Dynamic and Dynamic-Hybrid Instrumentation in Deformity Surgery

Deformite Cerrahisinde Dinamik ve Dinamik-Hibrid İnstrumentasyon

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ABSTRACT

Spinal deformity is one of the problematic issues of spine surgery. The variety of spinal deformities and the differences in pathomechanism require different treatment methods. Another important factor is that some deformities exist with spinal instability. The aim of surgical treatment in spinal deformity is to correct the existing deformities and to stabilize the spine. Therefore, particularly the fusion method, osteotomies and instrumentation applied to almost all cases. On the other hand, the well-known complications and side effects of the fusion method lead researchers to develop new techniques to stabilize the spine. In recent years, posterior dynamic and hybrid systems are used for deformity treatment. These new systems have advantages such as eliminating some complications and minimizing some problems that occur following the fusion method. The reports including short-term follow-up results with dynamic and/or hybrid systems encourage spine surgeons to use these systems in the treatment of spinal deformity.

KEYWORDS: Spine deformity, Posterior dynamic stabilization, Hybrid systems

ÖZ

Omurga deformiteleri omurga cerrahisinin en problemli konularından birisidir. Deformitelerin çeşitliliği, oluş mekanizmalarının farklılığı, tedavi yöntemlerinde büyük farklılığa neden olmaktadır. Bir diğer önemli sorun da deformite ile birlikte omurgada instabilite olmasıdır. Omurga deformitesinin cerrahi tedavisinde amaç, var olan deformitelerin düzeltilmesi ve stabil hale getirilmesidir. Bu nedenle, özellikle füzyon yöntemi olmak üzere, osteotomiler ve instrumentasyon hemen her olguda uygulanmaktadır. Diğer yandan füzyon cerrahisinin uzun yıllar kullanımı ile birlikte tekniğin neden olabileceği komplikasyonların görülmesi ve sonrasında oluşan ciddi yan etkileri nedeniyle, yeni bazı stabilize teknikleri geliştirilmeye çalışılmaktadır. Son yıllarda deformite cerrahisinde posterior dinamik sistemlerin ve hibrid sistemlerin üzerinde durulmaktadır. Füzyon tekniğinde olabilecek bazı önemli komplikasyonları elimine etmesi ve bazı sorunları da minimize etmesi, dinamik sistemlerin önemli avantajıdır. Yapılan çalışmalar ve kısa süreli sonuçlar bu yeni tekniklerin deformite tedavisinde etkin rol oynayabileceği konusunda ümit vermektedir.

ANAHTAR SÖZCÜKLER: Omurga deformitesi, Posterior dinamik stabilizasyon, Hibrid sistemler

INTRODUCTION

Spinal deformities are classified in three types; 1) sagittal plane deformity (e.g.; kyphosis, translational), 2) coronal plane deformity (e.g.; scoliosis, translational), 3) axial plane deformity (e.g.; rotational). The treatment method of each deformity is different. The patients with only rotational deformity usually do not need restorative surgery. On the other hand, most of the patients have multiple types of deformities. For example, a patient with degenerative lumbar scoliosis has both rotational and kyphotic deformities. Additionally, deformities involve more than one level in many patients. The other important factor is that deformities usually exist with instability. Panjabi described the chronic instability concept other than acute instability. Instability with a deformity is mostly a chronic instability that occurs in time. Deformity surgery is one of most problematic issues of spine surgery due to all these factors affecting each other.

The aim of surgical treatment in spinal deformity is to correct the existing deformity and to stabilize the spine. Fusion method osteotomies and instrumentation are therefore used for almost all cases.

Fusion Surgery

Albee used the first fusion procedure in spinal surgery in 1911, in the treatment of Pott's disease. In the same year, Hibbs applied fusion method in the treatment of spinal deformity (25). Particularly in the last 50 years, the fusion method is widely used in the treatment of spinal pathologies causing spinal instability due to technological advances that increase fusion rate (e.g.; metallic implants, synthetic bones, bone morphogenic factors etc.). Currently, fusion procedure is "gold standard" in surgical treatment of spinal instability (7,28,65,68). On the other hand, in the fusion method, loading increases in segments adjacent to the fused segment (11,40). This in turn, increases the rate of degenerative changes at segments adjacent to the fused segment (2,41,42,43,47).

Clinical Findings

The clinical picture is called "adjacent segment disease" (Figure 1). The pathologies forming this clinical picture include degenerative disc disease, disc herniation, degenerative spondylolisthesis, segmental instability, lumbar stenosis, degenerative arthritis of facet joints and proximal junction kyphosis.

Some authors reported that the degenerative changes at adjacent segments following fusion have no clinical importance (39,42,44). Lehmann et al. (42) reported that 45% of their 32 patients developed radiological instability at upper adjacent segment in 21 years of follow-up period after lumbosacral fusion. However they noted that this deformity did not cause any clinical complaint. Kumar et al. (39) reported 30 years of long term follow-up of patients with application of fusion and without fusion. They documented that there are twice as more degenerative changes at upper adjacent segment to the fusion segment compared to the non-fusion patients, however there was no clinical reflection of this radiological difference.

On the other hand, Rahm and Hall (54) reported that 35% of 49 patients developed adjacent segment disease with clinical finding in 5 years of follow-up period following a fusion procedure. Similarly, Etebar and Cahill (17) reported that 18% patients of 125 patients who had undergone a fusion procedure developed symptomatic adjacent segment disease after 4 years of follow-up.

Leong et al (43), documented developing of disc degeneration at adjacent segment following anterior fusion in 52.5% of 40 patients in 10 years of follow-up.

Particularly following long instrumentation for the treatment of multi level deformity, there is a risk of development of proximal junction kyphosis (Figure 2,3). Proximal junction kyphosis deformity develops in less than 30% of patients following idiopathic scoliosis surgery in the adolescent age group and more than 35% of patients following deformity surgery in adults (24,34,35,64,67). Yoon et al (24) reported two years follow-up of 89 patients with multi level instrumentation and fusion due to spinal deformity. They found that 11.2 % (10/89) of the patients were re-operated due to proximal junction kyphosis and 38.2% (34/89) of the patients were re-operated due to other reasons (pseudoarthrosis, implant failure, infection, implant related pain).

Studies and clinical observations have shown that there is a risk of development of abnormal sagittal balance following rigid fixation. In case of spinal alignment disruption in surgery,

Figure 1: L4-5 fusion performed for L4-5 spondylolisthesis. The MRI (sagittal T2) obtained in postop. 2Nd year for low back pain radiating to both legs. Adjacent segment disease has developed at the L3-4 segment.

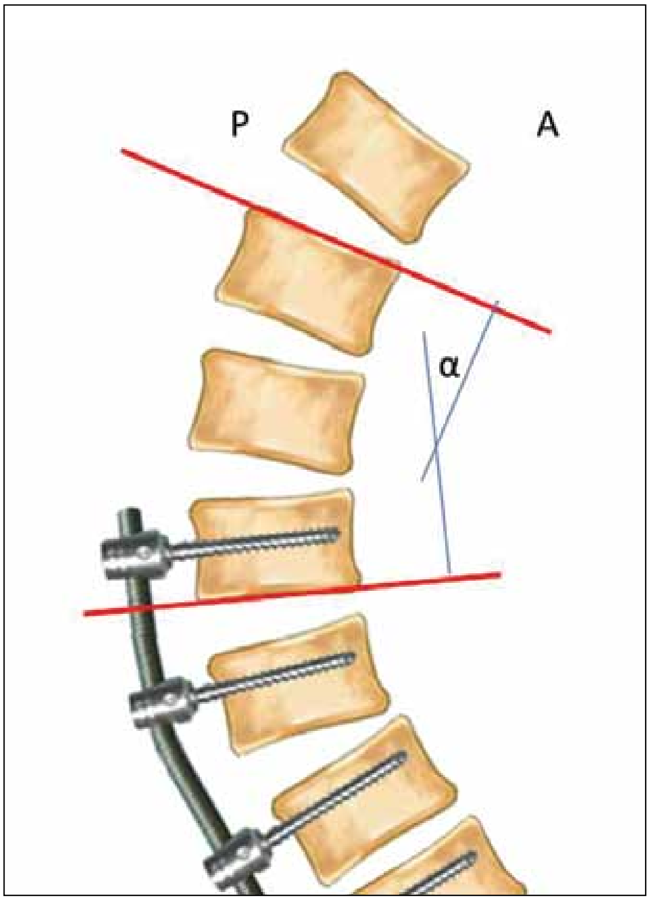

Figure 2: Kyphotic angulation has developed at proximal junction following long (multi level) posterior instrumentation (sagittal plane view, A; anterior and B; posterior). The angle (alpha) is measured; 1) If the angle is more than 10° and 2) there is more than 10° increase in postop measure compared to the preop value, the patient has developed proximal kyphotic deformity.

loading on the posterior column will exceed the normal limits. Facet joints shows rapid degeneration due to increased stress formed by translational forces and this in turn causes adjacent segment disease (1,17,38,56,57,60). Beside this, if the upper disc is degenerated, the degeneration process can accelerate following the fusion process (26,38).

The rate of adjacent segment disease is high after fusion application due to lumbar stenosis. The reason for this is that lumbar stenosis is a finding of degeneration and therefore after fusion the other segments have no capacity to resist the increased stress (23).

Age is an important factor, and the development of adjacent segment disease is high in patients over 55 years old. The theory is that there is diffuse degeneration in the spine and adjacent segment with aging and these cannot resist the increased stress following fusion (1,3,17,38,54,66).

Clinically observed adjacent segment disease following rigid fixation is also supported with biomechanical studies. Cunningham et al (11) showed 45% more load in axial compressive and flexion loadings at the upper adjacent segment to rigid fixation in the cadaver study.

The fusion method used in deformity surgery solves the problems in the postoperative short term, but the technique causes adjacent segment disease in a significant patient population (30%) (5,9,14).

Dynamic Stabilization

The problems and limitations in spine due to fusion have led to advances in motion preservation strategies. In recent years, there have been an increasing number of studies published regarding the use of artificial nucleus replacement (37,55), artificial disc replacement (10,21) and posterior dynamic stabilization (19,20,22,27,45,49,59) techniques in the surgical treatment of degenerative spine deformities.

The posterior dynamic stabilization technique shares the load applied onto the spine with the spine, which is different in rigid fixation that is applied to the spine for fusion. In rigid systems, the load is not shared with the spine (figure 4) (4). In the rigid fixation technique, the instrumented levels are not dynamic and act like a long bone. Therefore, the spine increases the range of motion at adjacent segments to reach a natural range of motion, and this causes an increase in loading at adjacent segments (40). The significant loading (stress) difference between the instrumented and non-instrumented adjacent segments precipitate deformity progression (36).

In recent years, the use of dynamic and hybrid instrumentation techniques as alternative methods to fusion has come into question due to the reasons mentioned above. Spinal deformities with chronic instability are treated with posterior dynamic stabilization techniques at an increasing rate. Henry Graf (19) first time used an artificial dynamic ligament, named his name, in degenerative disc disease. However, it is observed that the Graf ligament offers stability in the compression mode and this causes a narrowing of neural foramens and additionally the system shows laxity in hyperextension. Therefore the Dynesys system was developed to eliminate these problems (13). The spacers between the screws prevented the risk of developing foraminal stenosis. Additionally, biomechanical studies showed that the system stabilized the disrupted neutral zone at the affected segment (4,46). The Dynesys system is used in patients with degenerative deformity but without coronal and sagittal balance deformity and satisfactory outcomes have been reported (12,58). However it is reported that the spacers cause flat back syndrome when used in multi level segments

Hinged screw is designed to increase the applied load onto graft material for better bone healing. However in some patients with hinged screws, it was observed that even there is no fusion, the system with hinged screw stabilized the spine effectively. Numerous studies have reported satisfactory outcomes with this dynamic system without fusion (61,62,63)

The most important question in this regard is; are the dynamic systems as strong as rigid systems to stabilize the spine?

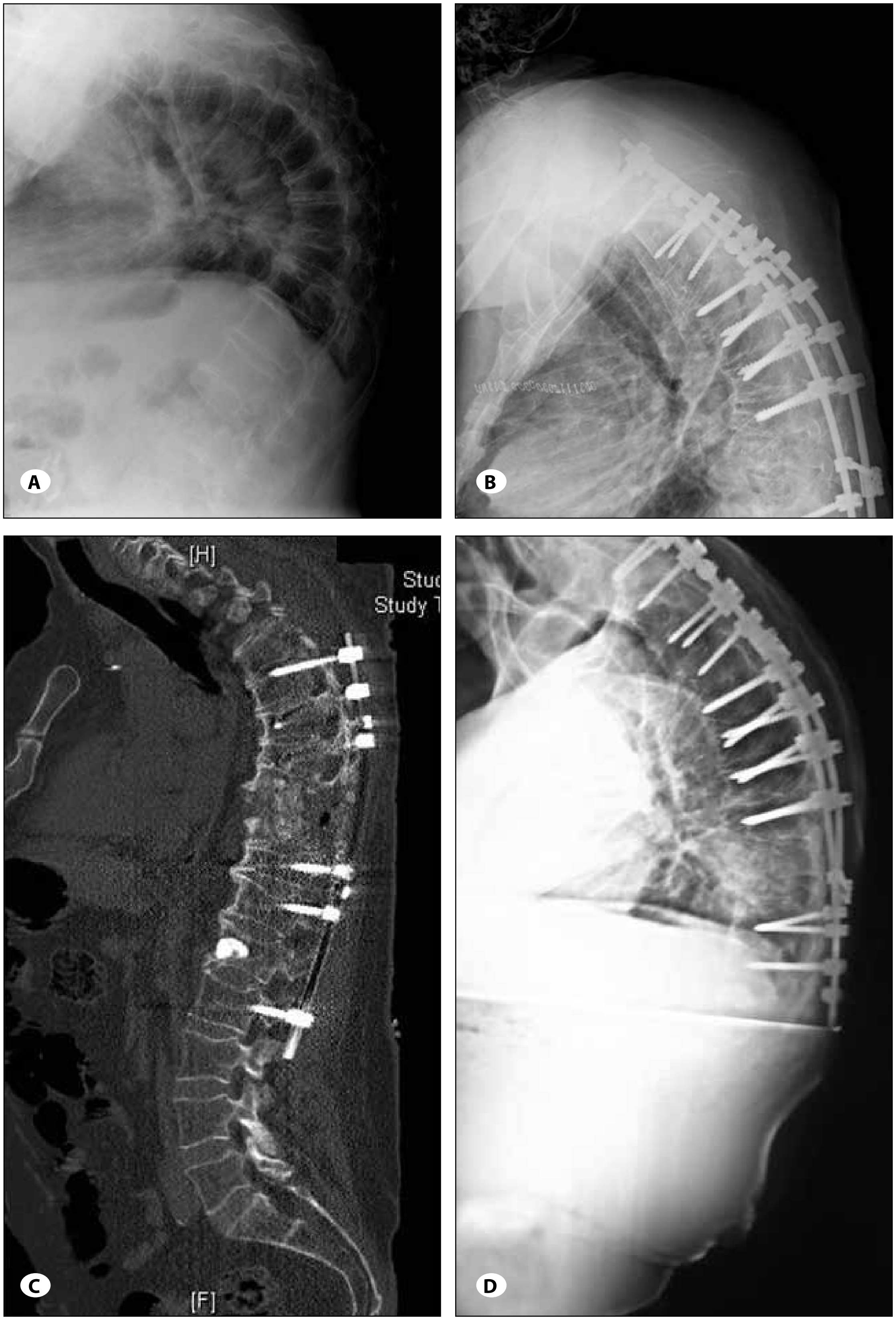

Figure 3: A) Kyphotic deformity (lateral plain x-ray), **B)** application of multi level rigid fixation (lateral plain x-ray), **C)** Postop 6. Month sagittal CT showed development of proximal kyphotic deformity, **D)** The patient was reoperated and instrumentation was extended cranially.

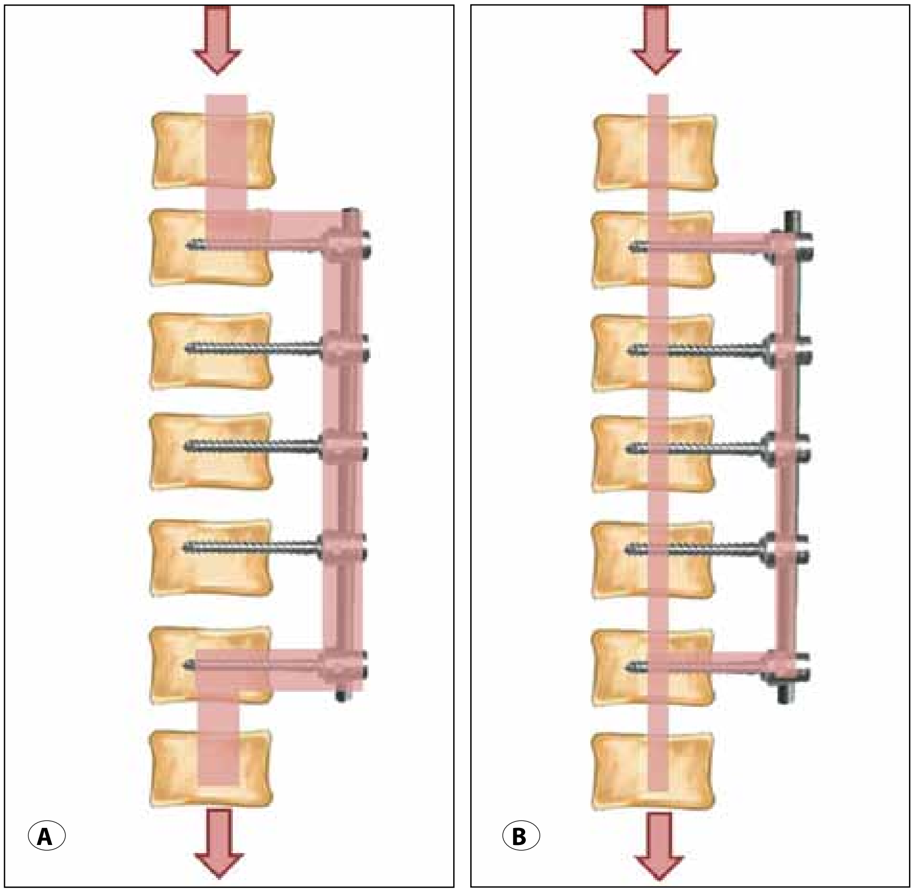

Figure 4: A) In posterior rigid instrumentation the load is transferred through metallic fixation, **B)** In posterior dynamic stabilization the load is shared with the spine (4).

Unfortunately there are not many biomechanical studies. However, there some studies that have documented that the dynamic systems stabilize the spine as effectively as rigid systems (4,6,46,50,57).

There is no problem in the application of dynamic systems to one segment. On the other hand, in the treatment of multi-level deformity, in the Dynesys system the stretched dynamic rod will act as a rigid rod, while in the hinged screw system the rod is already rigid, and therefore both systems will cause rigidity in posterior column and there will not be full dynamism. The systems that use a dynamic rod theoretically stabilize the spine while augmenting the posterior tension band, whether it is one segment disruption or multi level. Our opinion is to firm the attachment of a dynamic rod to thespine that supports the posterior tension band and allows motion in the normal range. This might be the solution for multi level stabilization, in other words solution of deformity surgery. In a finite element study we compared the rigid screw with the hinged screw. We observed that the rigid screws are under more stress than the dynamic (hinged) screws (Figure 5) (50). Therefore we believe that the healthiest way to attach a dynamic rod to the spine is with dynamic screws. We designed a more dynamic rod (Talin) compatible with posterior tension band movements for this purpose. We observed that the dynamic fixation technique restored the disrupted neutral zone to the range of motion of normal spinal neutral zone both with finite element and cadaver studies (Figure 6). This is a new concept in dynamic stabilization. The studies and application to a limited number of patients showed us that the healthiest way to attach the dynamic rod to spine is with dynamic screws (Figure 7) (50). Even though it is the key of chronic deformity treatment there is no dynamic rod as flexible as Talin, there is only one similar flexible rod (BalanC, Medtronic, USA) for one level stabilization. Dynamic rod with dynamic screw offers close to normal range of motion even in one (Figure 8).

In our clinic, we compared dynamic stabilization with fusion in the treatment of one level degenerative spondylolisthesis. We observed that dynamic fixation was as effective as fusion. Patients with degenerative deformity but without overt instability can be treated with posterior dynamic stabilization techniques (29) (figure 9). Our clinical observations support this approach (8,15,16,18,30,31,32,33,48,51,52,53). On the other hand, if the instability associated with deformity is overt, hybrid systems can be used. In this technique the aim is to perform fusion to the segment(s) where there is overt instability and to stabilize the remaining segments without fusion.

Scharzenbach et al. (58), applied a hybrid system to 31 patients for degenerative disc disease. They reported satisfactory outcomes as regards both fusion development and improvement in clinical complaints in 39 months follow-up.

The studies that will be performed on this subject in the future will define the role of hybrid systems in the treatment of spinal deformity. However the biomechanic properties of the system and the limited number of experiences indicates that hybrid systems will be used widely in near future (Figure 3, 10, 11).

Finally, we believe that there is no major problem with dynamic systems in the treatment of one level deformity or minor instability. However, if the problem is multi level

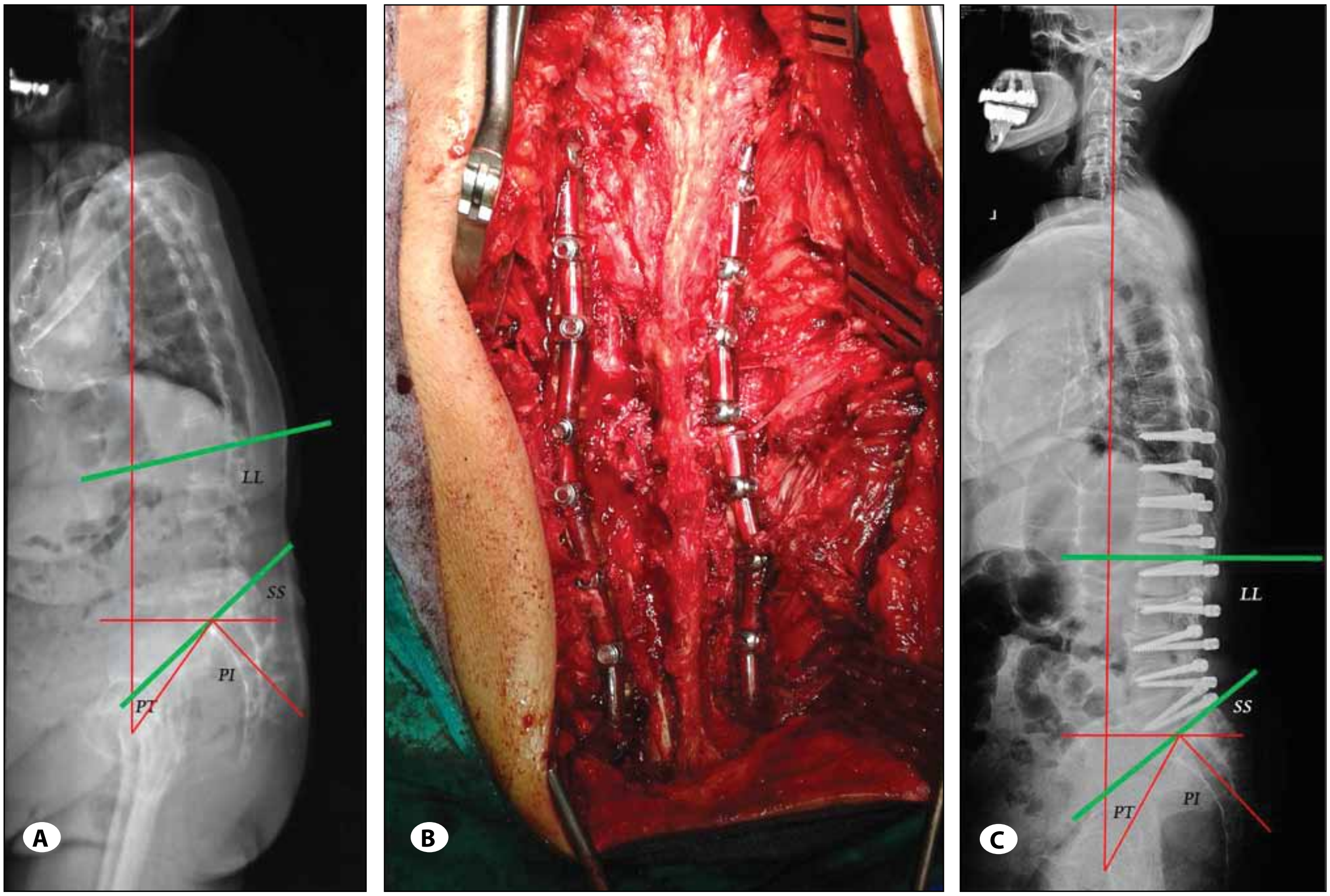

Figure 5: A) There is an imbalance in sagittal plane. The distance of vertebral axis to pelvis is increased, additionally the PI and PT is also increased, **B)** The placement of Dynesys System, **C)** The pelvic parameters are restored after surgery.

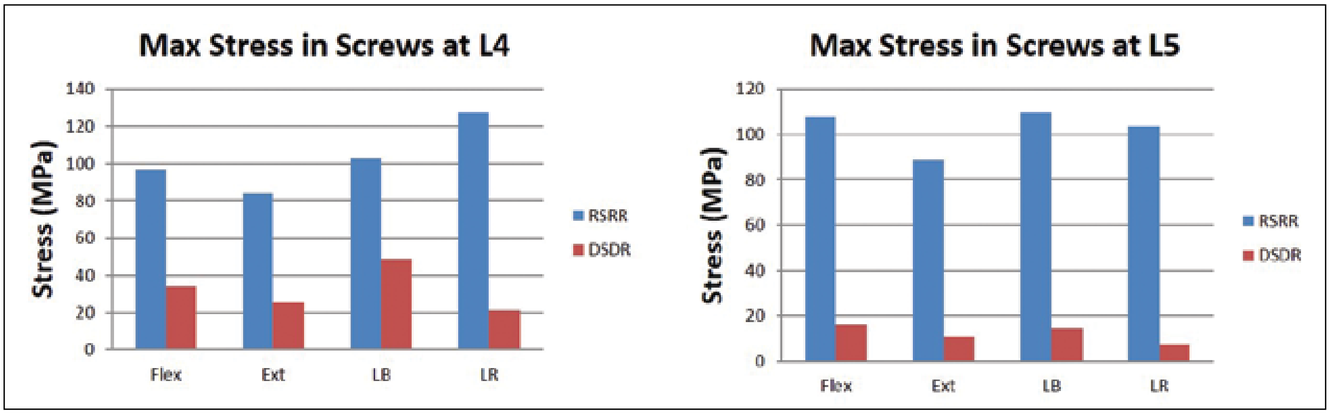

Figure 6: In a finite element biomechanical study the stress on dynamic system screws (dynamic screw-dynamic rod; DSDR) is less than the screws of rigid system (rigid screw-rigid rod; RSRR) under all loading conditions (**Flex;** Flexion, **Ext;** Extension, **LB;** left lateral bending, **LR;** left rotation).

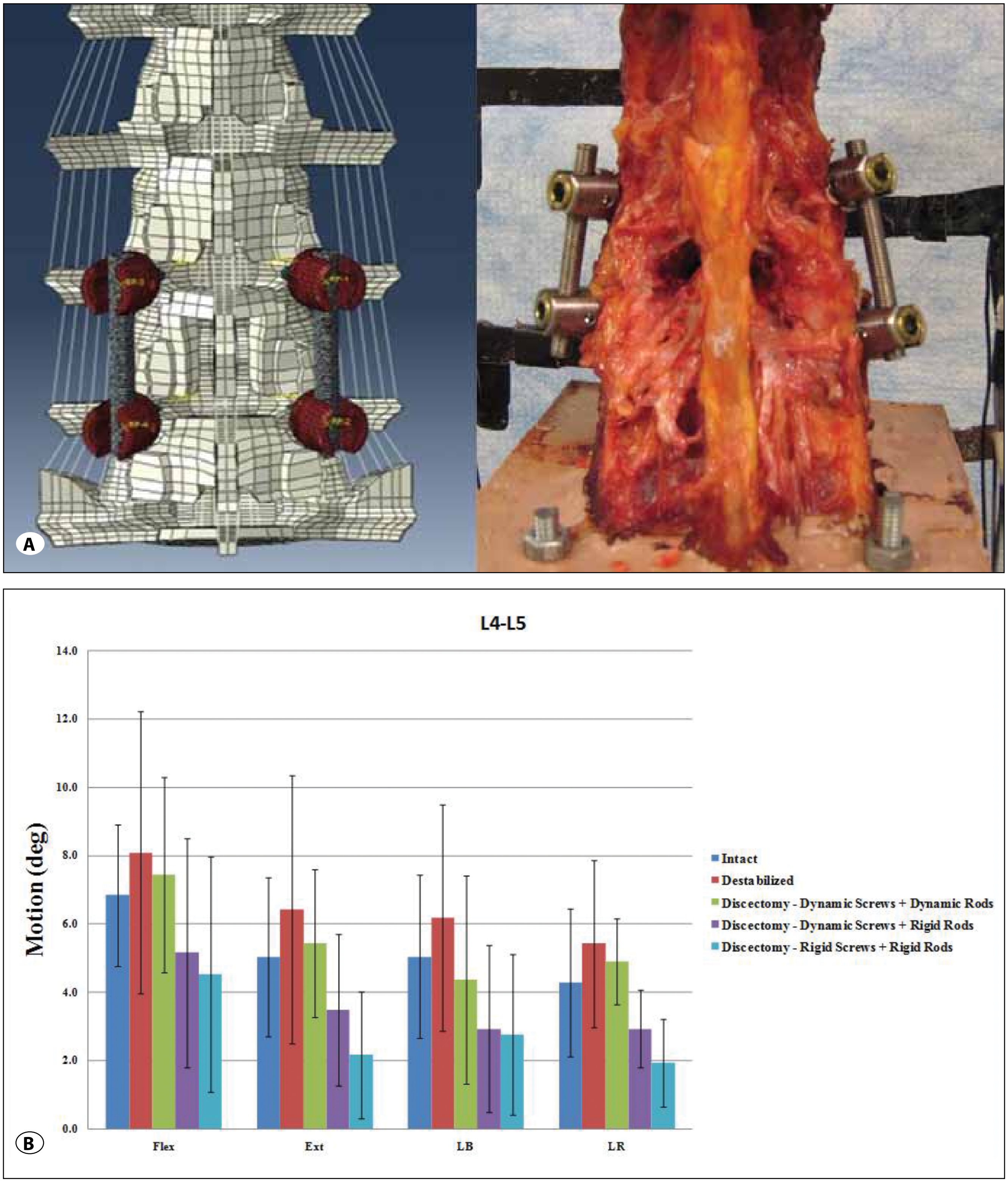

Figure 7: A) Dynamic screw-dynamic rod system is tested both with finite element and with cadaver study. Both studies showed that the disrupted neutral zone was restored with dynamic fixation, **B)** rigid screw-rigid rod and dynamic screw-rigid rod systems are also restored in the disrupted neutral zone but both techniques significantly limited motion. Dynamic screw-dynamic rod technique restores the disrupted neutral zone close to the intact spine.

degenerative deformity, the problem is not over. In the treatment of multi level deformity there is no any flexible dynamic rod like a Talin rod to support the posterior tension band and to allow fusion (hybrid system) if the patient has an additional balance problem. Our material studies to use the Talin rod in clinical application is an ongoing process.

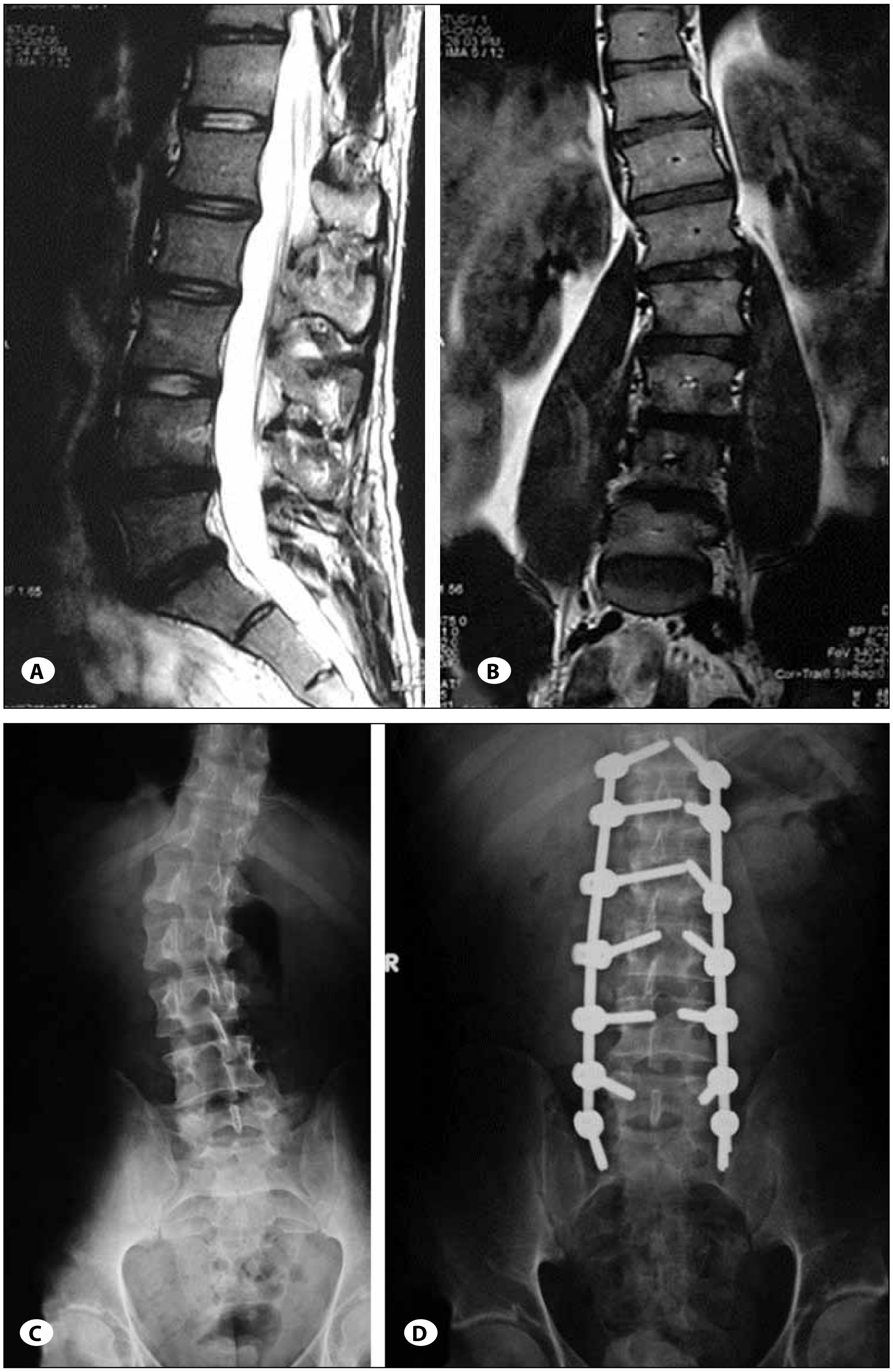

Figure 8: Degenerative scoliosis **(A,B,C)** case is operated with the posterior dynamic stabilization technique **(D)** (dynamic screw-rigid rod).

Figure 9: L5-S1 disc herniation **(A)** is stabilized with dynamic screw-dynamic rod (BalanC) **(B)**.

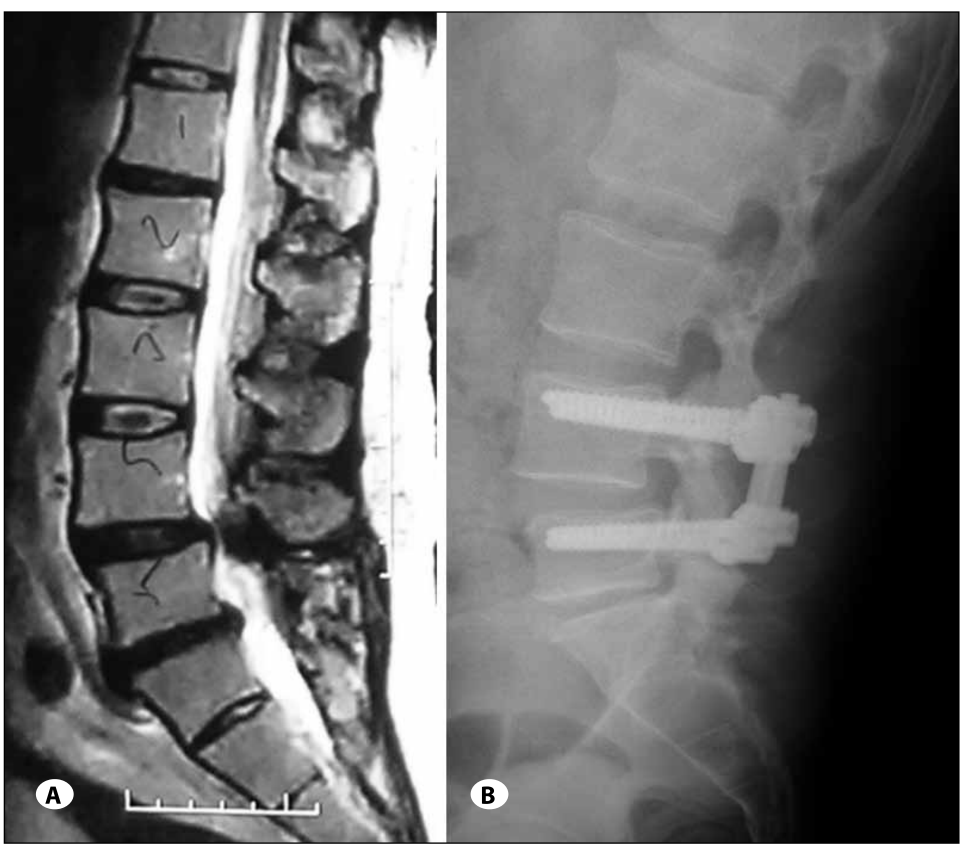

Figure 10: A) Degenerative spondylolisthesis (Sagittal T2 MR) **B)** operated with the osterior dynamic stabilization technique (dynamic screw-rigid rod).

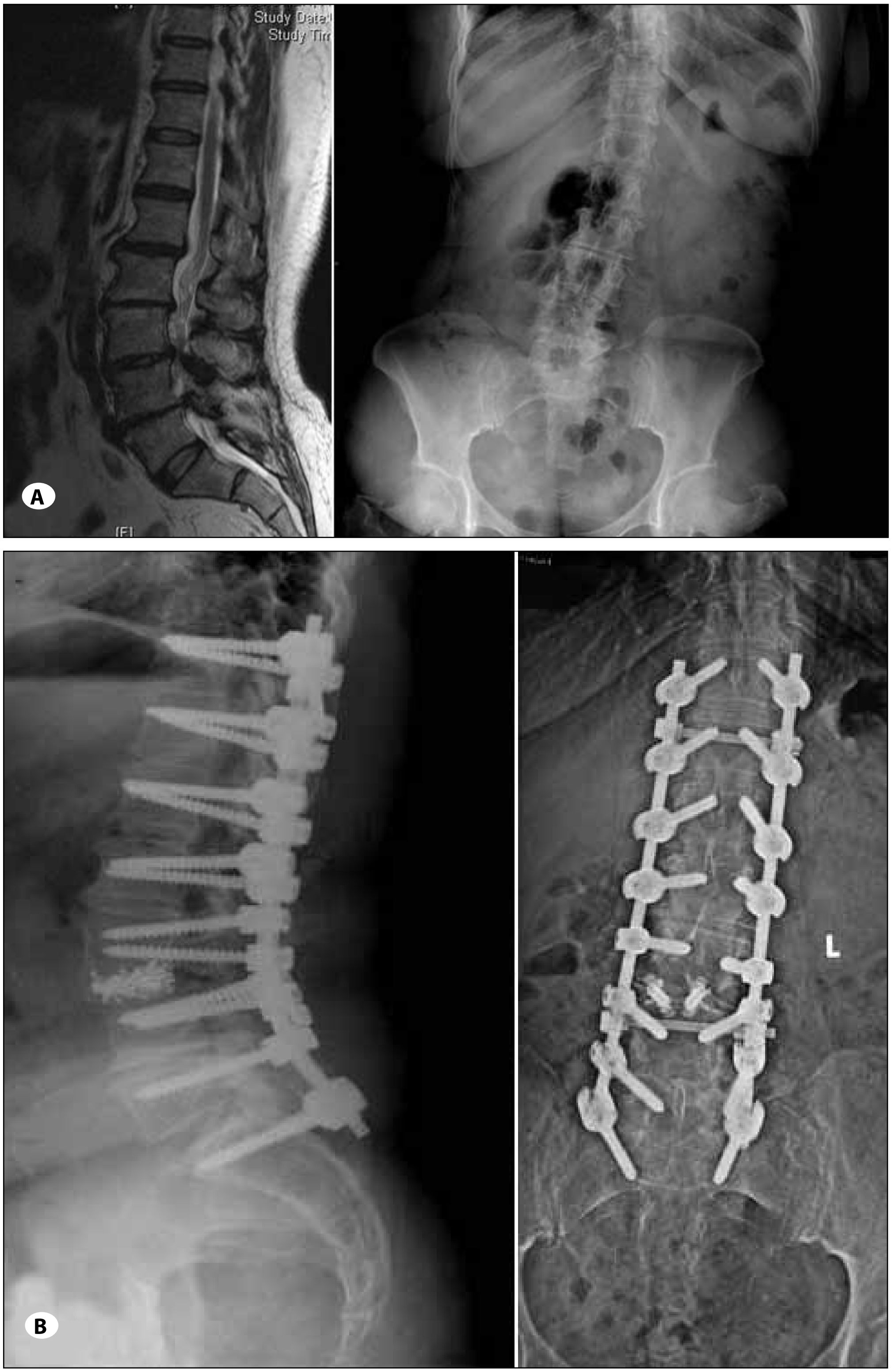

Figure 11: A) Lumbar stenosis (MR, sagittal T2) with degenerative scoliosis (AP plain x-ray), **B)** Decompression with fusion to L3-4 where overt instability exist (lateral and AP plain x-rays, metallic fixation at L3-4 level). Rigid screws were placed into L3 ve L4 vertebrae, the remaining segments stabilized with dynamic screws. The hybrid stabilization is achieved.

Figure 12: A) L5-S1 spondylolisthesis, L3-4 bulging (sagittal MR T2), **B)** L5-S1 isthmic defect (Sagittal CT) **C)** the patient stabilized with the hybrid system. Rigid fixation to the L5-S1 level and dynamic stabilization to the L3-4 and L4-5 levels were used. The flexible part of the dynamic rod was placed at the L3-4 level (arrow).

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