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Dynamic Stabilization of the Lumbar Spine – Current Concepts and Results

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Abstract

This paper gives an up-to-date overview of the most widely available types of pedicle screw-based and interspinous implants which allow dynamic stabilization of most degenerative conditions of the lumbar spine. The particularities of these techniques are briefly outlined and clear contraindications are discussed based upon on expert opinions and selected metaanalytic literature.

Dynamic implants of this kind are neither the magic bullet for all degenerative surgical conditions of the lower back nor should they be condemned up front. They provide an evolutionary kind of means to avoid adjacent pathology in fusion cases, to save segments from premature surgical fusion, and to reduce surgical comorbidities from fusion cages and homologous bone stock harvest.

Introduction

Whereas rigid stabilization with or without concomitant fusion is a well established concept in the treatment of traumatic, dysplastic, and degenerative disorders of the spine, many approaches have been proposed to minimize the inherent iatrogenic comorbidities of these procedures. One of the most common concerns is an accelerated postoperative adjacent segment degeneration due to mechanical overload caudally and cranially of pedicle screw-rod instrumentations.[1,2]

Replacing rigid implant components with dynamic parts (e.g. rods with mobile joints or semielastic materials) has been discussed since the late 1980s, but evidence for superiority is still sparse. Biomechanical tests, however, have yielded clear evidence for lesser loads in the adjacent segments as compared to traditional methods. Also a so-called topping-off of rigid instrumentations by means of elastic components is increasingly postulated.[3]

Such semirigid and elastic methods, in our concept, have clear indications and contraindications. Since 1987 we can now personally overlook their technological evolution, witnessing many implants being hailed and sometimes condemned shortly after. The current state of the art, which has become more or less a European “mainstream meanwhile allows safe application, reasonable recommendations for use and preconditions, and clear caveats which will be described and summarized concisely.

The subject surely is of interdisciplinary interest for orthopaedic, traumatologic, neurosurgical and general surgeons who often have back pain patients in their clientele, even if they do not perform such surgery themselves.

Overview of available concepts:

For purpose of stabilization of lumbar spine instabilities, except for fractures and tumours, different classes of “dynamic“ implants are currently available:

Pedicle screw – rod based systems (PRS)

- with metal rods including flexible elements
- with “elastic“ polymer rods
- with semirigid PEEK rods

Interspinous Devices (ISD)

All these implants can be used in a standalone manner, i.e. without combination with other implants or procedures, in combination with fusion (mostly above, “topping off“) and/or with or without additional decompressive surgery. Some of them are only suitable for one-segment procedures whereas others may be used polysegmentally as well. In some countries, these implants have been used also to achieve fusion, on the grounds of reduced stress shielding and reduced resorption of the bony fusion transplant. However, we shall not discuss this indication since it seems to us that this concept does not have significant proven advantages over the current gold standards of instrumentation with rigid pedicle screw-rods and optional intervertebral cage augmentation. Moreover, the increasingly less popular intervertebral disc prostheses, albeit being “dynamic“, are not to be discussed here.

In Figure 1, three PRS, in Figure 2 three ISD are depicted. These implants stand of course only as an arbitrary selection from a vast and continuously evolving industrial portfolio. Specific manufacturers will not be explicitly mentioned in the following text, no commercial interests of the authors are linked to this paper. An abundance of more or less fact-based information and pictures is accessible over the internet. The following remarks are meant to be a brief and guided introduction to the subject, favoring mention of only a few relevant clinical and biomechanical studies. The interested reader is encouraged to make himself familiar with the many and often controversial publications in this field.

Biomechanics

Elastic rod systems have unloading effects upon operated and adjacent segments. They stabilize in flexion/extension, lateral bending, and axial rotation (3D). Furthermore they may assist in bi- or unilateral distraction and act as axial “buffers“ and shear force reducers (dependant upon construction).

From several biomechanical *in vitro* analyses, the paper of Wendlandt et al. [4] may stand *pars pro toto* here: In a topping-off situation with rigid stabilization at L4/5, like depicted in Figure 1 (right side), the intradiscal pressure in L2/3 and L3/4 in extension was significantly reduced for a PRS. The same held true for topping of with an ISD, like that depicted in Figure 2 (right side). Reduced disc pressure under load is considered a predictor for longevity of the disc structures themselves.

Even ISDs have unloading effects upon the operated segment and the adjacent segment. Yet they can only stabilize in flexion/extension and depend upon at least partially preserved facet joints.

Schilling et al.,[5] in a group including the senior author of this paper, have confirmed unloading effects for both the stabilized and the adjacent segment for a variety of ISDs.

Over the years, it became clear that PRS *in vivo* show effects not only upon the range of motion in the instrumented, inferior, and superior adjacent segments, but also ISD, as shown in Table 1. That means that both concepts, dynamic PRS and ISD may not only influence the operated, but also the adjacent segments. Yet, not all of these effects are fully understood *in vivo* and still spark controversy among users and those not advocating the use of these implants. From that biomechanical point it has become clear that even after the use of PRS and ISD adjacent pathology may occur and that overly distracting a segment which remains mobile may inflict damage upon the posterior structures, especially of the disc and the posterior longitudinal ligament in the instrumented segment itself.

Clinical Aspects

Chou et al. [6] have recently shown in a metaanalysis of many studies that dynamic stabilization is at least "not superior" to rigid stabilization in the lumbar spine. This was often misunderstood. Most study designs aimed at proof of non-inferiority or equality; a proof of superiority often needs very large cohorts and long-term follow-ups. Also, the quality of most studies was allegedly poor and indications were not homogeneous.

Lee et al.,[7] in another metaanalysis, found equal outcomes for dynamic vs. rigid stabilization up to spondylolistheses grade 1, yet less blood loss, quicker discharge, and shorter operating time in the dynamic group. These aspects must not be underestimated in times of meager inpatient treatment resources.

Interestingly enough, another group[8] found, in a systematic review of ISD, no significant differences between decompression surgery plus fusion vs. decompression alone vs. decompression plus ISD.

Accordingly, we decided to retrospectively evaluate our own clientele:
570 patients 2003 – 2021
447 ISD patients
123 PRS patients (21.6%)
90 "standalone" patients since 2012
63 ISD patients among them
27 PRS patients among them (30,0%)
Mean follow-up time: 187 months.

Revision rates are the hardest criterion for success or failure of these procedures, not unlike as in spinal fusion. Equally, they differ vastly among the literature.[9,10] Sticking strictly to our indications mentioned in the conclusion, our specific implant related revision rate over 20 years was below 4%. In the last 10 years, a series of 90 patients from the same center allowed a good follow-up with acceptable drop-out rates and even lower numbers of implant related revisions.

Reasons for revisions were in no case dislocation of ISD, as often emphasized in the literature. We do not know the reason for that discrepancy, however, it might be speculated that this is due to the fact that we never implant ISDs without additional decompression under appropriate visualization of the spinous process and always consider osteoporosis a contraindication for ISD and PRS.

Yet it must be noted that with ISD and PRS, adjacent segment pathologies could not be completely prevented, particularly in cases where patients were unable to reduce weight or show non-compliant behavior. These (rare) cases were not considered having implant related reasons for revision since it is impossible to assess whether this would also have happened with fusion instead of dynamic stabilization.

It was noted that ISD implants explicitly did not prevent recidives of disc prolapses, most probably due to their distraction of the posterior longitudinal ligament without reducing torsional motion amplitudes. So we have abandoned using ISD in pure discectomy cases and these cases were considered implant related failures, although reprolapses naturally also occur without ISDs.

Implant loosening was not observed particularly often, perhaps because it could be noticed that over the years with PRS (and surprisingly often also with ISD) spontaneous ankylosis occured, after which screw loosening is rare. We observed somecases of screw breakage with the Dynesys implant, mostly at a stress concentration point in the middle of the screw shank. However, most of these material failures were found by chance without being related to clinical problems.

Implants with *ex post* proven constructional flaws (e.g. Agile) or ISD for the aim of primary fusion (e.g. Coflex F) had been fortunately avoided in our series.

Special care must alwas be taken, especially in the use of PRS, not to damage both the facet joints of the instrumented segment. For the adjacent facets, the same caveats as for fusion instrumentation with rigid implants apply. Usually, the insertion technique should follow a pronounced axial oblique direction, if possible, keeping the screw heads apart from the facets.

Admittedly, the insertion of monoaxial screws for equipping them with elastic rods is more demanding than for polyaxial screws. Polyaxial screws, alas, so far are not suitable for non-metal rods, except for PEEK rods, which have no axial buffering capability. So the dynamic use in the lumbosacral junction can be more difficult than for rigid stabilization and fusion. Also the often reduced purchase of screws in the sacrum with higher risk for screw loosening means that this segment is less commonly instrumented *via* PRS. The usually small spinous process of S1 makes ISD at L5/S1 often also impossible. These impediments should always be clarified prior to surgery by adequate radiological visualisation.

Conclusions

Our indications for which PRS and ISD can be utilized can briefly be summarized as follows:

- For pain relief of degenerated facet joints
- For restabilization of decompressed segments and protection against postoperative decompensation
- For "topping-off" to protect adjacent segments in fusion surgery.

As contraindications we and most other users with whom we have discussed it identify:

- Unstable spondylolisthesis (lytic and degenerative)
- Scoliosis
- Osteoporosis
- For ISD only: Hyperlordosis/dysplastic spinous process at L5/S1 and "standalone" use (i.e. without additional decompression)
- Sacrificed facet joints (especially bilaterally)
- Lack of patient compliance and "Failed Back"

Considering the aforementioned caveats and indications, modern PRS and ISD implants can be a valuable addition to the portfolio of lumbar spine surgery, particularly in younger patients with good postoperative compliance and in the hands of experienced surgeons.

Figure 1: Pedicle screw based systems – from left to right: Elaspine, S4, Firebird TDX

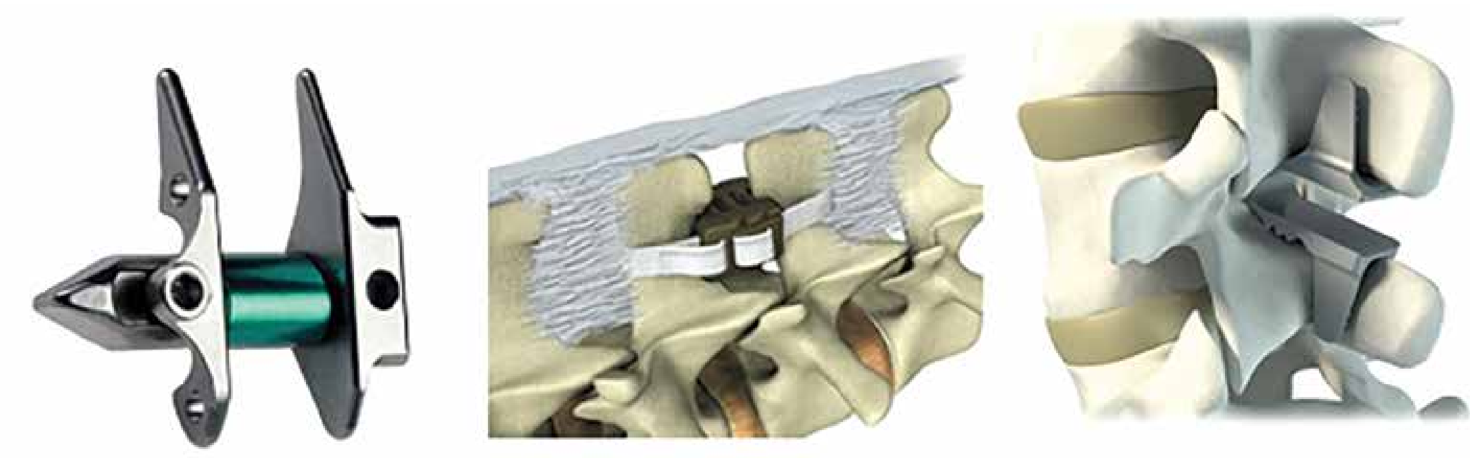

Figure 2: Interspinous devices for dynamic stabilization - from left to right: X-Stop, Wallis, Le-U/Coflex

Functional x-ray	Segment	Spinous process distance	Posterior Endplate distance	Angle of motion
Maximum Inclination	above	↓ $p<.05$	↓	↑
Maximum Inclination	Implant	↑	↑	↓
Maximum Inclination	below	↓	↓ $p<.01$	↓
Maximum Reclination	above	↓ $p<.05$	↓	↑
Maximum Reclination	Implant	↑ $p<.001$	↑	↓ $p<.05$
Maximum Reclination	below	↓	↓	↓

Table 1: From this own functional analysis it can be derived that on radiographs, taken in maximum inclination and reclination, ISDs not only have distractive effects, unloading the facet joints in the instrumented segment, but may also have some countering effects upon the adjacent segments. This is also known for (as compared to ISD's more rigid) pedicle srew based systems. In this respect they resemble rigid fusion systems, however, they preserve motion in the operated segment.

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