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Hybrid Constructs

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There are several disadvantages to fusion, such as obliteration of normal anatomy, elimination of movement, and increased stiffness. These disadvantages may increase the potential for other long-term complications ("fusion diseases") such as facet hypertrophy, facet arthritis, spinal stenosis, osteophyte formation, posterior muscular debilitation, and adjacent-level disc degeneration [1–6]. Motion-preserving techniques offer the opportunity to achieve intersegmental stabilization coupled with retained intersegmental mobility. Disc arthroplasty techniques may decrease transmission of detrimental stresses to the adjacent segments, which theoretically may counteract the early, accelerated degeneration often seen in these segments. Under proper adherence to their indications, these new motion-preserving techniques may help to avoid these fusion diseases.

Because the spinal motion segment consists of three well-balanced moving parts (ie, the intervertebral disc, the paired zygoapophyseal joints, and the surrounding soft tissue ligaments and muscles), some advanced-stage morphologic changes cannot be treated in an adequate manner with an anterior column disc replacement alone.

Types of hybrid constructs

Single-level hybrid constructs

Single-stage motion-preserving hybrid

Treatment with motion-preserving technologies should take into consideration all three moving parts of the motion segment. Thus, disc replacement technologies (nucleus replacement, total disc replacement) can be combined with posterior stabilizing elements (eg, dynamic pedicle screw–based devices, interspinous devices, or facet replacement) (Table 1, type 1).

Multistage motion-preserving hybrid

In this type of hybrid (see Table 1, types 2a and 2b), patients who already have an existing motion-preserving technology can have an additional one added later. This fact allows primary anterior and primary posterior technologies to be combined with secondary posterior or secondary anterior technologies in the future.

Multilevel hybrid constructs

Anterior motion-preserving technologies (nucleus replacement, total disc replacement) can be combined with posterior motion-preserving technologies (pedicle screw–based systems, interspinous devices, facet

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Table 1
Single-level hybrid constructs

Type	Level	Timing of surgical procedures	Type and location	
			Anterior	Posterior
1	Single	Single stage	yes	yes
2a	Single	Multistage	Previous surgery	yes
2b	Single	Multistage	yes	Previous surgery

replacement) at more than one level. The goal is to achieve three-dimensional, motion-preserving, biomechanically stable reconstruction of the involved motion segments, with a physiologic range of motion. Considering the treatment of a whole motion section, hybrids can be classified as follows:

Motion-preserving technologies combined with motion-preserving technology of any type (single-stage)

In this type of hybrid construct, only motion-preserving technologies are used (Table 2, type 3). Anterior technologies (nucleus replacement, total disc replacement) and posterior technologies (pedicle screw–based systems, interspinous devices, facet replacement) may be applied to different segments and combined in single segments. The goal of this kind of multilevel hybrid is to dynamically treat all of the affected spinal segments with motion-preserving technologies.

Motion-preserving technologies combined with fusion (single-stage)

If varying pathologies are found within multiple motion segments (eg, one segment has severe spondyloarthritis and complete segmental collapse, another segment has disc height reduced by 50%, and a third segment has a large central disc herniation—all without significant posterior element pathology), it makes no sense to reconstruct only the most affected motion segment with arthroplasty. In these cases, the application of a fusion technique in the lower or middle area can be considered so that a mechanically stable construct can be attained. This surgery is preferably done single stage (see Table 2, type 4).

Table 2
Multilevel hybrid constructs

Type	Level	Timing of surgical procedures	Type of procedure	
			Level x to z	Level y to z
3	multi	single stage	Motion-preservation techniques (anterior, posterior, or combinations)	Motion-preservation techniques (anterior, posterior, or combinations)
4	multi	single stage	Fusion procedure (any kind)	Motion-preservation techniques (anterior or posterior or combinations)
5a	multi	multistage	Previous surgery: fusion procedure (any kind)	Motion-preservation techniques (anterior, posterior, combinations)
5b	multi	multistage	Previous surgery: motion preservation (any kind)	Fusion procedure (any kind)

Motion-preserving technologies combined with previous fusion (multistage)

In the broadest sense, a hybrid is a combination of an already existing fusion with a motion-preserving technology (see Table 2, types 5a and 5b). This treatment is usually necessary due to a symptomatic adjacent-level instability. In these cases, the hybrids are created in different, consecutive surgical sessions. Anterior and posterior technologies or combinations of single-level hybrids can be applied.

Indications and contraindications to hybrid constructs

Indications

Because there is limited experience in combining these new technologies, indications for hybrid constructs are similar to those of the individual anterior motion-preserving devices (nucleus replacement, total disc replacement) or posterior dynamic devices

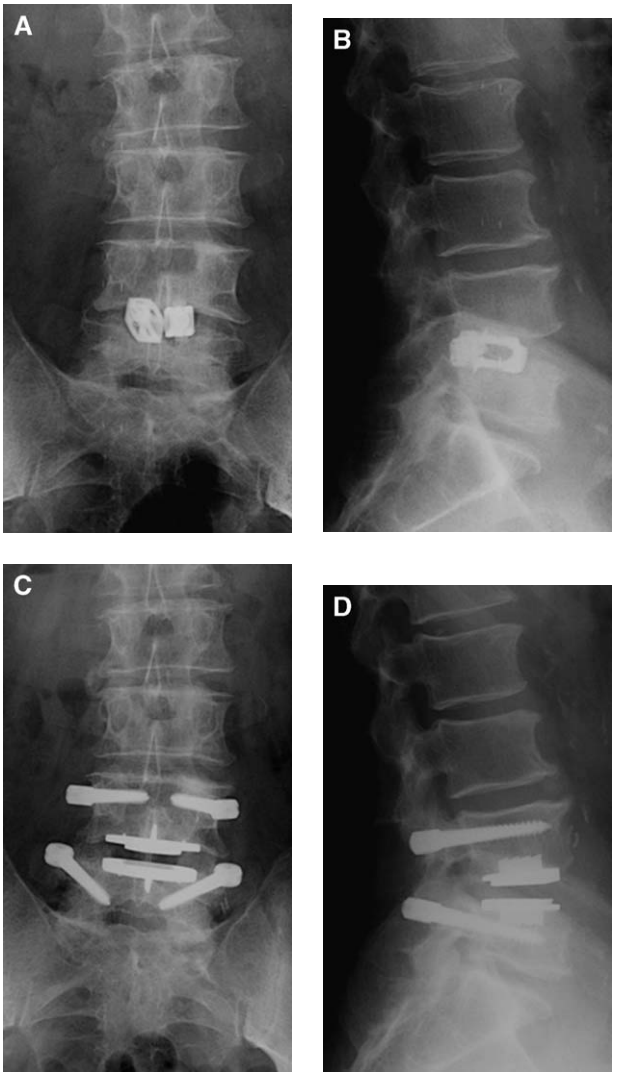

Fig. 1. Anteroposterior (*A*) and lateral (*B*) preoperative radiographs. Anteroposterior (*C*) and lateral (*D*) postoperative radiographs.

(pedicle screw–based systems, interspinous devices, facet replacement). Biomechanical and morphologic changes have to be taken into consideration to plan the reconstruction of a motion segment on a three-dimensional basis, which means the degree of degeneration and the degree of mechanical insufficiency must be considered by the surgeon before deciding on which technologies to combine.

Typical situations in which patients may benefit from hybrid constructs are multilevel-diseased spines in which all involved levels are symptomatic. These situations include multilevel degenerative disc disease with or without degenerative spondylolisthesis, degenerative scoliosis, combinations of isthmic or hypoplastic spondylolisthesis with degenerative disc disease–affected adjacent levels, breakdown of motion segments after fusion procedures, and many more situations that up to now have not been considered as candidates for a motion-preserving procedure.

Contraindications

The same contraindications that are considered for individual fusion and nonfusion technologies remain valid for these types of constructs. One of the biggest problems in considering motion preservation is osteoporosis or other major underlying bony pathologies (osteopenia, metastatic, or infectious diseases) that inherently reduce load-bearing capacities of the vertebral bodies and end plates. This is less of a concern in fusion-only reconstruction. In these conditions, the load-sharing capacities of any device that is anchored by pedicle screws or other fixation systems (posterior dynamic pedicle screw systems or interspinous systems) to the bony elements of the vertebrae or that rely on load transmission from one vertebral body to the other must be carefully considered preoperatively by the surgeon. Acute spinal fractures, spine tumors, discitis, and ventral approach–related problems are also generally considered contraindications [2]. In any surgical procedure, proper adherence to accepted indications is vital to achieve maximally successful postoperative results. As a good general rule, all conservative treatment options should be exhausted before surgery is undertaken.

Case studies

Hybrid construct type 1: Dynesys system plus ProDisc prosthesis

A 68-year-old man who had a previous fusion surgery at the L4-5 level using a posterior lumbar interbody fusion with two titanium-block cages de-

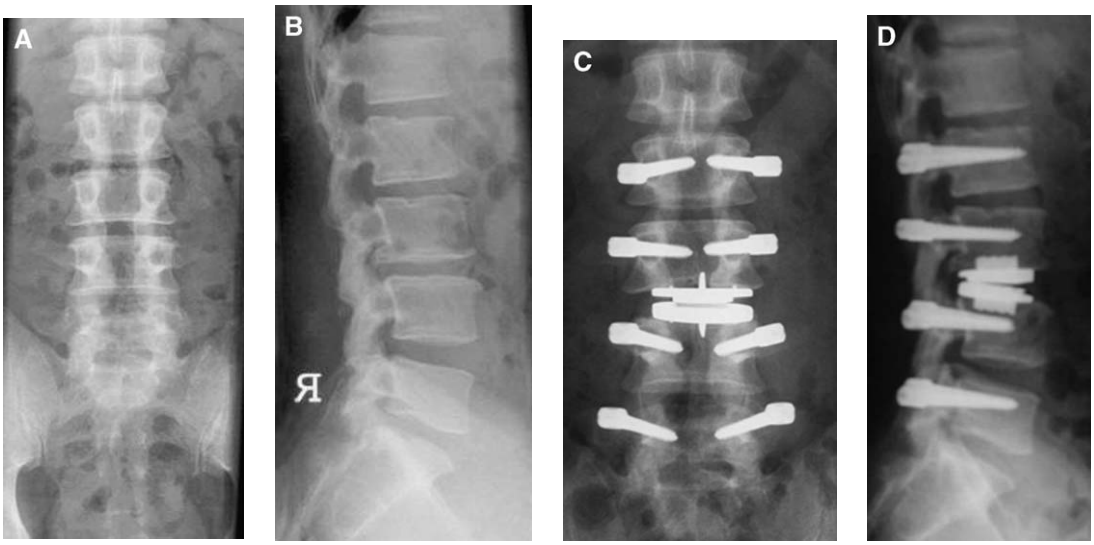

Fig. 2. Anteroposterior (*A*) and lateral (*B*) preoperative radiographs. Anteroposterior (*C*) and lateral (*D*) postoperative radiographs.

veloped persistent low back pain due to failure of bony incorporation through the implanted cages. In addition, later disc degeneration at the L3-4 and L5-S1 levels was diagnosed (Fig. 1A, B). In an anterior revision surgery, the cages were explanted and a ProDisc lumbar prosthesis (Synthes, Oberdorf, Switzerland) was implanted at the L4-5 level. In addition, a posterior reconstruction with dynamic instrumentation (the Dynesys system [Zimmer Spine, Warsaw, Indiana]) was performed at L4-5 as part of the same surgery. Postoperative radiographs showed good positioning of the implants (Fig. 1C, D). Within the first few days after surgery, a significant pain reduction was observed.

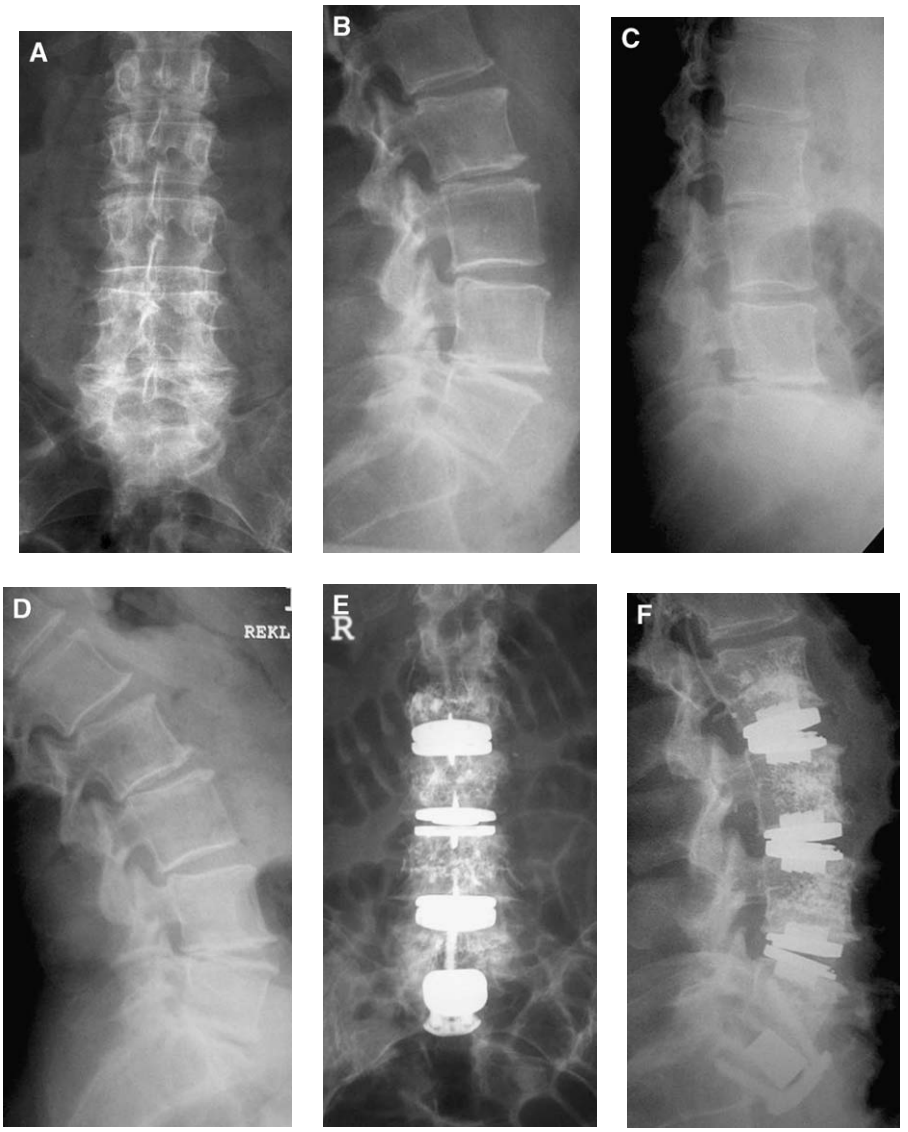

Fig. 3. Anteroposterior (*A*), lateral (*B*), flexion (*C*), and extension (*D*) preoperative radiographs. Anteroposterior (*E*), flexion (*F*), and extension (*G*) postoperative radiographs.

Fig. 3 (*continued*).

Hybrid construct type 3: ProDisc plus Dynesys system (three-level)

A 42-year-old man with a multiyear history of low back pain remained resistant to conservative treatment. He was several years postlaminectomy/discectomy at the L3-4 level and had developed degenerative disc disease at adjacent levels (Fig. 2A, B). The patient was treated with implantation of a ProDisc at the L3-4 level and dynamic instrumentation with the Dynesys system from L2 to L5 (Fig. 2C, D).

Hybrid construct type 4: anterior lumbar interbody fusion plus ProDisc (three-level)

A 61-year-old woman with disabling low back pain had a history of previous disc surgery at L4-5 and partial decompressive hemilaminectomies at L4-5 and L5-S1 (Fig. 3A–D). The recommended treatment was fusion surgery (anterior lumbar interbody fusion) at L5-S1 and multilevel arthroplasty surgery at the L2-3, L3-4, and L5-S1 levels with implantation of three ProDisc lumbar prostheses. In addition, vertebroplasty was performed at the L2 to L5 levels (Fig. 3E–G).

Hybrid construct type 4: 360° fusion plus Pyramid plate plus ProDisc prosthesis

A 38-year-old female heavy manual worker with no previous surgery suffered from severe episodic

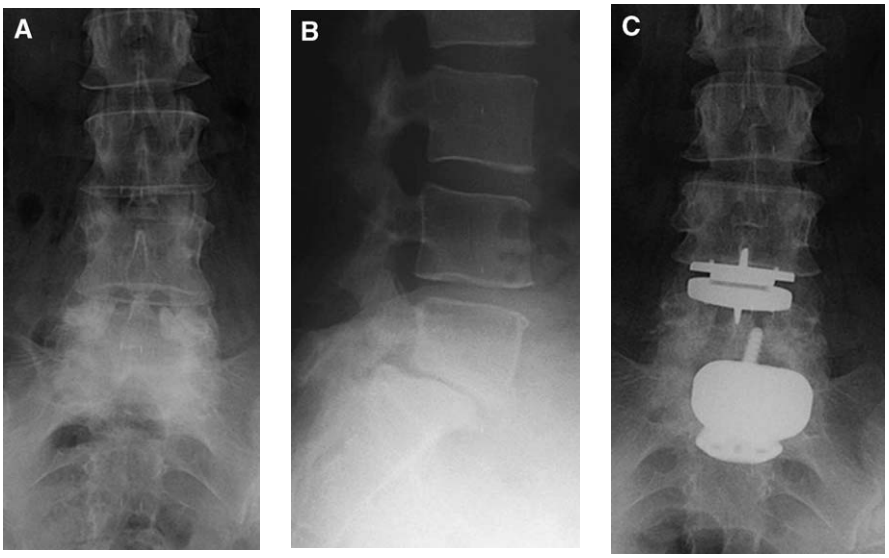

Fig. 4. Anteroposterior (*A*) and lateral (*B*) preoperative radiographs. Anteroposterior (*C*) and lateral (*D*) postoperative radiographs.

Fig. 4. (*continued*).

left leg pain and numbness in both legs. All nonsurgical treatment had failed. Radiographs demonstrated a grade I spondylolisthesis at the L5-S1 level and degenerative disc disease at L4-5 (Fig. 4A, B). It was elected to treat the L5-S1 level with a 360° fusion using a ventral Pyramid plate (Medtronic Sofamor Danek, Memphis, Tennessee) and to implant a ProDisc prosthesis at the L4-5 level (Fig. 4C, D). At 1-year follow-up, the patient was completely satisfied with the surgery. The visual analog scale score declined from 8.0 preoperatively to 2.0 1 year postoperatively.

Hybrid construct type 4: anterior lumbar interbody fusion plus Maverick prostheses (two-level)

A 50-year-old woman suffered from low back pain for several years despite an attempted fusion at L3-4 (segment still unstable). Symptomatic degenerative disc disease at the L2-3 and L4-5 was also diagnosed. Surgical treatment was total disc replacement with Maverick prostheses (Medtronic Sofamor Danek, Memphis, Tennessee) at the L2-3 and L3-4 levels and an anterior lumbar interbody fusion at the L4-5 level. Postoperative radiographs showed correct positioning of the devices and a good restoration of disc height (Fig. 5A, B).

Hybrid construct type 5a: 360° fusion plus ProDisc prostheses (two-level)

A 38-year-old man had an L5-S1 360° fusion for disabling disc disease. He did well for 18 months

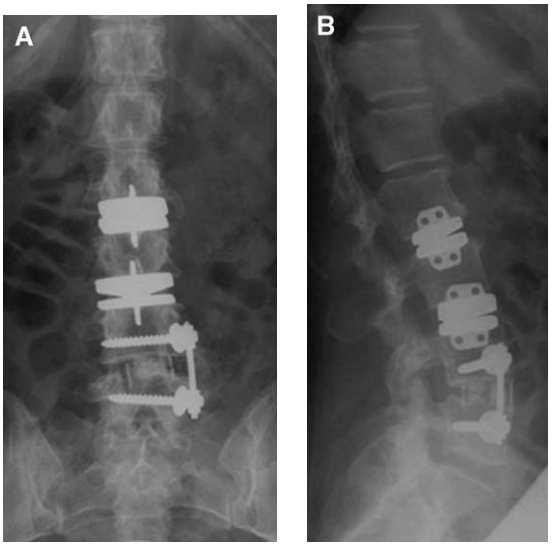

Fig. 5. Anteroposterior (*A*) and lateral (*B*) postoperative radiographs.

but developed progressively increasing pain. A new discogram at that time demonstrated internal disruption of L3-4 and L4-5, with significant pain reproduction at both levels. L2-3 was anatomically normal and painless. A special Compassionate Use waiver was obtained from the Food and Drug Administration to allow implantation of two ProDisc prostheses above his previous fusion (Fig. 6A–C). At 1-year follow-up, the patient is doing exceptionally well, working without restrictions, and delighted with his result.

Hybrid construct type 5a: posterior lumbar interbody fusion plus ProDisc prosthesis

A 45-year-old woman had a previous fusion surgery with posterior lumbar interbody fusion at the L5-S1 level in 1993. Eight years later, lumbar and radicular pain recurred (visual analog scale score: 8.0). Radiographs showed solid fusion at L5-S1 and instability at the L3-4 and L4-5 levels (Fig. 7A–C). All conservative treatment had failed. The patient was treated with implantation of a ProDisc lumbar pros-

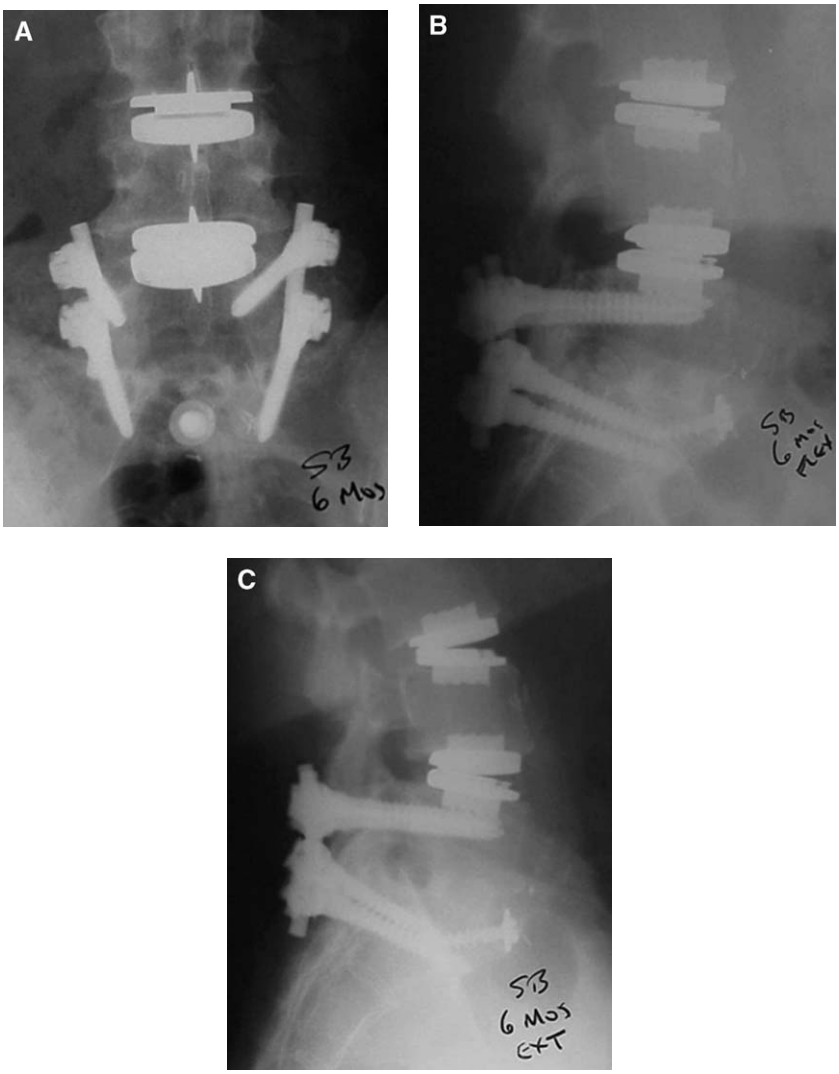

Fig. 6. Anteroposterior (*A*), flexion (*B*), and extension (*C*) postoperative radiographs.

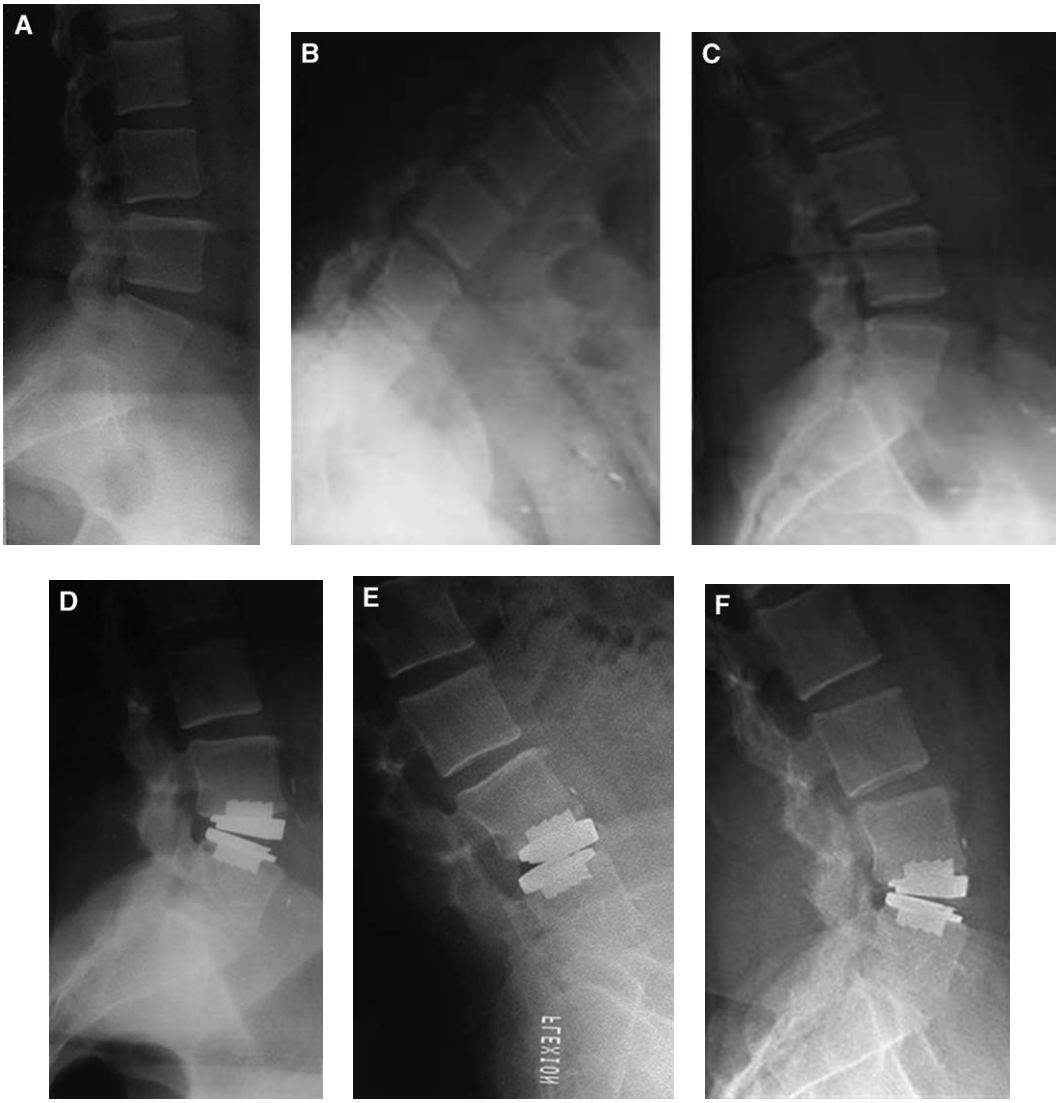

Fig. 7. Lateral (*A*), flexion (*B*), and extension (*C*) preoperative radiographs. Lateral (*D*), flexion (*E*), and extension (*F*) postoperative radiographs.

thesis only at the L4-5 level to re-establish lumbosacral lordosis. Postoperative radiographs showed good mobility of the prosthesis (Fig. 7D–F). Two years after surgery, the visual analog scale score was 2.0.

Summary

Because the spine is a very complex motion-serving organ consisting of three mobile columns, it may not be an ideal treatment strategy to replace only one of those columns. When the biomechanical insufficiency of all three columns is far advanced (eg, disc collapse following discectomy and posterior laminectomy or facetectomy), reconstruction of the posterior or anterior columns alone may result in an insufficient mechanical restoration of the motion segments, with persisting pain and disability. The mechanical necessity to control mobility in all three columns is more important in motion-preserving techniques than in fusion alone.

The promising results of anterior or posterior nonfusion techniques in single-column dysfunction have suggested an expansion of the indications in

degeneratively diseased patients with multicolumn or multilevel pathologies. The authors' early experience with the limited expansion of current indications using a combination of motion-preserving technologies demonstrates promising results. Nevertheless, an expansion of these indications should only be performed under scientific scrutiny of those individuals in whom these techniques have been combined. This scientific scrutiny is particularly important because few of these technologies have prospective, nonrandomized data available for their isolated use, and the combination of these techniques in more complex situations increases the likelihood of complications. Short-, intermediate-, and long-term side effects of these combination therapies are currently unknown, and these patients must therefore be carefully followed so that the surgeon community can learn from these experiences. The casual use of these hybrid constructs should strictly be avoided. Furthermore, controlled single- and multicenter studies should be performed to explore the clinical value of the hybrid constructs described herein.

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