Introduction and General Concepts

Fusion techniques in spine surgery are accepted as evidence-based gold standards. Intervertebral motions are restricted with achievement of the fusion and thus, back pain will be improved. The patients may be satisfactory in a short term but there are a lot of reports regarding the long-term problems. Innovative attempts are still continuing to solve long-term complications of fusion surgery. One of the options is the implant that mimics the physiological motion of intervertebral segments.

Adjacent segment degeneration is one of the long-term complications of lumbar fusion surgery. Especially in the lower lumbar and lumbosacral spine fusions, the adjacent segment is attempting a biomechanical property of L5-S1 motion segment and then degenerative process begins. Expected period of degeneration is shorter if primary pathology of the patient is degenerative spine disorder. Repetitive surgeries carry a lot of risks and increase the economical costs.

Motion sparing systems allow the physiological motions with motion segment stabilization. Total loss of movements in motion segment is not a purpose and bone grafting is not advocated. The goal of these systems is restriction of excessive movements of motion segment under excessive loads.

The first application of dynamic systems was published by Graf at the end of 80’s. In Graf’s ligamentoplasty, the objective was maintaining physiological lordosis during flexion and extension and decreasing the discal pressure with aim of the posterior distractive ligaments. Discogenic pain will be diminished by low discal pressure. Similar systems were developed and presented to the market. However, clinical results did not correlate with theoretical basis. Dynamic systems should mimic the biomechanical behavior of normal spine, for this reason biomechanical properties of motion segment must be well understood. The classification of posterior dynamic systems in market is shown in Table-1.

### Table 1:
Motion sparing instruments.

<table>
<thead>
<tr>
<th>Anterior Dynamic Stabilization Systems</th>
<th>Posterior Dynamic Stabilization Systems</th>
<th>Total Facet Replacement Systems</th>
<th>Posterior Interspinous Distraction Devices</th>
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<tbody>
<tr>
<td>Disk Prosthesis</td>
<td>Rigid Screw + Dynamic Rod</td>
<td>Total posterior arthroplasty</td>
<td>Total facet arthroplasty</td>
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<tr>
<td>Nukleus Pulposus Alternatives</td>
<td>Artificial Ligament Rod</td>
<td>Total facet arthroplasty</td>
<td>Anatomic facet arthroplasty</td>
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<tr>
<td>Nukleus Pulposus Cell Cultures</td>
<td>Dynamic Metal Rod</td>
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<td></td>
<td>Dynamic Screw + Dynamic Rod</td>
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Biomechanical Properties of Motion Segment

Biomechanical properties of dynamic systems must mimic the normal spine motions. The term of motion segment consists of two end plates and all articulations of adjacent vertebrae. The articulations of motion segment contain both bony-cartilage articulations and ligamentous connections. In this way, all elements harmoniously contribute to physiologic spine motions.

In biomechanical point of balance, the sum of the forces acting on an object is zero. Spine balance or stability is quite different. Spine stability can be described as the normal motion without any neurologic deterioration of motion segment under physiologic loads. The main units that contribute to this stability are spinal column, spine muscles and nerve control units. Complex motions achieved by the motion segment. Addition of these complex motions leads to total body movement. Compressive force is the main load received by the body of the vertebra. The anterior column of the spine carries almost all of the body weight. Posterior elements such as facet joints, pedicles and laminae carry very small part of compression, but they are resistive to distractive forces. The transition zone of compressive and distractive forces in motion segment locates at the anterior part of the facet joint and just posterior of the vertebral body. Haaher refers this point as Instantaneous Axis of Rotation. The changes of the location of instantaneous axis of rotation may lead to abnormal instable movements. Anterior migration of the axis increases the lordotic loads. Shear forces impacts to the body of the vertebra. Whereas, posterior migration of axis increases the kyphotic loads, and posterior ligamentous insufficiency and posterior stability corruption can be seen. (figure 1a and b)

Instantaneous axis of rotation is very important for dynamic system designs. Rotation axis of dynamic system must be very close to the instantaneous rotation axis for prevention of excessive shear forces. The shear forces between bone and implants may lead to implant failures such as loosening end breakage.

Indications of Dynamic Stabilization Systems

Absolut indications for dynamic stabilization systems are not clear. Primary goal for posterior dynamic stabilization systems is achievement spinal stability and normal physiologic motion without fusion of the spine. All dynamic systems successfully diminish the segmentary motion. However, posterior dynamic systems become rigid in flexion position, thus rotational restriction of motion is insufficient. It is unknown that which motion must be restricted and how much motion must be restricted in different pathological conditions. That’s why clinical results of posterior dynamic systems are sometimes different from theoretical expectations.

Figure 1: Instantaneous axis of rotation is referred as a theoretical stationary point between two vertebrae (black dot). It is located at just posterior part of vertebral body and anteriorly from facet joint (A). Instantaneous axis of rotation is displaced posteriorly when vertebral body insufficiency or kyphotic deformities occur (B). (All drawings are made by the author)
Posterior dynamic systems are not only segmentary motion restriction devices. As a general rule, decompression is mandatory with posterior motion sparing systems. Poor clinical results will be anticipated in degenerative spine disorders that treated only with dynamic systems without any neural decompression.

**Which one is Better, Fusion or Posterior Dynamic Systems?**

The answer is still unknown. Fusion techniques are accepted as gold standard because long-term results, clinical success rates and complications are well described. In dynamic systems, which are developed as a solution for problems of fusion, long-term results of randomized prospective studies are not clear. High success rates were reported in some series, but in some series vice versa. In one study, spine stability and physiologic spine movements are achieved after posterior dynamic system implantation in addition to decompression with laminectomy and partial facet joint resection. Clinical results were found quite well in same patients. 19 It is suggested that disc bulging can be diminished with achieving the stability in hypermobile segments by using the pedicle screw based systems with non-metallic connections.3 Thereby, discogenic back pain may be reduced. However, in the literature there is no sufficient evidence. If the motion center of dynamic systems accurately locates close to instantaneous axis of rotation, the system may perfectly mimic the physiologic motions of the spine. This relation between rotational axis of the system and the spine determines the implant stability. Breakage or loosening can be seen in implants for fusing the spine, although loosening is generally expected in dynamic system implants.

Long-term results of ligamentoplasty based posterior dynamic systems are not as satisfactorily as they expected. 5 In another study, it is found that the posterior ligamentous systems may be useful for meticulously selected patients who have back pain and conservative treatment has failed. 13 Clinical results of posterior dynamic systems are moderate or worse when the patient has significant radiologic instability, neurologic findings, radicular and central stenosis, and back pain with undefined etiology.

In a cadaver study, pedicle screw based dynamic systems are compared with spine fusion and it is found that posterior dynamic systems maintain stability of the spine in all directions.16 However, their contribution to the stability in flexion and side-bending was found insufficient. The authors stated that there were no differences between dynamic implants and fusion systems in flexion posture. These types of studies are cadaver studies and the effects of muscles and ligaments are ignored. In this study, it was assumed that under loadings, the movements of motion segment implanted by dynamic systems might help to prevent adjacent segment degeneration.

Dynamic systems were compared with fusion in finite element analysis models and significant differences were found. Although the movements are determined in motion segment with dynamic systems, physiologic correlation of range of motion of dynamic systems are variable. In another word, the motion of a dynamic system is related with the elastic modulus of raw material. For this reason the importance of designs and producers increase.

Different results have been reported in studies of adjacent segment degeneration. Load distribution of fusion and dynamic systems during physiologic movements at intervertebral disk, facet joint and adjacent segments is investigated with cadaver based biomechanical studies.1,2,9,17 In some series, only mechanical effects of dynamic systems in adjacent segments and implantation site were investigated1,2,9,17 while differences of fusion and dynamic implants were evaluated in other studies. 9,17 It is found in all studies that the dynamic systems can bear physiologic loads of motion segments. In addition, excessive loads at adjacent segments may be decreased to physiologic ranges. Briefly, biomechanical properties of posterior dynamic systems may be decreased adjacent segment loadings theoretically. Some clinical studies have been supported this theory. 11 In a study with 77 degenerative cases, the patients were divided into two groups according to their fusion implants or dynamic system implants.14 Mean follow-up time was 36 months. Preoperative and postoperative lumbar kinematic measurements and intervertebral disk properties were compared. As a result, kinematic range of motions were found superior in dynamic system group and magnetic resonance images of intervertebral disks were more
clear at dynamic group. However, radiologic parameters might not be correlated with clinical results in all cases. Clinical results of dynamic systems were generally found satisfactorily in short-term studies. But these studies are designed as short-term retrospective case series.

In some reports clinical results could not correlate with excellent biomechanical results. Long-term effects of dynamic systems at superior and inferior adjacent segments were investigated in patients with segmentary instability due to degenerative spine disorder. Degeneration was increased at the cranial junction in 12% of patients, and at the caudal junction in 16% of patients. Significant clinical complaints were observed in two of the five patients that have adjacent segment degeneration and operated with posterior dynamic systems. The authors stated that the posterior dynamic systems could not alter the adjacent segment degeneration in the treatment of degenerative lumbar spine disorders.

In epitome, there is still no clear evidence to prove the superiority of fusion or posterior dynamic systems in the treatment of degenerative spine problems.

**Complications**

There is no specific complication of posterior dynamic systems. Deformity, softening or adaptation to the segmentary instability may be seen with time in non-metallic devices. Stability of motion segment may be decreased and clinical complaints may be seen in such cases. A new dynamic device or fusion techniques can be used for revision.

Most common complication of posterior dynamic systems is fatigue failures. Screw or rod breakage and loosening between screw and bone interface can be seen. Indication errors are also very important in fatigue failure, as well as system designs. Implant failures in fusion surgeries are generally associated with pseudo arthrosis. In dynamic systems, major aim is physiologic and continuous motion, that’s why dynamic systems carry more failure risks. When the rotational axis of dynamic system locate far from the instantaneous axis of rotation of motion segment, shear forces load between the screw and bone interface. This is the main mechanism of loosening. The patient behaviors and co-morbidities may be the reason of implant failures.

Wu et al. investigated 658 dynamic screws of 126 patients. 31 screws (4.7%) of 25 patients (19.8%) were failed. The failure rates were found high in this patient population. Older age and diabetes were reported as most important risk factor for implant failures.

**Conclusion**

As a conclusion, there is no superiority between fusion techniques and posterior dynamic systems yet. While long-term clinical results and complications are well known, there is lack of knowledge about the long-term effects of posterior dynamic systems to the spine. Prospective randomized controlled studies in large group of young patients are needed for high level of evidences.
References

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