Although, the degeneration process and source of pain in degenerative disc disease has not been identified yet, histopathological and anatomical changes in the intervertebral disc secondary to degeneration are well known. These changes, shortly, are decrease in hydrophilic glycoprotein and chondroitin sulphate levels, and increased levels of less hydrophilic keratan sulphate; changes in the types and levels of collagen and parallel to these changes decreased levels of water content within the disc; tears in the annulus fibrosus and decrease in the height of intervertebral disc. The degeneration in the intervertebral disc has is examined in three stages; a dysfunctional stage started between the ages 15 and 45, an ongoing instability stage between the ages 35 and 70, a stabilization stage after the age 60. This degeneration, abnormal movement and instability occurring in the functional spinal unit, such as ligamentous hypertrophy and osteophyte formation triggers a chain of events leading to pain and neurological deficit.

Although, genetic and tissue engineering of degenerative disc disease, stem cell therapies, modulation of pro-inflammatory cytokines, anti-catabolic agents (TIMP-1/2), mitogens (IGF-1, EGF, FGF, etc.), morphogenes (TGF-β, BMP-2, etc.) and intracellular regulators (SMADs, SOX9, etc.) are promising modalities in the future of the treatment, they are yet experimental methods.

Besides of these medical or biological treatments, many surgical options are available as well. These options are mainly the fusion, dynamic stabilization and lumbar arthroplasty. There are advantages and disadvantages of each of these options. In this paper, the opinions and thoughts on the future of the effectiveness of dynamic stabilization and lumbar arthroplasty is discussed.

I. Dynamic stabilization

Today, arthrodesis of the lumbar spine is the accepted treatment of choice for many traumatic, neoplastic and infectious lumbar diseases. Increased rigidity of the reconstruction is the main factor that increases the fusion rate. Yet, increase in fusion rate results in adjacent segment degeneration, and eventually emerges as a new problem.

The process of degeneration is progressive and triggered degeneration in the adjacent-level of the spine is reflected on the postoperative clinical picture (4,8,13). Therefore, all the established theories aimed to prevent degeneration in this patient group, and the concept of dynamic stabilization as a result of these theoretical approaches has emerged.

On the other hand, while our knowledge on different aspects of spinal fusion that is performed over a century is sufficient, literature on dynamic systems that have a history of the last 20 years are more limited. The present situation of both fusion and dynamic stabilization should be examined, before discussing the future of dynamic systems.

Degenerative Diseases Spinal Fusion: Is the solution to the problem?

Low back pain in degenerative diseases is due to abnormal load distribution and abnormal movement. Recent studies hold abnormal load
distribution responsible for the pain as much as abnormal movement. Especially in the presence of disc disorganization due to degenerative disc disease, abnormal loads are transmitted to the lower segment, and the load which is otherwise isotropically distributed, distribute in an anarchic way, or distributed to create extreme stress in the annulus (1) (Figure 1).

According to Mulholland’s “gravel in the shoe” theory, the abnormal load transmission results in disc pain (28). While abnormal movement is completely eliminated with fusion, abnormal load distribution can not be solved, sometimes even with modern fusion techniques. Moreover, intervertebral fusion cages are argued to be ineffective to resolve this problem. This is mainly because the cages increases the adjacent level degeneration by increasing the rigidity of the construct. On the other hand, it should not be overlooked that in cages, the effective fusion takes time and limitation of fusion to footprint of the cage leads to continuous abnormal load transmission, and a healthy load transmission is only possible in the occurrence of fusion bridges between the vertebra corpuses (1).

Future of dynamic stabilization:

We are faced with many questions, regarding the future of the dynamic stabilization, when the current clinical and biomechanical data were analyzed. Dynamic stabilization, unlike other motion preservative systems, does not require removing a portion of the disc or facet. Today, in this context, interspinous devices, pedicle screw-based hinged screws, flat or taut band that serves as a dynamic rods and

**Degenerative diseases such Dynamic Stability: Is the future is in motion?**

When dynamic lumbar stabilization is used in a relatively young and middle-aged patients, it is expected that it provides stability and works against degenerative process throughout the life of the patient (6,7,20,40,41,45). A number of studies revealed that disc degeneration was slowed after dynamic stabilization, and in some cases evidence of regeneration, as well (5,23,29,35,38). It is essential for screws to have a solid grip to bone or pedicles at least. This requires, in case of non-fusion, more robust implants that do not have breaking problem, and a patient without severe osteoporosis or degeneration (42).
tapes can be mentioned. The main reason that makes it difficult to compare, is the different patient groups and the variety of dynamic systems. At present, the following considerations can be propounded on the basis of the results.

1. Indications

Today the most important indication is discogenic low back pain. However, it is observed that the indications are gradually narrowing. From this perspective, since the intervertebral disc level range of motion is between 10-18 degrees, and according to the Kirkaldy Willis theory that describes the process of degeneration, it should be remembered that in the early phase of disc degeneration there is instability, and in the delayed phase there will be lack of movement and restabilization (22).

Pedicle screw-based systems reduce pain by restricting especially flexion and extension range of motion (44). However, these systems are not as effective in axial rotation issues. For this reason, in rotational instabilities, lateral spondylolisthesis and scoliotic deformities these systems are not useful.

Dynamical systems are used in many centers for low-grade spondylolisthesis. However, the effectiveness of pedicle screw-based systems in restoring sagittal balance is controversial. These systems are effective in axial load carrying and sharing, but they are less effective in preventing scissoring forces. Therefore, their application fields are restricted in spondylolisthesis or different designs shall be clearly defined which takes this issue into consideration.

2. Prophylactic place of the dynamic stabilization

Adjacent segment degeneration after fusion was described by many authors (26,34,37,47). This situation has been proposed to be connected to the adjacent segment hypermobility and prophylactic dynamic stabilization have been proposed (12,14,25).

On the other hand, asymptomatic degeneration in the adjacent segment has also been shown to be triggered after fusion (2,9,39). Therefore, in these cases prophylactic dynamic stabilization is proposed. In theory, although prophylactic dynamic stabilization seems logical in these patients, both biomechanical and comparative clinical trials are very limited. One biomechanical study has been published by Strube et al (47). In this study, biomechanical effects of dynamic stabilization applied to a level adjacent to a 360 degree stabilized level have been investigated. This cadaveric study revealed that the number of levels and the rigidity of an added fixation system are very important, and also showed that addition of a dynamic system, by means of load sharing, as well as restricting the range of motion blocks the adjacent level hypermobility. Whilst this prophylactic effect acts through biomechanics, clinical results are still contradictory. Although this effect is shown in several clinical trials, there are studies showing it is not effective. For instance, Schwartzzenbach et al. reported safe and efficient results with dynamic stabilization of adjacent levels to fusion in treatment of degenerative disc disease (43). However Putzier et al. in a recent study, addressed the pre-existing asymptomatic adjacent segment degeneration prior to fusion. Accordingly, they performed only 360-degree fusion and rigid stabilization in a group of patients, and an additional prophylactic dynamic stabilization in addition to rigid stabilization in the other group of patients. According to this study, asymptomatic degenerated segment benefited from prophylactic dynamic stabilization and showed slow progression, this time the next segment to dynamically stabilized segment developed degeneration. Moreover, the authors observed instrument breakage and loosening in the dynamic group, they did not recommend prophylactic dynamic instrumentation (36).

3. The material used

The main problem in dynamic systems is the screw loosening or breakage. Although there is a very low complication rate reported in the literature, screw loosening or breakage constitute the chief problem. Stoll reported screw loosening in 10% of his 73 patients in whom he used Dynesys system (46). Implant failure has been reported in 22% of dynamic rod implanted patients by Sanches Reyes et al. (38). Although different percentages have been reported in the literature, lack of fusion with the fact that these systems remain faced with long term stress, the metallurgical properties of these systems requires further evaluation.
4. The selection of appropriate construction

While, several studies reported that effectiveness of dynamic systems based on dynamic pedicle screw is usually valid for one or two levels, trials with longer segments suggest motion should be provided by dynamic systems using dynamic rods that serve as a taut band. Although in appropriate cases, recent studies suggest dynamic rod + pedicle screw-based dynamic systems and disc prosthesis + posterior dynamic system provide a normal range of motion of the spine, these issues requires both clinical and biomechanical evidence. Additionally, the biggest drawback is that the existing literature does not contain the long-term results (1,19,20,32).

Propositions for the future

Ideally, a dynamic system should consist of hinge type pedicle screws and, while maintaining the motion, it also should ensure equitable distribution of the load. All of the current systems based on pedicle screw cause the axis of rotation to shift backwards, which causes non-physiological kinematics on the disc. In normal disk, during flexion there is increased loading at the anterior portion of the disc and reduced loading at the posterior portion of the disc, while during extension the opposite of the situation occurs. However, in pedicle screw-based dynamic systems, in flexion movement loading is observed at all portions of the disc and, in extension all the load on the disk is abolished (Figure 2). Therefore, the present solution does not seem exactly the physiological. To overcome this problem, different solutions must be sought.

II. The Future of lumbar arthroplasty

While the aim in spinal fusion surgery for degenerative disc disease is to eliminate pain by fusing the functional spinal unit that produces pain in motion, the aim in dynamic lumbar stabilization is to restrict abnormal lumbar movement to protect and restore the distribution of the load. On the other hand, the objective of the lumbar arthroplasty is to eliminate the chain of events that are causing pain in intervertebral disc and to preserve physiological movement of the disc in pathological segment. Fernstrom, in 1950, performed the first lumbar disc arthroplasty using iron balls placed in to the disc space, but this method has been abandoned because of poor clinical
outcome (11). From that day until today, prosthetic materials and the lumbar arthroplasty technique have been in constant change and development, and as a result lumbar arthroplasty procedures have been becoming widely used. As with all new techniques, however, many problems must also be answered about lumbar arthroplasty. The problems and solutions that might be encountered in the future will be important in determining the place of lumbar arthroplasty for the treatment of degenerative disc disease.

The first of these problems related to lumbar arthroplasty is the lack of a laboratory model that fully reflects biomechanics of the human spine. Although today’s chimpanzee, sheep and human cadaver models provide important clues about biomechanical and biological suitability of the prostheses, there are many gaps such as lack of long-term results or difficulties in examining axial loadings (17,24). Thus, currently it is necessary to develop a suitable laboratory model on the lumbar arthroplasty.

Another issue that will shape the future of lumbar disc prosthesis is the chemical, radiological and biomechanical features of the arthroplasty materials. Studies to increase prosthesis’s osteo-integration to the vertebrae, e.g. using the titanium, the porous surface coatings such as cobalt-chrome and hydroxyapatite, or to increase fixation of the prosthesis to vertebra such as a comb design are still in progress (21,31). Currently, on the moving surfaces of prostheses, various materials such as metal-metal, metal-polymer, ceramic-ceramic or diamond-diamond are used. The negative effects of corrosion, metal wear and eventually inflammatory and immunologic responses to bone biology and other adverse effects to internal organs caused by these materials are well known, but long term results of these responses occurring near the neural and vascular structures are not known (30). In addition, the uncertainty in biomechanical assessment of lumbar arthroplasty continues. The ideal disc arthroplasty prosthesis is expected to protect ideal height of the disc, not to disturb the flow of proprioceptive sensation, to prevent excessive movements while allowing physiologic limits during flexion, extension, rotation, and lateral mobility, and to preserve the shock absorbing feature (39). However, a disc prosthesis with an optimal design covering all these characteristics do not exist yet. Moreover, the biomechanical needs of each spinal level differ and it has been argued that while some designs are compatible for certain levels, other designs may show the same performance at other levels (59). For instance, previously arthroplasty has been recommended for all lumbar levels; however, currently, experienced surgeons recommend fusion for the level of L5-S1 and arthroplasty for the level of L4-S (16). In addition, the uncertainty remains about reflections of biomechanical performance of the device on the clinical implications. During the evaluation of these results, it is also expected arthroplasty prostheses to show radiological features enabling optimum long- and short-term radiological examinations.

There is also no consensus about the future of the clinical applications lumbar arthroplasty. Good bone quality and healthy vertebral end-plates and facet joints are needed for the application of arthroplasty. Often young adult and middle-aged patients fit into these criteria. Indications accepted by the FDA for lumbar arthroplasty are male and female patients under 50 years of age, one or two level degenerative disc disease evidenced by a positive discography, the radiologically large central disc herniation, intervertebral disc height reduction more than 4 mm and absence of facet joint degeneration (27). In addition, patients should be without radicular leg / back pain and also should have no benefit from conservative treatment. The question to be answered, however, is that the actual superiority of lumbar arthroplasty over spinal fusion surgery should be approved. In the literature there are contradictory results on this issue. Theoretically, lumbar arthroplasty must be superior to spinal fusion surgery in prevention of adjacent segment disease. However, studies conducted to prevent adjacent segment disease supports lumbar disc arthroplasty only at class-C data level (15). Moreover, the confusion continues in clinical evaluation of the results, while some studies reported better results, the others do not report the difference between the two applications in terms of clinical outcomes (18). As a result, whether the lumbar arthroplasty in the future will be an experimental surgical procedure or the standard treatment of degenerative disc disease will largely be determined by the results of controlled comparative clinical trials.

Lumbar arthroplasty and ‘movement preservation technology’ is a new technology for spinal surgery, and this comes with a certain economic cost as well
as all the new technologies. Boden et al. proposed to ensure a logical price-performance ratio and adequate control of misuse of these devices in the criteria of determining the efficacy and safety of materials related to arthroplasty (3). This subject has also been considered at SAS 10th Annual Global Symposium on the preservation of the movement, and it has been concluded that with proper patient selection, high-quality research papers and adequate economic studies related to arthroplasty, lumbar arthroplasty would be more widely accepted in the future (15).

As a result, the value of lumbar disc arthroplasty in the future, which opened up new horizons and expected to fill a gap between decompression and fusion for the treatment of degenerative disc disease, will be determined by the above-mentioned problems and solutions.

References