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Review Article

Dynamic stabilization of the spine in osteoporotic patients

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Abstract

Dynamic stabilization is an alternative fusion technique that aims to eliminate or at least minimize the possibility of degeneration of adjacent levels. The object of dynamic stabilization systems is to allow limited movement of the spine while maintaining stability. Based on experimental and clinical data, osteoporosis is a contraindication for the application of dynamic spinal fusion systems, due to the fact that the reduced bone density disrupts the osteointegration of the pedicle screws, resulting in an increased chance of loosening, which compromise the success of the operation. For this reason, most clinical trials analyse the effects of dynamic spinal fusion include osteoporosis in the exclusion criteria.

Keywords: Dynamic stabilization, Osteoporotic spine, Spine fusion

Introduction

Spinal fusion reduces spinal mobility, causing increased loads on adjacent vertebrae. Stiffness can lead to fusion failure, increased complications, porosity disorders, degenerative spinal lesions, and decreased patient satisfaction[1,2] For these reasons, dynamic spinal stabilization systems have been developed, which allow controlled movement that is similar to the normal movement of the spine. In this respect, dynamic stabilization can be considered as a method of internal splinting. The dynamic stabilization represents a group of interventions related to the treatment of degenerative vertebral arthropathy or degenerative disc disease, as an alternative to vertebral ligation and disc arthroplasty[3-6].

Dynamic spinal fusion is usually at a single level, but can be described up to 4 vertebral levels[1]. Dynamic stabilization either as monotherapy or as a complementary treatment of spinal fusion. . In the second case, vertebral ligation is applied at the complementary level of the spine while at the adjacent plane a dynamic vertebral ligation system is applied, in an attempt to limit movement and prevent degeneration at the non-vertebral level.

Dynamic spinal stabilization systems serve to relieve discogenic pain by modifying the biomechanics of the intervertebral disc and reducing the compression and lateral shear loads exerted on the intervertebral disc that cause pain[4,7,8]. A prerequisite for the installation of dynamic spinal fusion systems is that the disc should not be completely degenerated. Dynamic spinal fusion systems are also used to treat spinal stenosis and lumbar spine instability[1,9]. Finally, these systems can prevent the development of small deformities of the spine, such as degenerative spondylolisthesis and early degenerative scoliosis in adults[4].

There is a wide assortment of dynamic stabilization systems that have been studied, at different stages of development each. Most are based on pedicle screws, using a flexible, elongated section that allows movement. These systems change depending on the type of rods they use. The system that is probably most common in the US is the Dynesys (Zimmer Spine) which uses pedicle titanium screws and a long arm consisting of a cord inside a plastic sheath. Instead of the rigid rod or plate as part of the spinal fusion

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material, Dynesys uses a cord inside a plastic sheath as the elongate part that connects the pedicle screws. This system allows the controlled movement of the operated vertebral level, instead of a rigid stabilization, without affecting the intervertebral discs and the articular processes (dynamic stabilization)[1,9].

A potential advantage of dynamic spinal fusion systems is that the effect of the system on the anatomy of the spine is less than that caused by spinal fusion surgery. Dynesys does not affect the intervertebral disc and does not require the use of a bone graft[10,11]. It has FDA approval as a complementary method of spinal fusion and approval for use in cases of porosity failure (pseudoarthritis). There are other systems of dynamic stabilization, which are in various stages of development. In all, pedicle screws are used to fix them to the spine and the difference lies in the system that joins the screws.

In biomechanical studies, dynamic spinal ligation systems have been shown to be effective. Although dynamic spinal fusion systems are designed to protect the spine from the adverse effects of rigid fixation, ten years of clinical use have failed to demonstrate the superiority of these systems in clinical or radiographic results. There were no differences in the rate of degeneration in adjacent dynamic systems compared to rigid systems[12,13].

Dynamic spinal fusion in osteoporotic patients

In a dynamic stabilization system, the pedicle screws receive most of the system load. Consequently, loosening the screws, when it occurs, is critical to the function of the system[14-16]. The extraction force of the pedicle screws has been shown to be related to bone density[17] and is lower in patients with osteoporosis[18]. Therefore, the logical conclusion is that the pedicle screws systems of dynamic spinal fusion are contraindicated in patients with osteoporosis. Experience with the Dynesys dynamic spinal stabilization system has shown that this method has limitations in elderly patients with osteoporotic bone. Such cases have an increased risk of failure[3].

Experimental studies

An experimental study by Giavaresi et al, analyze the adhesion of the pedicle screws of the Dynesys dynamic spinal fusion system to osteoporotic vertebrae. Eight sheep were divided into two groups of four animals each: 4 sheep underwent bilateral ovariectomy, while the remaining 4 underwent surgery simulation. Eighteen months after the operation, the Dynesys® system was placed on the sheep using pedicle screws. Four months after the application of the dynamic spinal fusion system, the laboratory animals were euthanized and the tissue samples were collected from the operated spines. Ovatectomized animals had significantly lower local bone density than fake animals. Osteointegration and bone-graft contact rates were found to be significantly lower in osteoporotic animals[19].

In an experimental study, Meyer et al, studied 5 cervical lumbar vertebral specimens from cadavers. All samples were subjected to bone density measurement preoperatively. Dynesys and TOPS dynamic spinal fusion systems were fitted to all specimens and biomechanical measurements were made after applying bending, extension and rotation forces. No significant correlation was found between the T-scores and the magnitude of the torque of the pedicle screws. However, the authors report that screw-bone contact surface failure is expected to occur more rapidly in osteoporotic bone[20].

A recent biomechanical study by Qian et al compared the biomechanical characteristics of dynamic pedicle screws with traditional pedicle screws. A traditional pedicle screws on one side and a dynamic pedicle screws on the other side were placed on 45 cervical vertebrae. The vertebrae underwent multiple loading cycles, and bone density was also recorded. A correlation was found between the maximum screw extraction force and the bone density ($p=0.024$). The pedicle screws provides stronger fixation stability in non-osteoporotic patients than the traditional pedicle screws, but similar stability in osteoporotic patients to the traditional pedicle screws. The authors recommended increased attention to the use of dynamic pedicle screws in osteoporotic patients[21].

Clinical studies

A recent retrospective study by Loffler et al compared 23 elderly patients with pedicle screws loosening after semi-rigid spinal fusion with 23 controls. Patients who experienced loose screws had significantly lower bone density ($p=0.001$). Screw loosening was more significant in patients with a bone density of less than 81.8 mg/cm^3. The authors concluded that the loosening of the screws in the semi-rigid vertebrae was greater in elderly osteoporotic patients[22].

Another prospective clinical study by Schaeren et al included 26 patients (18 women, 8 men), with a mean age of 71 years, with symptomatic lumbar spine stenosis and degenerative spondylolisthesis. All patients underwent pedalectomy and posterior dynamic spinal fusion with the Dynesys system. In a mean follow-up of 4 years, 2 osteoporotic fractures were observed: One O4 osteoporotic fracture at 18 months treated with O3-O5 vertebral ligation and another O5 osteoporotic fracture at 30 months postoperatively treated with O4-I1 vertebral ligation. The authors attributed the two osteoporotic fractures to the increased rigidity of the Dynesys system[23].

A large prospective study by Kuo et al in 291 patients who underwent dynamic spinal fusion with the Dynesys system (1064 screws in place) found that the screw loosening rate was 20.4%. The mean age of patients with screw loosening was significantly higher than the mean age of patients with intact screws (64.6 years versus 60.1 years, p=0.03). When the spinal fusion included the I1 vertebra, the screw failure rate was 28.8%. The authors attributed this phenomenon to the fact that elderly patients have higher rates of osteoporosis, and therefore a greater chance of loosening the screws of dynamic spinal fusion[24].

An observational study by Tu et al investigated the short-term effects of minimally invasive dynamic spinal fusion in 47 patients, mean age 47.6 years, with lumbar spine stenosis. In one case a screw failure was observed and the patient underwent surgery again. Although, in the reoperation, a screw as long as possible was used and bone grafts were placed, the screw loosened again. The authors attributed the fact that the patient is a postmenopausal woman, in whom the preoperative measurement of bone density revealed that she suffered from moderate osteoporosis[25].

A study by Schwaiger et al, in 63 patients, mean age 66 years, who underwent dynamic spinal fusion for spinal instability, assessed clinical and radiological parameters at 2-year follow-up. After multifactorial analysis, patients with high bone density were found to have a significant improvement in the Oswestry Disabilty Index, indicating that the clinical outcomes of dynamic spinal fusion are better in patients without osteoporosis[26].

The X-Stop dynamic spinal fusion system is designed to treat patients with neurogenic intermittent claudication due to lumbar spine stenosis. Discharges the posterior elements of the adjacent vertebrae and the intervertebral disc, reducing the extent of the spine and improving the narrowing of the spine. A retrospective study by Bowers et al investigated the clinical and radiological results of the application of the dynamic X-Stop spinal ligation system in 13 patients with spinal stenosis. After a mean follow-up of 43 months, decreased bone density was found to be associated with 3 fractures of the spinous processes and 2 cases of recurrence of the root disease[27].

In general, most prospective clinical trials of dynamic spinal fusion systems consider osteoporosis and osteopenia as contraindications for application of the method and include it in the exclusion criteria[26,28-34].

Conclusions

In osteoporotic patients, bone density and quality are clearly affected. As a result, the quality of the connection of the pedicle screws to the dynamic spinal fusion systems is affected and their osteointegration into the vertebrae is disrupted. This increases the risk of implant loosening and the need for reoperation. For this reason, osteoporosis is a contraindication for dynamic spinal stabilization and the application of such systems should not concern osteoporotic patients.

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