet joints and ligaments. The lever arm of this stabilization system depends on the pedicular sizes, influencing in the effectiveness of the posterior musculature (Harms and Tabasso, 1999).

The function and effectiveness of the posterior elements to provide stability depends on the integrity of the anterior column (Harms and Tabasso, 1999). Kirkaldy-Willis and Farfan described this degenerative cascade (1982), the degeneration of the disc (anterior column) causing an overload in posterior elements, thus inducing a degeneration of muscles and facet joints.

Modic (1984, 1991), using Magnetic Resonance Imaging (MRI) studies, described degenerative changes in the intervertebral disc, with overload to the endplates (**Figure 3**). Biomechanical failure on the facet joints, and muscular failure, with overload to the endplates, leads to a nociceptive pain (Kusslich et al, 1991), and the progression of the disease leads to cyst formation on the facets, hypertrophy, with narrow disc space, that can cause central or *foraminal stenosis* (Dubois et al, 1999).



Fig. 3. The overload in the endplates, caused by disc degeneration, induces changes in the MRI. **A)** Modic type 1, the endplates are black in T1 incidence and white in T2 incidence (edema). **B)** The endplates are white in both T1 and T2 incidences (fat). **C)** The endplates are black in both incidences (sclerotic). (Adapted from Zhang et al, 2008)

Albert and Manniche (2007) demonstrated, in a randomized controlled trial with 181 patients, that Modic changes type 1 is more strongly associated with non-specific low back pain than Modic changes type 2. They also suggested in this study, that disc herniation is a strong risk factor for developing Modic changes in the same level, during the following year (Albert and Manniche 2007).

1.3 The adjacent segments

Over the years, the “gold standard” technique to treat severe degenerative lumbar spondylosis has been spinal fusion (Lehman et al 1987, Ko et al 2010). However, since the beginning of this use, the damaging effects of creating rigid segments in the spine, with overload to the adjacent levels (transition syndrome) have been discussed (Fymoyer et al, 1979, Stokes et al, 1981, Aota et al, 1995, Rahm et al, 1996, Christensen et al, 2004, Fritzel et al, 2003, Cheh et al, 2007, Kumar et al, 2001, Wiltse et al, 1999, Miyakoshi et al, 2000, Lee et al, 1988, Min et al, 2008, Yang et al, 2008, Korovesis et al, 2009).

No surgical technique is perfect, even in this “gold standard” method, patients are subject to a number of short and long-term morbidities. The relative immobility of fused spinal segments transfers stress to adjacent segments, leading to acceleration of adjacent level degeneration, because the sagittal alignment of a fused spinal segment is fixed and cannot adapt to variations in posture (Weinhoffer et al, 1995).

A series of studies have shown, in cadavers and in vitro, that fusion increases intradiscal pressures, end plate stresses, and annular stresses at adjacent segments (Lee et al, 1984, Weinhoffer et al, 1995, Cunningham et al, 1997, Rohlman et al, 2001, Eck et al, 2002, Rao et al, 2005, Sudo et al, 2006). The restricted motion in the fused segments, in an active body, having fixed sagittal alignment, increases motion and stress at adjacent levels, in sitting, supine and erect postures (Huang et al, 2005).

This stress doesn't lead to hypermobility in the adjacent levels after fusion since degeneration progresses. Avoidance of hypermobility at the adjacent levels is frequently attributed to nonfusion technology. A few studies already reported about such an effectiveness of dynamic stabilization techniques (Olsewki et al, 1996, Phillips et al, 2002, Shono et al, 1998, Panjabi et al, 2007).

The incidence of adjacent disc degeneration is not clear. But, it has shown clinical evidence. Sears and coworkers (2011), in a retrospective cohort study, associate the risk of a new surgery for adjacent level degeneration with the number of levels fused. They concluded that, although young patients who underwent single-level fusions are at low risk, patients who underwent fusion of three or four levels had a threefold increased risk of further surgery, compared with single-level fusion, and a predicted 10-year prevalence of 40%.

Szpalski and coworkers (2002) published a comprehensive review of nonfusion implants, which comprises posterior dynamic stabilization, interspinous devices, and total lumbar disc replacement. The potential reduction of the adjacent disc disease is mainly attributed to the avoidance of increased stress at the adjacent segments. Such increased stress is anticipated in instrumented fusion procedures, leading to hypermobility at the adjacent segments. Shono and coworkers (1998) demonstrated that hypermobility at the adjacent levels was proportional to the length and rigidity of the instrumented constructs.

2. When is surgery necessary?

Low back pain is the first symptom of disc degeneration. The degenerate intervertebral disc is associated with structural failure, with radial failures, prolapse, endplate damage, annular protrusion, internal disc rupture, and disc space narrowing (Dubois et al, 1999, Schnake et al, 2006). Especially the discs, posterior and capsular ligaments, as well as the vertebral

endplates have been found to be the major sources of nociception leading to pain (Kusslich et al, 1991). With the progression of the disease, hydration of the nucleus pulposus decreases, and this composition alters, leading to loss of disc height and reduction of its intradiscal pressure. As described by Kirkaldy-Willis (1982), this cascade evolves, leading to overload the annulus fibrosus and the facet joints. Loading with inadequate nuclear turgor leads to shearing forces in the transitional zone between the nucleus and annulus (Huang et al, 2005). As a result, we have ruptures and radial tears in the annulus fibrosus, and overload of the facet joints. This change leads to instability. In addition to disc protrusion toward the spinal canal, disc height decreases, and there is spinal canal or neural foramen stenosis, that leads to radicular pain (Yu et al, 1988, Urban et al, 2003).

Pain from degenerative diseases may arise from stenosis, facet overload, the disc itself, and eccentrically loaded vertebral endplate. In patients with radicular pain, secondary to radicular compression, consequence to disc prolapse, surgical procedures have to be carried out, if the conservative therapy fails. However, operative treatment, like discectomy or nucleotomy, leads to progression of the disc degeneration (Dunlop et al, 1984, Gottfried et al, 1986, Brinckmann et al, 1991). In 2004, Jansson and collaborators published that approximately 10% of all operated discs reherniate and approximately 27% of all operated patients have to undergo a second operation within 10 years.

Nonsurgical management must be considered, in low back pain, especially in patients without radicular compression signs.

Stabilization devices leave the pain-generating disc tissues in situ, but restrict certain types of motion and alter load transfer through the functional spinal unit (Huang et al, 2005). Fusion implants are designed to unload the disc and facets by load sharing.

In 1954, Verbiest described the so called neurogenic intermittent claudication secondary to lumbar spine stenosis. Recent studies show that clinical or nonsurgical treatment have poor results comparing to surgical procedures (Weinstein et al, 2008). Surgical treatment based on decompression alone presented poor results, related to progression of symptoms and deformity (Hanley et al, 1995). At the same time, adding an arthrodesis to the decompression procedure increases the operative time and blood loss, and consequently the complication rate (Di Silvestre et al, 2010).

3. Nonfusion techniques: Advantages and disadvantages

For many years arthrodesis has been acknowledged as the gold standard treatment for a wide variety of spinal pathologies such as deformities, unstable and painful conditions of the lumbar motion segment (Mayer et al, 2002).

Nevertheless, spinal fusion in degenerative disc disease when there is no instability or disturbed curvature, though often performed, is not a consensus among the spinal community (Greenough et al, 1994, 1998, Kozak et al, 1994, Mayer et al, 1998). In most cases, there is indication of arthrodesis when all kinds of conservative therapies fail.

However, the results seem to not always justify these decisions (Mayer et al, 2002). Fritzell and coworkers (2003) observed a 12% 2-year incidence rate of major complications following lumbar arthrodesis, with a reoperation rate of 14.6%. Complications include pseudarthrosis,

bone graft donor site pain, instrumentation failure, infection and simple failure to relieve pain (Frelinghuysen et al, 2005, Tropiano et al, 2005). Not to mention the possibility of an adjacent segment degeneration, which have made spinal surgeons think of an alternative method that could avoid such complications (Rham et al, 1996).

It's important to mention that there are increasing numbers of patients who have undergone spinal fusion for degenerative disc disease with images showing adjacent level degenerative changes, but not necessarily with a strong clinical impact. In a long term follow-up of 30 years, there was a significantly higher incidence of radiographic changes at adjacent levels after lumbar fusion, but this was not accompanied by a significant change in the functional outcomes (Kumar et al, 2001).

Non fusion technologies in spine surgery are being developed to address the arthrodesis' disadvantages (Jansen and Marchesi, 2008).

Non fusion implant types include total disc replacements, prosthetic nuclear implants, and posterior stabilization devices.

Potential advantages of nonfusion implants (Mayer et al, 2002, Huang et al, 2005):

1. Elimination of the need for bone graft.
2. Reduction in surgical morbidity
3. Elimination of pseudarthrosis
4. Reduction of adjacent level degeneration

Pseudarthrosis and the need for bone graft are truly eliminated, as well as the above mentioned reduction in surgical morbidity. Nevertheless, it is questionable whether nonfusion technologies significantly decrease the incidence of adjacent level disease, especially if segmental motion is not well maintained. Furthermore, if bone graft substitutes prove to be efficacious and economically viable alternatives to autogenous bone grafting, avoidance of autograft harvest will no longer be a significant advantage of nonfusion implants.

Potential disadvantages of nonfusion implants (Mayer et al, 2002):

1. Mechanical failure and device migration
2. Implant subsidence
3. Same level degeneration

Considering the fact that nonfusion implants are characterized by motion, therefore they are subject to mechanical failure or migration.

It is believed that subsidence is a significant contributor to poor outcomes after total disc replacements and this is probably the most significant challenge to long-term outcomes with these implants. Optimized implant design and end plate coverage may diminish the chances of subsidence happening.

The preservation of segmental motion obtained in nonfusion technology created the concept of symptomatic same level degeneration, as opposed to what is seen in a solid fusion. The possible sources of same level degeneration are the intervertebral disc, the facet joints, and the ligamentum flavum.

In conclusion, the potential pitfalls and benefits of nonfusion implants have to be carefully considered before the selection of this technology. Long-term randomized prospective studies are necessary and are currently unavailable, so non fusion procedures should be reserved for use in a small population of highly selected patients.

4. Total disc arthroplasty

4.1 Overview

Lumbar fusion has been developed for several decades and became the standard surgical treatment for symptomatic lumbar degenerative disc disease (DDD). Disc arthroplasty devices have been designed in an attempt to replace functionally the intervertebral discs, as opposed to the gold standard method (fusion) which could not achieve that (Fekete et al, 2010). Hence, a method of motion preservation would be the best alternative to spinal arthrodesis, considering that it could theoretically prevent adjacent level degeneration. However, the long-term stability, endurance and strength of the prosthesis are unknown for the majority of implants (Freeman et al, 2006).

The most important functions of the intervertebral discs are the transmission of load and the maintenance of motion and disc height. Nevertheless, none of the implants currently available can reproduce totally the kinematics of a healthy intervertebral disc (Fekete et al, 2010).

There are basically two types of disc arthroplasty devices: nucleus or total disc replacement (TDR) devices, the latter being the most frequently used.

The first total disc arthroplasty implant to be widely used was the three component SB-Charité prosthesis, a metal-polyethylene-metal construct, devised by Schellnack and Buttner-Janz in 1984. Since then, three different prototypes of the SB-Charité prosthesis have been developed. Of all the other types of total disc arthroplasty, the Pro-disc prosthesis, devised by Marnay, also in the 1980s, has been widely used (Zigler et al, 2004) (Figure 4).

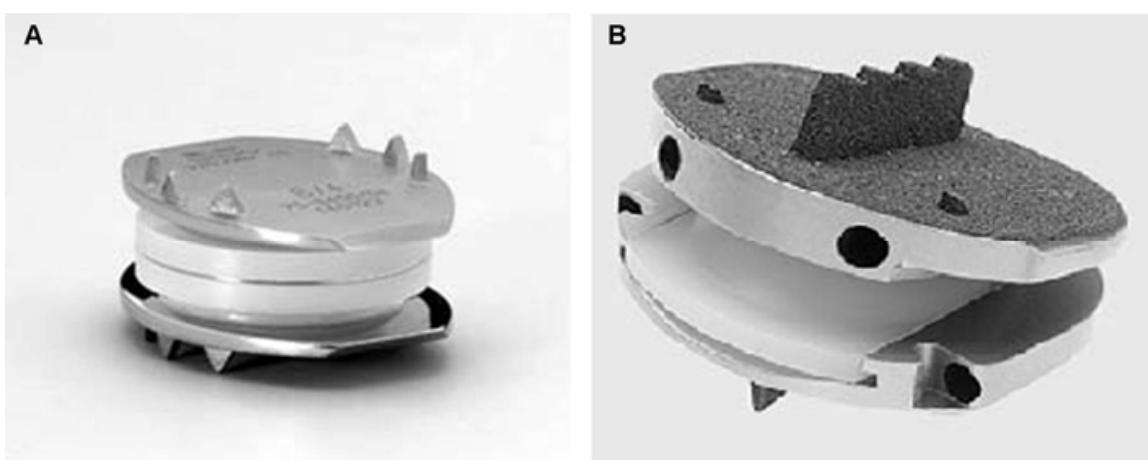


Fig. 4. Total disc replacement in lumbar Spine: A) Sb-Charité, B) ProDisc prosthesis

Each artificial disc comprehends two or three components including two endplates and an articulating mechanism with either a metal-on-metal or metal-on-polymer surface. In order to keep the disc in place and providing stability within the host vertebral body, devices

feature different designs, such as teeth-like components called spikes or fins that are driven into the vertebral bone, a porous coated surface on the endplates, promoting bony in-growth around these structures, or are secured into the recipient vertebral body with screws (Mayer et al, 2005; Jansen and Marchesi, 2008).

Arthroplasty devices can be classified based on their biomechanical properties, as (Errico et al, 2005):

1. Constrained implant: Have mechanical restrictions in motion within the physiological range, providing a fixed center of rotation.
2. Semi-constrained implant: allows motion in the physiological range
3. Non-constrained implant: allows hypermobility in comparison to the physiological range

The healthy tri-joint complex (intervertebral disc and the two facet joints) represents a semi-constrained system that allows physiological motion and prevents abnormal (excessive) motion. This motion unit in its healthy state allows for six potential motion directions: compression, distraction, flexion, extension, lateral bending, and axial rotation (McCullen et al, 2003).

Unlike spinal fusion, artificial disc replacement (ADR) is designed to preserve motion at the target spinal level. As well as possibly providing greater pain relief, this motion preservation may potentially decrease stress on and mobility of the adjacent segment structures, factors that are thought to contribute to adjacent segment disease. ADR can also restore pre-degenerative disc height and spinal

Alignment and the benefit of not depending upon a bone graft. Other theoretical advantages include maintenance of mechanical characteristics, decreased perioperative morbidity compared with fusion, and early return to function (Fritzell et al, 2001).

4.2 Indications

The leading indication for total disc arthroplasty is symptomatic, degenerative, monosegmental instability of the lumbar spine between L2 and S1. The patient must be refractory to all kinds of conservative treatment, having persistent pain (intensity greater than 5 on the visual analog scale) for at least six months. Age should range preferably between 30 and 50 years old. Furthermore, there must be a correlation between imaging studies and symptoms. MRI shows degeneration of the disc, with only mild loss of height of intervertebral space. Provocative discography reproduces the patient's typical pain (Kraemer et al, 2009).

Contraindications to the implantation of disc prosthesis include: osteoporosis, infection, deformities, tumors, malformations, multisegmental degeneration and psychosocial disturbances (Kraemer et al, 2009).

4.3 Surgical method

Insertion of the prosthesis involves an anterior approach and is usually performed by a general surgeon and a spine surgeon. Potential problems associated with ADR may include injury to other structures (vascular, neurologic, intestinal, or urogenital), infection,

loosening, polyethylene or metal wear, loss of motion over time, impact on adjacent discs and facet joints, subsidence, implant failure, heterotopic ossification, and device related endplate fracture (Geisler et al, 2004, 2008).

4.4 Clinical results

It is still uncertain, though, whether TDR is really more effective and safer than the gold standard treatment, lumbar fusion. To systematically compare the effectiveness and safety of TDR to that of arthrodesis treating lumbar DDD, Yajun and collaborators performed a meta-analysis, which has been published in 2010. The authors observed that the group of patients submitted to TDR had slightly better functioning and less back or leg pain without clinical significance, and significantly higher satisfaction status in TDR group compared with lumbar fusion group at the 2-year follow-up. Later on, at five years follow-up, these outcomes have not shown significant differences between comparing groups. The complication and reoperation rate of two groups are similar both at two and at five years.

The authors concluded that TDR does not show significant superiority for the treatment of lumbar DDD compared with fusion. The benefits of motion preservation and the long-term complications are still unable to be concluded. More high-quality RCTs with long-term follow-up are imperative to come to new conclusions.

In a systematic review of the literature, Freeman and coworkers (2006) stated that significant facet joint osteoarthritis is a contraindication to TDR, but that could be a difficult situation to identify in its early stages.

Moreover, the future of facet joints following a total disc replacement is obscure and facet joint hypertrophy, which accelerates spinal stenosis, may be a potent long-term complication that kind of implant. Not to mention that revision procedures will unquestionably be technically difficult with a great risk of vascular injury, particularly at the L4/5 level.

Therefore, that review of the literature concluded that the use of TDR may be limited to the treatment of degenerative disc disease in its early stages, with preservation of disc height. That would limit its indications, eliminating its uses in the majority of patients.

Up until now, only few studies have examined the direct effects of disc arthroplasty on adjacent levels. These studies show contradictory conclusions. While some of them support the idea of decreased adjacent-level degeneration, although lacking a clinical significance (Huang et al, 2006) others raise concerns about the high rates of index-level facet joint arthrosis and adjacent-level degeneration, despite motion preservation (van Ooij et al, 2003, Shim et al, 2007, Siepe et al, 2007) A trustworthy analysis of these results is difficult , considering the limitations in study design as well as the differences in the kinematics of the various implants examined.

5. Interspinous implants

5.1 Overview

With population aging, degenerative spine disorders became more common. The degenerative cascade, described by Kirkaldy-Willis and Farfan (1982) leads to disc and

articular changes, with disc bulging and facet hypertrophy, causing effects in the spine, such as central and/or foraminal stenosis. Verbiest (1954) described neurogenic intermittent claudication secondary to degenerative lumbar stenosis. Thus, some kind of management has to be proposed, either conservative or surgical, in order to relieve symptoms. Weinstein (2008) suggests, in his study, that surgical procedures achieve better results, compared to conservative management.

Symptoms of spinal stenosis most often occur in patients 50 to 70 years old. These symptoms include low back pain, buttock pain, and/or trochanteric and posterior thigh pain (Trautwein et al, 2010). Neurogenic claudication occurs when these symptoms exacerbate with walk, in extend position, and relieves when sitting or flexion of the spine.

A surgical treatment, for decompression and fusion of the segments, has increased operative time and blood loss, increasing complication rate in elderly patients (Carreon, et al, 2003, Deyo et al, 1993, Benz et al, 2001). To prevent complications and relief symptoms, with minimally intervention, new techniques have been developed to manage this condition.

Interspinous devices were first described in 1950, by Dr Fred L Knowles (Bono et al, 2007). But, the results are poor, with high number of devices dislodged, needing to be removed. Sénégas (1988) described an interspinous spacer, made of titanium, with Dacron tapes to fix the devices to spinous process. He had success in the treatment of more than 300 patients. After that, other implants have been developed (Coflex, Wallis, X-stop, Diam), with another material types (Titanium, peek) (Sengupta, 2004), but follow-up studies are still running to access its efficiency, and precise its indications (**Figure 5**).

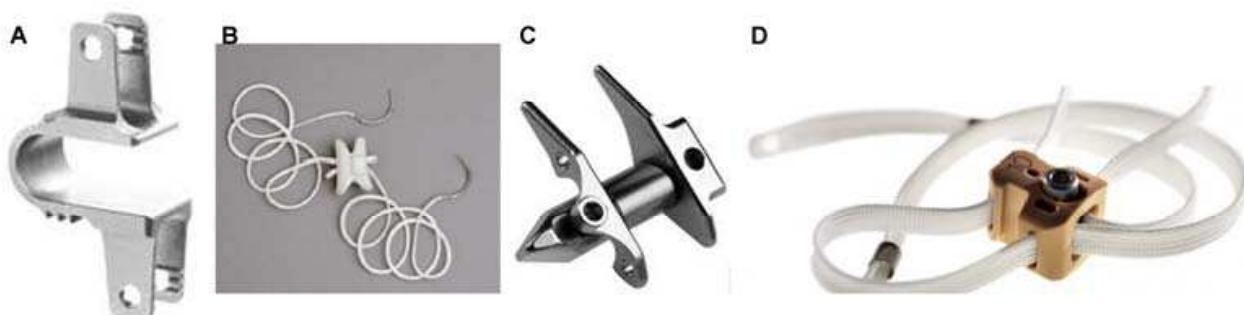


Fig. 5. Interspinous distraction devices: A) Coflex, B) Diam, C) X-stop and D) Wallis.

5.2 Indications

The interspinous distraction devices, keep the segment in flexion. In this condition, the device reduces loading to the intervertebral disc, and also reduces spinal and foraminal stenosis (Sengupta et al, 2004). For this reason, this procedure is indicated in patients in whom the symptoms are increased in extension (Gunzburg et al, 2003). For better results, it is indicated for patients aged 50 years or older, with moderately impaired physical function related to neurogenic intermittent claudication, and may be implanted at one or two lumbar levels (Yi et al, 2010). Better results are related to pain relief in lumbar flexion, with or without low back pain, and failure of nonsurgical care (Laurysen et al, 2007). The Wallis mechanism to treat low back pain, caused by degenerative instability, is indicated for: Massive disc herniation, with substantial loss of disc material, reherniated disc with second

discectomy, disc herniation in traditional level, like sacralization of L5, adjacent segment degeneration, to previous fusion, and isolated Modic I lesion, that leads to chronic low back pain. (Sengupta et al, 2004). Contraindications include: Disc degeneration grade V of Pfirrmann classification, spondilolisthesys, severe osteoporosis, spinal anatomy that would prevent implantation or cause instability, cauda equine syndrome and active systemic infection or localized infection at the site of implantation (Yi et al, 2010).

5.3 Surgical method

The X-stop device was developed to a minimally invasive approach, with short time surgery, to prevent complications in the elderly patients (Sengupta et al, 2004). For the procedure, patient must be placed in prone or lateral decubitus. They are positioned in flexed position, to keep distraction between the spinous process of the vertebral segment that will be treated. With a 4-5cm midline incision, the spinous processes are approached at the appropriate disc level, which is confirmed radiographically (Zucherman et al, 2004). The supraspinous ligament has to be maintained, to prevent kyphosis and stabilize the implant (Yi, et al, 2010, Zucherman et al, 2007). The distractor is placed through the interspinous ligament, after distraction, to maintain flexion of the segment. The spinal canal is not violated, with no need of laminectomy, laminotomy or foraminotomy.

The Wallis device must be placed with local or general anesthesia. Patient is placed in a prone position, in neutral. A neutral position of physiological lumbar lordosis is best to optimize the effect of the implant. All efforts should be made to avoid subsequent lumbar kyphosis (Sénégar et al, 1988). The supraspinous ligament must be retained, to prevent kyphosis, and stabilize the segment. The procedure itself takes less than 15 minutes (Sénégar et al, 2008).

5.4 Clinical results

Some studies have shown that surgical procedure, using X-stop device for chronic low back pain, substantially superior to conservative treatment, when is related to 1 or 2 level spinal stenosis, in cases where pain is relieved with flexion. These clinical results are based in a 2 years follow-up with claudication Questionnaire criteria (Zucherman, et al, 2004, 2005, Hsu et al, 2006, Anderson et al, 2006).

Comparing patients who received X-stop implants, with patients who underwent laminectomy without fusion (decompression surgery), Kondrashov et al (2007) have shown, in their study, an improvement of 15 points in the Oswestry Disability Index, defining patient success (78% of the X STOP group, versus only 33% of the laminectomy group, had successful outcomes at 4 years follow-up).

Biomechanical studies have shown beneficial effects of X-stop in kinematics of the spine (Kabir et al, 2010), with limitation in flexion/extension movement in the instrumented level, increase in spinal canal and neural foramen, decrease in intradiscal pressure, decrease facet overload, no degenerative affection in adjacent levels, and no significant changes in biomechanics of the segment. Kutcha et al (2009) indicated, after Oswestry scores and Visual analogic scale evaluation, that X-stop implantation provides short and long term satisfactory clinical outcomes. However, some cases with severe stenosis and claudication have unsatisfactory results with these implants.

Barbagallo and coworkers (2009) looked into the complications of X-STOP. Of a total of 69 patients, 8 had complications (1 interoperative and 7 postoperative). These included 4 device dislocations and 4 spinous process fractures, one of this peroperative, in a double-level implant. Of these, 7 patients (10.14%) required revision surgery. Korovessis and coworkers (2009), in a prospective controlled study, concluded that Wallis interspinous implant changed the natural history of adjacent disc degeneration incidence until up to 5 years after surgery. Sénégas and coworkers (2009), in a 13 year follow up study with 107 patients, with canal stenosis or herniated disc, who underwent dynamic stabilization with Wallis, reported that the implants had to be removed in 20 patients, leading to fusion. The other 87 with Wallis had better clinical results in a retrospective evaluation, compared to fusion group. Floman and coworkers (2007), in a retrospective study with 37 patients who underwent primary lumbar disc excision and stabilization with Wallis, have shown 13% of recurrent herniations, suggesting that this implant does not reduce the incidence of recurrent herniations.

Trautwein and coworkers (2010), evaluated Coflex device (interspinous U shaped titanium alloy process), and concluded that fatigue failure of the spinal process and lamina is extremely rare. Kong and coworkers (2007), in a retrospective study, compared clinical results of patients who underwent lumbar decompression surgery, with Coflex placement, with patient who underwent posterior lumbar interbody fusion (PLIF). They assumed that Coflex leads to a lower stress in adjacent levels than PLIF.

6. Pedicular stabilization

6.1 Overview

To reduce pain and disability, spine surgical procedures have three main components: decompression, stabilization and correction of deformity (Schwarzenbach et al, 2005). For many years, spine fusion of the affected segments has been the gold standard procedure for this treatment. However, patients undergoing arthrodesis are subjected to a large number of short and long-term morbidities (Huang et al, 2005).

Considering the concepts of spinal instability, defined by Junghanns (1968), Kirkaldy-Willis and Farfan (1982), and White and Panjabi (1990), and the history of instrumentation in the spine, stabilization methods must diminish pathologic motion, prevent deformity, reduce deformity and compensate iatrogenic destabilization (Schwarzenbach et al, 2005).

Dynamic stabilization with pedicular screws has been developed, as an alternative to fusion, to achieve segmental stabilization, without complications seen in fusion (Di Silvestre et al, 2010).

Henry Graf (1992) first described the system of pedicular screws, surrounded by nonelastic polyester ligament with tension to lock the motion segment in extension. This concept was to lock the facet joints, stopping rotation (Sengupta et al, 2004). This system presented some problems, because the lordosis that the Graf produces results in stenosis of lateral recess, especially if there was any preexisting facet arthropathy or in-folding of the *ligamentum flavum*, and increases load in posterior annulus, which is a feature of painful degeneration of the disc (Grevitt et al, 1995).

In 1994, Dubois proposed the Dynesys system, a pedicular screw-based system, with flexible rods as a dynamic stabilization. Based on Kirkaldy-Willis concept of degeneration, Dynesys attempts to alter the first and second phases, reducing segmental motion to a physiologic level, neutralizing bending, torsional, and shear forces, thus reducing load on disc (Schwarzenbach et al, 2005)(**Figure 6**).

Strempl and coworkers (2000) introduced a pedicular based stabilization system, with rigid rods and hinged head screws. With this architecture, a division of the load between implant and anterior column is achieved. Screws are made of titanium alloy and, since 2002, are covered by hydroxyapatite for better bone ingrowths (**Figure 6**).

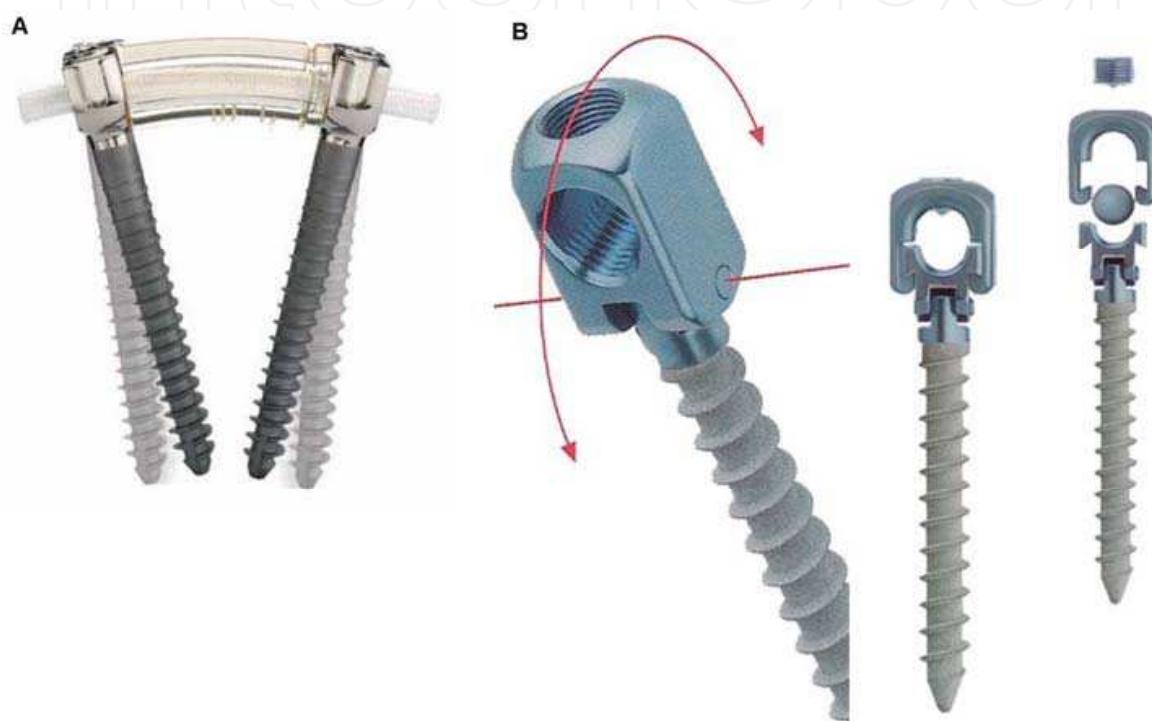


Fig. 6. Pedicular stabilization devices: **A)** Dynesys – dynamic in the flexible rod, **B)** cosmic: Hinged head screws

6.2 Indications

In instability, dynamic devices are indicated in some conditions, based on their design and biomechanical effects (Schwarzenbach et al, 2005). The main goal of Dynesys is to stabilize the degenerated segments in early stages of degeneration, defined by Kirkaldy-Willis (1982). Ko and coworkers (2010) presented a study with patients who underwent dynamic stabilization with Dynesys. These patients had symptomatic low back pain, as result of degenerative spondylolisthesis, radiculopathy, or neurogenic claudication and they failed to respond to conservative treatment.

Strempl and coworkers (2000) said that cosmic system may possibly relieve pain as well as restore the neurologic function without correction. Fusion is necessary when corrections (mostly in the sagittal plane) are necessary to treat pain. With limitation, this system won't be used when there's a need to treat more than three segments of the spine. Indications for cosmic are: Symptomatic lumbar stenosis, chronically recurring low back pain in the case of

discogenic pain and facet syndrome, recurrent disc herniation, combination with a spondylodesis, and extension of an existing spondylodesis in the case of a painful adjacent level degeneration (the last 2 indications are hybrid constructions).

Di Silvestre (2010) consider to use dynamic stabilization system with Dynesys to treat lumbar degenerative scoliosis in the elderly, as an alternative to fusion methods, in order to decrease blood loss (there is no need to decortications of the facets and transverse processes), eliminate need of bone graft, and thus decreasing operative time.

6.3 Surgical method

Patients were treated under general anesthesia, in prone position (Di Silvestre et al, 2010, Ko et al. 2010, Maleci et al, 2011). Medial unique incision must be made, but Wiltse intermuscular plane approach is an option in stabilization procedures without wide decompression (Wiltse et al, 1988, von Strempe, 2000). In cases of stenosis, using Dynesys stabilization, and needing wide laminectomy, patients are positioned with hips flexed in 90 degrees and, after decompression, patients are repositioned to maximum lordosis (Di Silvestre et al 2010).

Pedicular screws are placed, by fluoroscopic control, in a lateral point entry, at the basis of transverse process with convergence angle between 13 and 18° in Dynesys (Di Silvestre et al, 2010), and between 20 and 25° in cosmic (Strempe et al, 2000) horizontal to the sagital plane. The screws must be as long as possible to prevent shear forces. Removing and reinserting of the screws must be avoided, to prevent screw loosening (Di Silvestre et al, 2010, Strempe et al, 2000).

After screw placement, distraction must be taken up to 4mm in cosmic system (Maleci et al, 2011), and 2mm in Dynesys system, to expand the neural foramina. In cosmic system, when decompression is necessary, a transverse stabilizer must be placed (Maleci et al, 2011).

6.4 Clinical results

Nonfusion techniques have been developed to prevent complications seen in spinal fusion, as adjacent segment disease (Cakir et al, 2009). Additionally, fusion involves longer operative time and blood loss, increasing the complication rate, mainly in elderly (Di Silvestre et al, 2010). Not to mention the need of bone graft, with potencial effects on donor site (Huang et al, 2005).

Graf ligamentoplasty has been often unsatisfactory, not preventing postoperative instability, with high percentage of destabilization of the affected segment (Guigui et al, 1994). This system presented some problems, because the lordosis that the Graf produces results in stenosis of lateral recess, especially if there was any preexisting facet arthropathy or infolding of the ligamentum flavum, and increases load in posterior annulus, which is a feature of painful degeneration of the disc (Grevitt et al, 1995). Kanayama and coworkers (2005) showed poor clinical outcomes with Graf.

Di Silvestre (2010) evaluated clinical results after dynamic stabilization with Dynesys in elderly patients with lumbar degenerative scoliosis, with questionaries (oswestry disability index, Roland Morris, and visual analog scale), and radiologic imaging. In this study,

clinical results have shown nonfusion stabilization as a safe procedure in elderly patients, with low complication rate, and statistically significant improvement in clinical outcomes.

Cakir and coworkers (2009), compared patients who underwent surgical treatment with decompression and Dynesys or decompression and fusion, having concluded that, in monosegmental instrumentation, no differences in adjacent level have been found, in a minimum follow-up of 24 months.

In 2006, Schanke and coworkers found signs of degeneration in disc adjacent to Dynesys stabilization in 29% of discs after 2 years. In the same follow-up period, the authors reported complications in 17% of patients, with 4 loosen screws and 1 broken screw out of 96 screws. This proportion was maintained in a continuous follow up, after 2 years, and no progression of instability has been shown (Schaeren et al, 2008). Screw loosening was assessed by Ko and coworkers (2010). Seventy one patients, who underwent decompression and stabilization with Dynesys were evaluated. Loosening of the screws occurred in 19,7% of patients, but this did not affect their clinical improvement. It is interesting to note that such findings had never occurred in the middle vertebrae in intermediary level. It's more likely to occur on marginal segments.

Treatment of the dysfunctional segmental motion was assessed by Cansever and coworkers (2011), using radiologic parameters in postoperative time, in one year follow-up. Their results suggest that decompression with dynamic stabilization were effective for radiologic stability over time.

A recent article described nonfusion method in lumbar spinal fractures (Kim et al, 2011). In a 4 year follow-up (2002 – 2006), their results suggests that this method is one of the most effective to manage thoracolumbar fractures, especially in younger people.

Clinical results published with cosmic system, shows improvement in quality of life after dynamic stabilization, with decrease in visual analog scale of pain (Rodrigues et al. 2010, Stremppel et al, 2006, Stremple et al, 2008). As complications, screw loosening was found in 5,2% and 5,03% cases, and just 1 case of adjacent disc degeneration was related. Screw breakage occurred in a low rate, but not all of them were symptomatic.

Rodrigues and coworkers (2010), in a retrospective evaluation of patients submitted to a pedicular dynamic stabilization with cosmic, showed an improvement in quality of life of these patients during the 29,5 months follow-up period. The SF-36 score ranging from 33.15% preoperatively, to 75.99% in the postoperative, was statistically significant using the *student t test* ($p <0,0001$). Maleci and coworkers (2011), using cosmic system, in a 2 year follow up period, showed good results, with a low complication rate. In this article, they emphasized advantages, such as reduction in surgical trauma, avoidance complication in graft donor site, and preservation of intervertebral cartilage. No spontaneous fusion has been observed in the follow-up, but a fibrous rigidity has been present.

7. Conclusion

Nonfusion techniques are new, compared to fusion, as an option in the surgical treatment for low back pain. As new techniques, long-term prospective studies must be designed to achieve their effectiveness.

The effects of fusion are well known in a long term analysis, with a large number of complications. Adjacent disc degeneration, donor site pain, pseudoarthrosis and high blood loss are aspects that must be avoided with nonfusion technologies.

The right indication is the most important key to the success of the surgical treatment. Up to now, good results have been shown with nonfusion surgeries, and these technologies are improving, to avoid complications, and preserve the physiological motion of the spine.

Long-term Follow-up studies must be taken, to a better understanding of these procedures, and indications in a large scale. But, the results obtained up to now are encouraging and hopeful.

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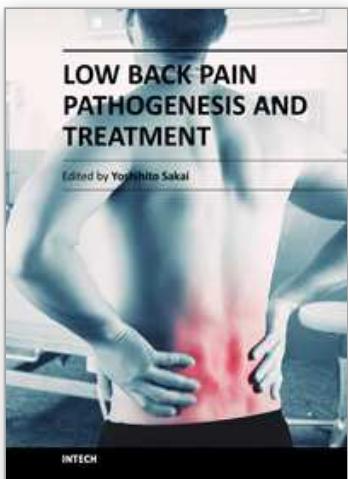
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Low Back Pain Pathogenesis and Treatment

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Low back pain is a common disorder which affects the lumbar spine, and is associated with substantial morbidity for about 80% of the general population at some stages during their lives. Although low back pain usually is a self-limiting disorder that improves spontaneously over time, the etiology of low back pain is generally unknown and the diagnostic label, "non-specific low back pain", is frequently given. This book contains reviews and original articles with emphasis on pathogenesis and treatment of low back pain except for the rehabilitative aspect. Consisting of three sections, the first section of the book has a focus on pathogenesis of low back pain, while the second and third sections are on the treatment including conservative and surgical procedure, respectively.

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