RadioGraphics

Lumbar Spine Fusion and Stabilization: Hardware, Techniques, and Imaging Appearances[1]

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ONLINE-ONLY CME

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LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Recognize the differences between lumbar spine fusion and stabilization and between the surgical approaches used to perform them.
- Identify the main types of fusion and stabilization devices on the basis of their normal imaging appearances.
- Describe the advantages and disadvantages of different imaging methods for evaluating lumbar spine instrumentation.

TEACHING POINTS

See last page

Stabilization and fusion of the lumbar spine may be performed by using various anterior and posterior surgical techniques and a wide range of devices, including screws, spinal wires, artificial ligaments, vertebral cages, and artificial disks. Because spinal procedures are increasingly common, such devices are seen more and more often in everyday radiologic practice. For evaluation of the postoperative spine, radiography is the modality most commonly used. Computed tomography and magnetic resonance (MR) imaging may be useful alternatives, but MR imaging of the postoperative spine is vulnerable to metal-induced artifacts. For an accurate postoperative assessment of spinal instrumentation and of any complications, it is important that radiologists be familiar with the normal imaging appearances of the lumbar spine after stabilization, fusion, and disk replacement with various techniques and devices.

Abbreviation: SE = spin echo

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Introduction

Spinal instrumentation was first described in 1911 as a method for treatment of Pott disease (1). Since then, a wide range of devices have become available, and lumbar spine instrumentation is now used in various clinical settings, including degenerative disk disease, spondylolisthesis, tumors, infection, and trauma. The choice of device depends on the clinical problem, the anatomic location, and the surgeon's preference. The instrumentation used in fusion surgery is not designed to replace the bony elements of the spine, but to stabilize them during fusion, and it is generally accepted that instrumentation without intact osseous fusion will fail (2). Disk replacements were developed to overcome clinical problems associated with pseudarthrosis and to reduce the incidence of adjacent vertebral segment degeneration. Dynamic stabilization devices, which are designed to limit abnormal segmental motion, may be used as an alternative to vertebral fusion procedures.

Teaching Point

To recognize normal postoperative imaging appearances or detect malpositioning or complications of lumbar spine instrumentation, radiologists need an understanding of the range of approaches, techniques, and hardware devices used in lumbar fusion and stabilization and in disk replacement. The article provides an overview of these procedures and of normal postoperative imaging features that are commonly seen at radiography, magnetic resonance (MR) imaging, and computed tomography (CT).

Imaging of the Lumbar Spine after Instrumentation

Postoperative imaging is typically performed *(a)* to assess the progress of osseous fusion, *(b)* to confirm the correct positioning and the integrity of instrumentation, *(c)* to detect suspected complications (eg, infection or hematoma), and *(d)* to detect new disease or disease progression.

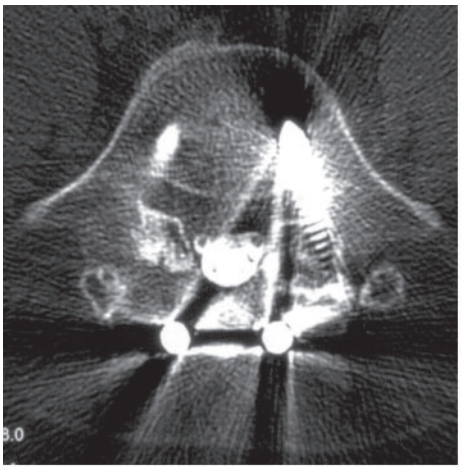
The modality and protocol used to image the postoperative spine depend on the site, the clinical question, and the type of instrumentation. There is currently no reference standard for noninvasive imaging evaluation of fusion (3).

Radiographic Evaluation

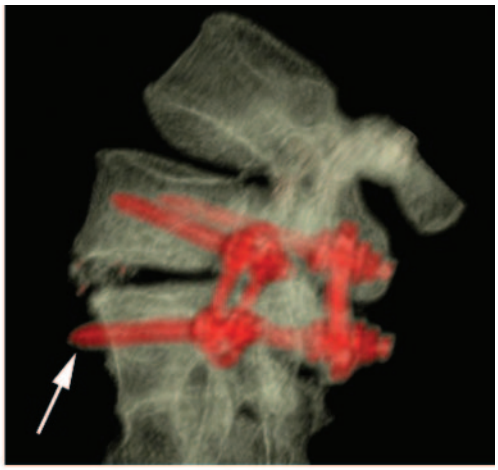
Radiography is the noninvasive modality most commonly used for the assessment of fusion, although CT is reported to be more accurate (4). Radiography also is useful for the investigation of spinal instrumentation when breakage or incorrect placement is suspected (5). However, radiography cannot be used to reliably exclude the presence of metastases to bone or of cauda equina compression, both of which are common indications for postoperative MR imaging of the lumbar spine. In the evaluation of patients after lumbar spine instrumentation, it is particularly important to compare the current radiographs not only with the most recent previous images but also with multiple previous studies so as to identify subtle progressive changes (eg, in spinal alignment and in the position of the hardware devices) that may signify the imminent failure of a device or other complications. Flexion and extension views have been advocated for the routine assessment of fusion (6,7), but there is no clinical consensus regarding their value for that purpose (8), and they are not in routine use at our institution.

Evaluation with CT

CT is the modality of choice for imaging bony detail in the spine to enable accurate assessment of the degree of osseous fusion; however, surgical exploration remains the reference standard for evaluating fusion. The quality of CT images may be severely degraded by starburst-type artifacts due to metallic implants, which cause marked x-ray attenuation ("hollow projections") in selected planes. Titanium has a lower x-ray attenuation coefficient than stainless steel and therefore causes a less severe artifact (9). The starburst-type artifact seen on CT images, unlike that on MR images, is not restricted to the area immediately adjacent to the metallic implant (Fig 1). Patient movement often exacerbates such artifacts, although it is less commonly a problem since the introduction of high-speed multidetector CT technology. Imaging and reconstruction algorithms may help minimize starburst-type artifacts (10,11). For example, multiplanar reformation often results in higher-quality images that are more useful clinically than axial images alone (9) (Fig 2).



1.



2.

Figures 1, 2. **(1)** Axial CT myelogram shows an extensive streak artifact caused by a metallic device implanted in the lumbar spine. **(2)** Volume-rendered three-dimensional reformatted CT image shows the position of pedicle screws and plates at the level of the L5 through S1 vertebrae. The tip of one screw has breached the anterior sacral cortex (arrow). Bone graft material also can be seen anteriorly in the L5-S1 disk space. Reformatted CT images often allow a better and more complete three-dimensional evaluation of spinal instrumentation.

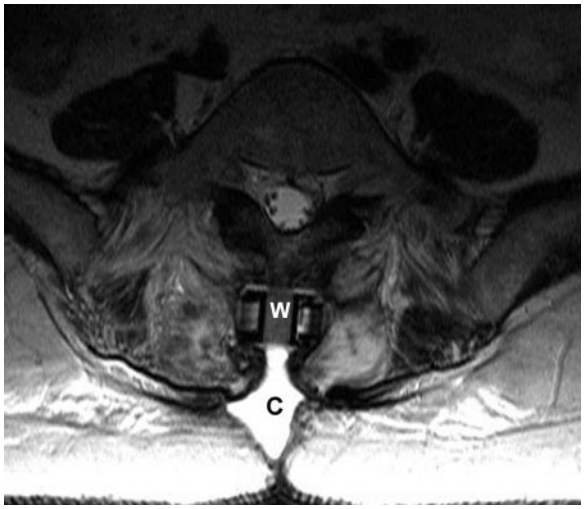
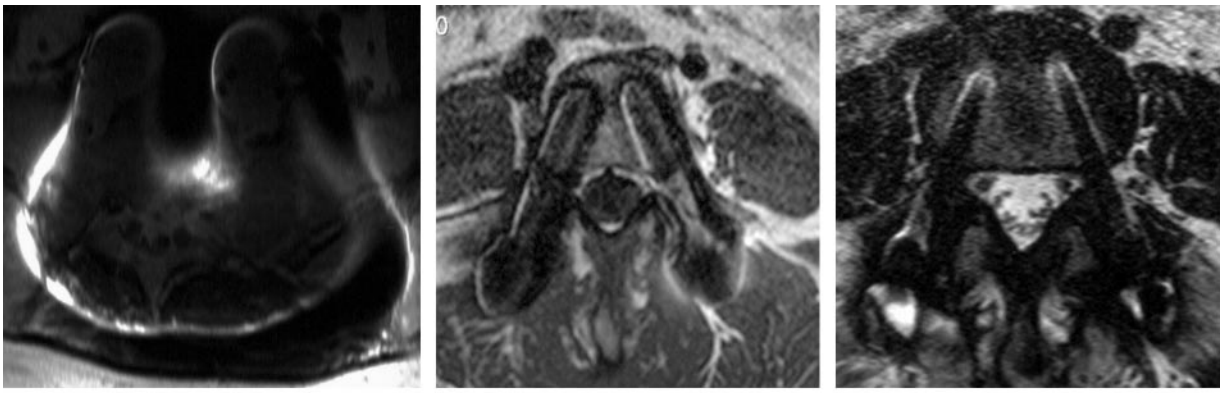


Figure 3. Axial T2-weighted MR image clearly demonstrates a simple postoperative fluid collection *(C)* located anterior to a Wallis ligament *(W)* dynamic stabilization device.

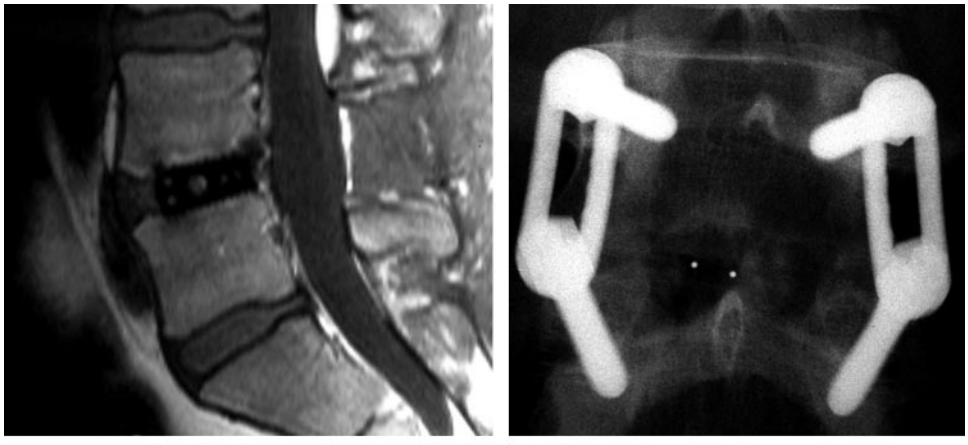
MR Imaging

MR imaging is useful for evaluating sequential postoperative changes in the spine and better demonstrates intraspinal contents than do other imaging modalities. It is particularly useful for detecting and monitoring infection or postoperative collections (Fig 3). However, magnetic susceptibility artifact may be a problem, particularly in the presence of stainless steel devices (Fig 4a). Modern implants made of titanium alloys are less ferromagnetic and thus produce less severe magnetic susceptibility artifacts, but these artifacts remain a significant obstacle to visualization of areas in close proximity to metallic hardware (12) (Fig 4b). Sequences have been developed to reduce the artifacts (13), but their use may necessitate increased image acquisition time and may result in image distortion. Gradient-echo sequences are more vulnerable to magnetic susceptibility artifact than are spin-echo (SE) sequences (14) and are best avoided. Reduction of the echo time may lead to an increase in the signal-to-noise ratio while minimizing artifact. Increasing the bandwidth also helps significantly reduce the artifact magnitude with SE and turbo SE sequences, although this method also leads to a decrease in the signal-to-noise ratio. At our institution, a protocol that includes a three-dimensional T2-weighted turbo SE sequence has been developed to reduce magnetic susceptibility artifact in the presence of



a. b. c.

Figure 4. Axial MR images show susceptibility artifacts of varying severity. **(a)** Stainless steel pedicle screws cause a significant susceptibility artifact that completely degrades the diagnostic quality of the image. **(b)** Titanium alloy pedicle screws cause a much less severe artifact than that in **a**. **(c)** The severity of the susceptibility artifact from the titanium screws in **b** is further reduced on an image obtained with a T2-weighted turbo SE sequence.



a. b.

Figure 5. **(a)** Sagittal T1-weighted MR image shows a nonmetallic cage that is situated posteriorly within the disk space and slightly wedged to enhance lumbar lordosis. **(b)** Radiograph shows the linear outline of the radiolucent cage, which has become more visible as the adjacent bone graft has consolidated around it.

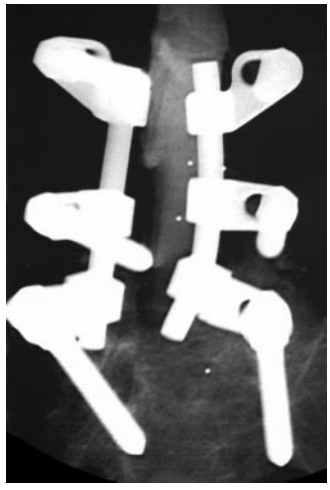


Figure 6. Fluoroscopic myelogram obtained in a patient with a lumbar spinal fusion device consisting of stainless steel rods and screws (Isola; DePuy-AcroMed, Cleveland, Ohio).

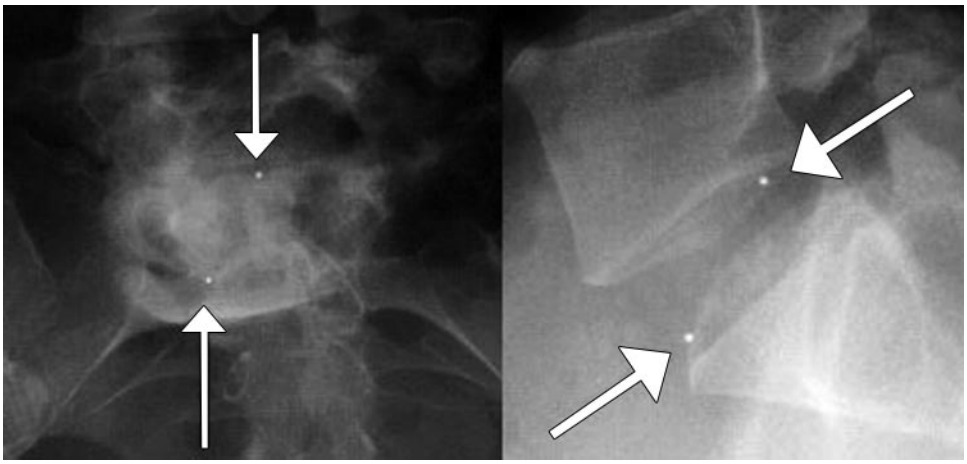


Figure 7. Anteroposterior (left) and lateral (right) radiographs show the metallic markers (arrows) used to enable a radiographic assessment of the position of intervertebral ramps. One marker is positioned at the lower right anterior aspect of the ramp, and the other is positioned at the upper left posterior aspect of the ramp. Note the spondylolysis depicted in the lateral view. Posterior instrumentation was subsequently performed in this case.

titanium implants (Bryant JA, MSc thesis, 2004) (Fig 4c). Nonmetallic devices, such as nonmetallic interbody spacers, are MR compatible and produce little artifact (Fig 5a).

Ultrasonography

The usefulness of ultrasonography for evaluation of the lumbar spine is largely restricted to the identification of postoperative fluid collections.

Nuclear Medicine

Bone scintigraphy may be performed to assess fusion (the fused segment should be "cold" after 6–12 months) (15). It also is useful for detecting infection.

Myelography

If MR imaging is contraindicated or MR images are nondiagnostic because of artifact, myelography may be performed (Fig 6). However, after instrumentation of the lumbar spine, puncture of the lumbar thecal sac may be complicated by distortion of the anatomy (eg, scarring, removal of posterior elements, addition of bone graft material) or the presence of metallic implants. Occasionally in this situation a cervical puncture is necessary. Following the injection of contrast material into the thecal sac, radiographs may be acquired at an angle to avoid obscuration of the relevant nerve roots by the implanted devices. Conventional myelography is usually supplemented with CT myelography.

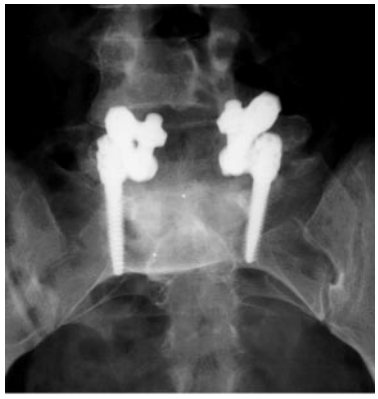
Lumbar Spinal Fusion and Instrumentation

Rigid internal fixation (spinal instrumentation) is necessary to promote bone fusion, which occurs within 4–5 months after spinal fusion surgery, and to prevent pseudarthrosis (3). Lumbar spinal fusion involves the insertion of bone graft material with or without one or more interbody spacers and other devices to provide additional support and stability. Spinal fusion surgery is commonly performed in patients who require decompression for nerve root pain and whose symptoms are largely diskogenic.

Teaching Point

Instrumentation Used in Fusion

Interbody Spacers.—Interbody spacers are made of titanium or a radiolucent material such as polyetheretherketone. They may be solid constructions (ramps) or openwork structures filled with bone graft material (cages) and may be used singly or paired (positioned side by side). On postoperative radiographs, the outlines of radiolucent cages become increasingly apparent as the adjacent bone graft consolidates over time (Fig 5). Most spacers contain two radiopaque markers to enable radiographic assessment of the spacer position (Fig 7). An observation of a posterior



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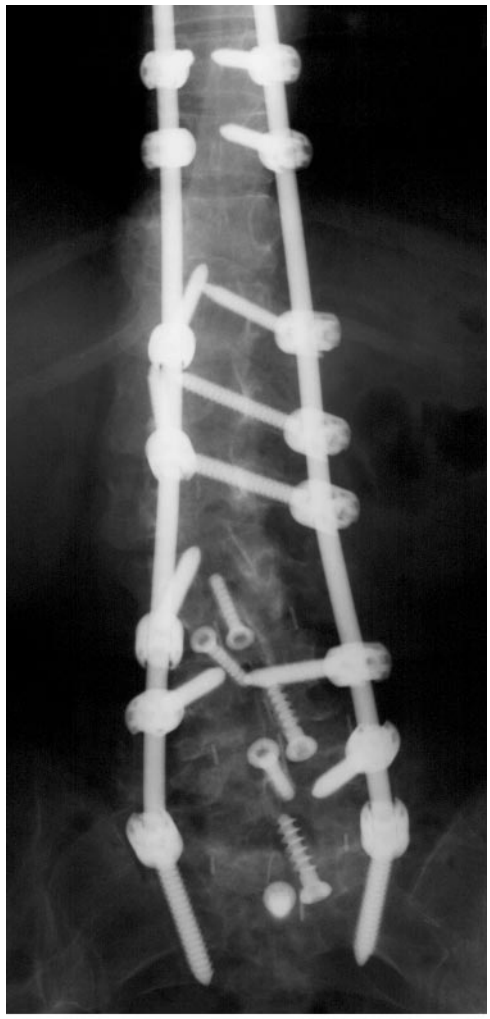


9.

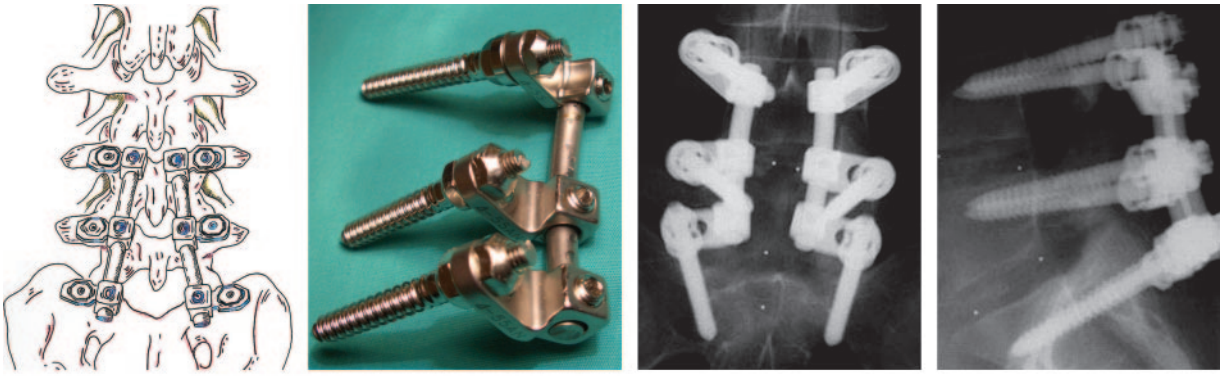
Figures 8, 9. **(8)** Anteroposterior radiograph shows single-level instrumentation (L5 through S1 vertebrae) with a device made of rods and screws. **(9)** Anteroposterior radiograph shows a rod and screw device that spans multiple levels.

marker located at least 2 mm anterior to the posterior vertebral body margin provides reassurance that the ramp is not protruding into the spinal canal.

Plates or Rods with Pedicle Screws.—In these devices, pedicle screws are connected by plates or rods that span single (Fig 8) or multiple (Fig 9) vertebral segments. Crossbars may be added for additional strength. For multilevel fusion, rods (Fig 10) are generally preferred over plates (Fig 11) because rods can be individually cut and molded as required to facilitate maintenance of sagittal alignment. The tips of pedicle screws should be embedded in the vertebral bone and should not breach the anterior vertebral body cortex, but there is no consensus on their optimal length. Sacral screws may be anchored in the anterior cortex of the sacrum for additional stability.

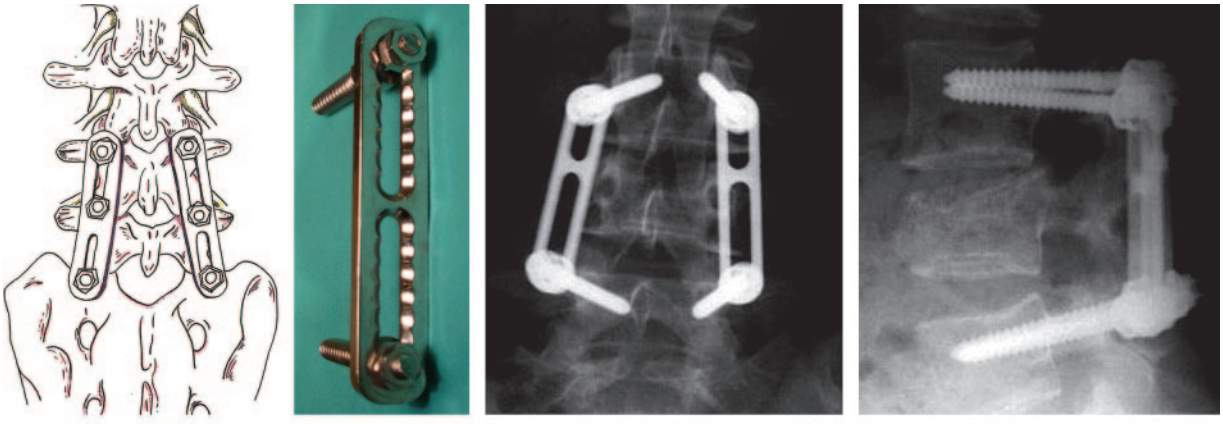
Translaminar or Facet Screws.—Translaminar or facet screws provide an alternative form of posterior instrumentation when the posterior spinal elements are left intact. The screws may be inserted by using a minimally invasive approach and oriented at different angles to avoid impingement on other screws.

Hartshill Rectangles.—Hartshill rectangles are a fixation device that consists of stainless steel rectangles held in place posteriorly by sublaminar wires (Fig 12). Because the wires (particularly those at the superior end of the rectangle) contribute to the structural integrity of the device, a wire fracture is considered a significant finding. This device was used before the advent of pedicle screws but is seldom used now.



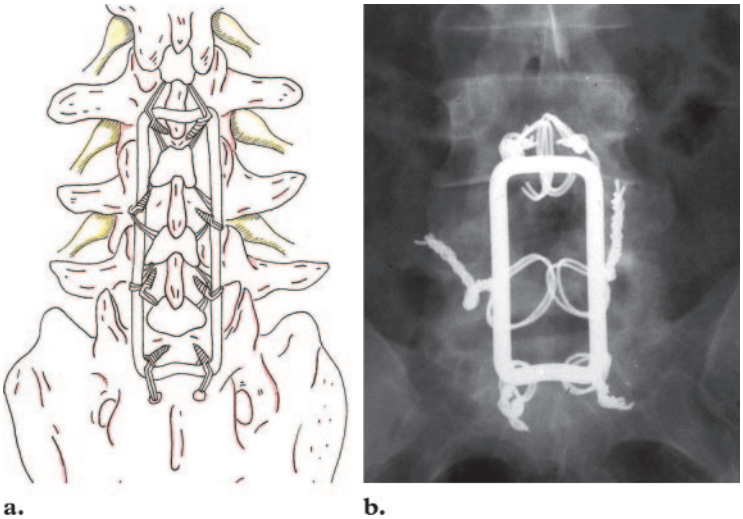
a. b. c. d.

Figure 10. Rod and screw device. **(a)** Diagram shows spinal fusion with a typical rod and screw device spanning the L4 through S1 vertebrae. **(b)** Photograph shows a metallic rod and screw device (Isola). **(c, d)** Anteroposterior **(c)** and lateral **(d)** radiographs show the same device as in **b** after positioning at the L4 through S1 vertebral levels. Radiopaque markers that delineate the anterior and posterior aspects of spacers in the L4-L5 and L5-S1 disk spaces also are visible.



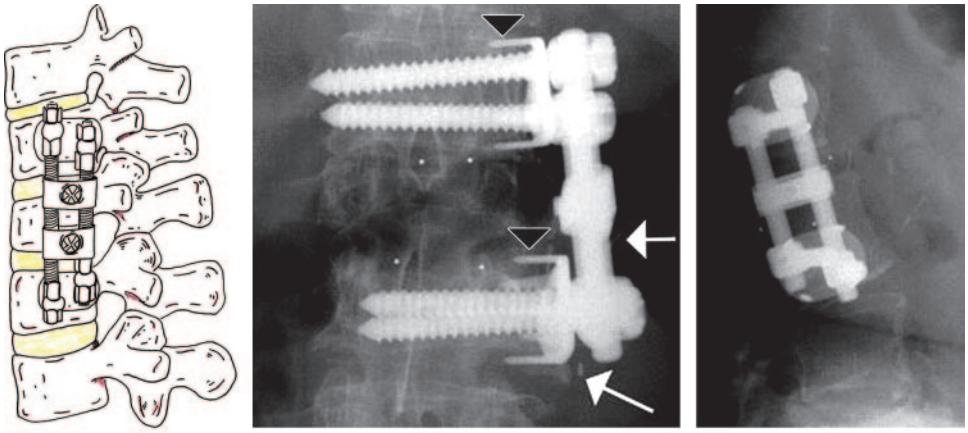
a. b. c. d.

Figure 11. Plate and screw device. **(a)** Diagram shows spinal fusion with a typical plate and screw device spanning the L4 through S1 vertebrae. **(b)** Photograph shows a Steffee interbody fusion device, which consists of a metallic plate and pedicle screws. **(c, d)** Anteroposterior **(c)** and lateral **(d)** radiographs depict spinal fusion with the plate and screw construct shown in **b** at the L3 through L5 vertebral levels. In **d**, a burst fracture is visible in the L4 vertebra with retropulsion of a vertebral fragment.



a. b.

Figure 12. **(a)** Diagram shows lumbar spinal fusion with a Hartshill rectangle. **(b)** Anteroposterior radiograph shows a Hartshill rectangle secured in position posteriorly by sublaminar wires.



a. b. c.

Figure 13. **(a)** Diagram shows the Kaneda device, which consists of two threaded rods secured by orthopedic staples and vertebral body screws. The device is inserted by using an anterior approach. **(b)** Anteroposterior radiograph shows the staples (arrowheads), which reinforce the purchase of the screws in the vertebrae, resulting in very firm fixation. Surgical clips (arrows) on segmental vessels should not be confused with the metallic markers within spacers. **(c)** Lateral radiograph shows the same device as in **b**.

Posterior Surgical Approaches

A posterior approach is used when posterior decompression is required in addition to fusion.

Posterior Lumbar Interbody Fusion.—The posterior lumbar interbody fusion procedure is performed by using a posterior surgical approach. Bilateral partial laminectomies are performed (caudad and cephalad) and are followed by diskectomy. Bone graft material is packed into the anterior disk space before the insertion of an interbody spacer or two interbody spacers placed side by side and packed with graft material. Further bone graft material is then packed into the remainder of the disk space. Posterior instrumentation is performed to provide a rigid support until bone fusion occurs.

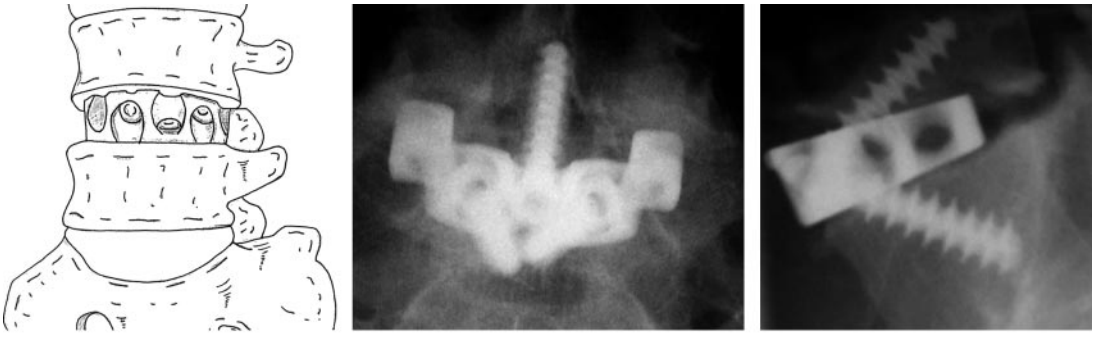
Transforaminal Lumbar Interbody Fusion.—This procedure is similar to the posterior one but is performed by using a more lateral approach that leaves the midline bone structures intact, minimizes central spinal canal disruption, and reduces dural tube traction and exposure. A total facetectomy is generally performed to gain access to the lateral disk space. Transforaminal interbody spacers are crescent shaped and are placed anteriorly in the disk space.

Posterolateral Fusion.—This procedure is performed as an alternative to posterior lumbar interbody fusion when there is a severe loss of disk space height and when the insertion of a posterior interbody spacer might cause neurologic compromise. Bone graft material is placed laterally (between transverse processes) rather than anteriorly (between vertebral bodies). Posterolateral fusion is usually supplemented by posterior instrumentation.

Anterior Surgical Approaches

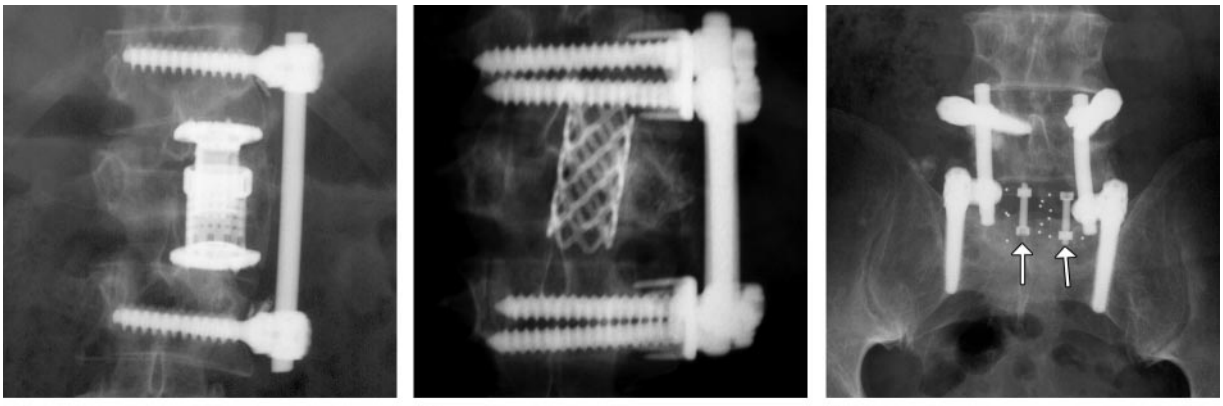
Fusion is performed by using an anterior approach when pain is predominantly diskogenic and posterior decompression is not required.

Anterior Lumbar Interbody Fusion.—Like the posterior and transforaminal lumbar interbody fusion techniques, the anterior fusion procedure is performed to remove degenerate disk material, replace disk height, and give immediate stability for anterior osseous fusion. However, anterior lumbar interbody fusion is performed by using a lower abdominal incision or retroperitoneal approach through the flank. The spacers used in anterior fusion are single, large cages. These are supplemented by screws and rods or plates, which may be placed either anteriorly or posteriorly, depending on access. At the level of the L5 through S1 vertebrae and sometimes that of the L4 through L5 vertebrae, anterior fusion must be supplemented by instrumentation with a posterior approach because the iliac crests limit lateral access. Several rod and screw devices, such as the Kaneda device (DePuy Spine, Raynham, Mass), are specifically designed for insertion with an anterior approach (Fig 13).



a. b. c.

Figure 14. **(a)** Diagram shows a stand-alone lumbar interbody fusion cage. **(b, c)** Anteroposterior **(b)** and lateral **(c)** radiographs show the screws that fix the cage to the adjacent vertebrae.



15. 16. 17.

Figures 15–17. **(15)** Anteroposterior radiograph shows an expandable metallic cage (Synex) placed in the L1 vertebral body after a burst fracture. Such cages may be tilted or positioned noncentrally within the vertebral body, depending on the individual case. Lateral instrumentation was performed with rods and screws for stability. **(16)** Anteroposterior radiograph shows a Moss cage placed in the L1 vertebra for management of a burst fracture, and a Kaneda device positioned for additional stability. **(17)** Anteroposterior radiograph shows stackable carbon fiber–reinforced cages held together by metallic rods (arrows). Radiopaque dots mark the positions of individual cages.

Stand-Alone Lumbar Interbody Fusion.— This procedure is similar to the others, but the cage is fixed with screws to the adjacent vertebral bodies to obviate further posterior instrumentation (Fig 14).

Vertebral Body Replacement

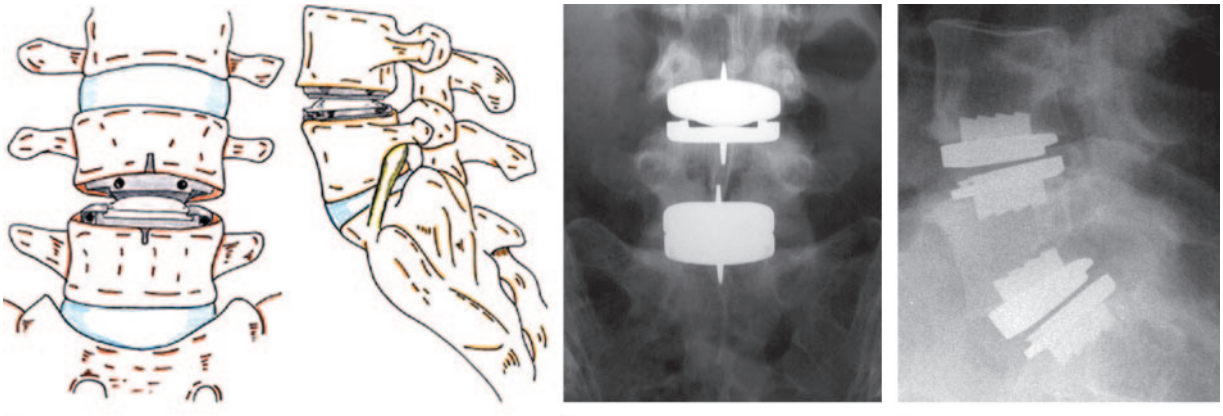
Teaching Point

A vertebral body replacement may be necessary after a resection (corpectomy) because of a tumor, infection, or major trauma. The vertebral body replacement device may be an expandable hollow cylinder packed with bone graft material or cement, like the Synex cage (Synthes Spine, Paoli, Pa) (Fig 15), or made of mesh, like the Moss cage (DePuy-AcroMed) (Fig 16). Vertebral body replacement may involve one or more segments. Stackable carbon-fiber-reinforced polymer cages are radiolucent, but the metallic rods that hold them together mark their position, as do radiopaque metallic dots (Fig 17). Lateral, anterior, or posterior screws with plates or rods are inserted for additional stability.

Disk Replacement

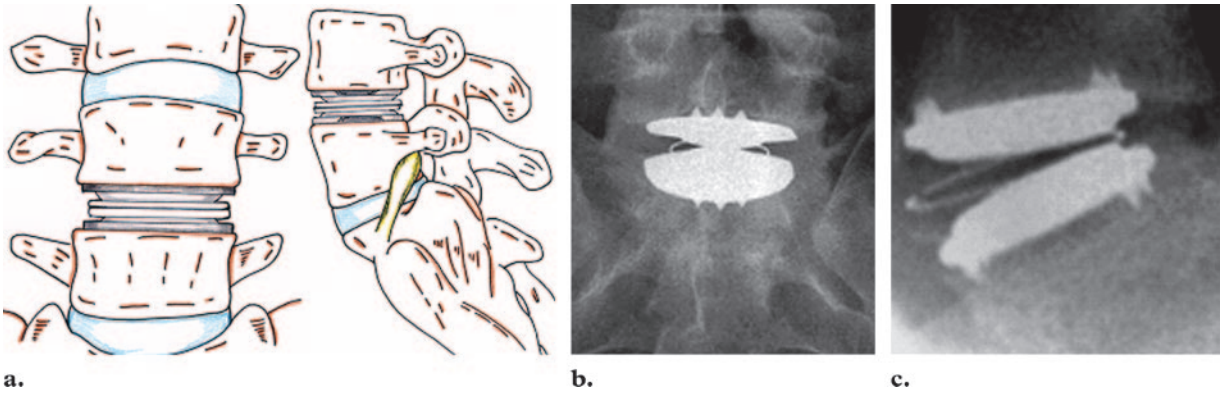
Teaching Point

Total disk replacement is performed in patients whose pain is believed to originate primarily from disk degeneration without nerve root involvement, rather than from spinal stenosis or spondylolisthesis. The presence of facet joint degeneration is a contraindication to total disk replacement. There must be at least 4 mm of residual disk height and a lack of significant endplate degeneration to provide satisfactory anchorage for the replacement device. The goal of disk replacement is to avoid arthrodesis-related complications of pseudarthrosis, iliac crest donor site pain, and degeneration of the adjacent segment. The technique is still evolving. The first human disk prosthesis, which consisted of a single ball bearing, was inserted in the late 1950s (16). Modern artificial disks consist of two parallel plates (usually



a. b. c.

Figure 18. Total disk replacement with the ProDisc device (Spine Solutions, New York, NY). **(a)** Diagrams show correct anteroposterior (left) and lateral (right) positioning of the disk replacement device. **(b, c)** Anteroposterior **(b)** and lateral **(c)** radiographs show two disk replacement devices in the correct position: The endplates appear to be parallel in **b**, and the devices are well contained within the intervertebral disk spaces in **c**.



a. b. c.

Figure 19. Total disk replacement with the SB Charité device (Waldemar Link, Hamburg, Germany). **(a)** Diagrams show correct anteroposterior (left) and lateral (right) positioning of the replacement disk device. **(b, c)** Anteroposterior **(b)** and lateral **(c)** radiographs show the device in the lumbar spine. Note the three anterior and three posterior teeth that anchor each (superior and inferior) half of the device to the adjacent vertebrae. A metallic ring within the device helps identify its location and evaluate positioning.

made of a metal alloy) with exterior toothlike projections that are designed to anchor the device securely to the adjacent vertebrae (17). A polyethylene core between the plates allows motion and provides cushioning (Figs 18, 19).

Dynamic Stabilization

Teaching Point

Dynamic stabilization may be an alternative to fusion in some patients with low back pain originating from chronic degeneration of the lumbar spine. By altering load bearing and controlling abnormal motion, stabilization helps limit the stress placed on the segment adjacent to the level of fusion and thus helps prevent progressive degeneration.

A wide variety of dynamic stabilization devices are in various stages of clinical development (Table). These devices may be used alone for stabilization or used in combination with fusion devices. Dynamic stabilization devices may be broadly grouped, according to their design, in the following categories: *(a)* pedicle screws and artificial ligaments (eg, Dynesys device [Fig 20], Graf

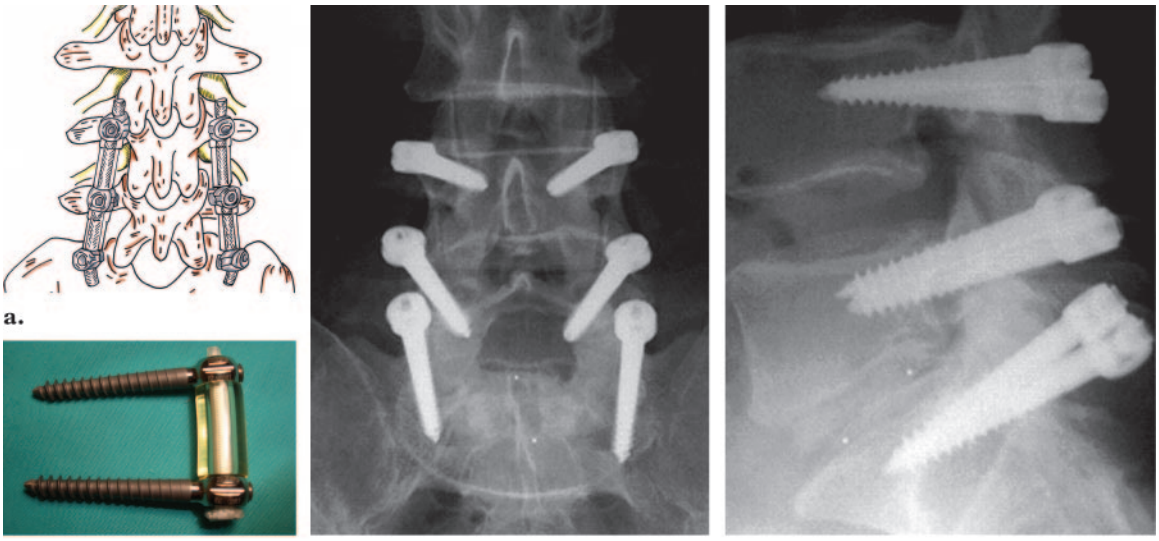


Figure 20. Dynesys semirigid artificial ligament system. **(a)** Diagram shows correct positioning of the device in the lumbar spine. **(b)** Photograph shows the device, which consists of two titanium alloy pedicle screws connected by a cylindrical polycarbonaturethane spacer through which a polyester cord (the artificial ligament) is strung. **(c, d)** Anteroposterior **(c)** and lateral **(d)** radiographs show the device positioned correctly in the lumbar spine. To avoid interfering with facet joint function, the screws are positioned more laterally than are normal pedicle screws. In this case, fusion of the segment at L5 through S1 was performed (note the presence of a spacer at this level) and the Dynesys system was used for dynamic stabilization of the L4 through L5 segment.

Dynamic Stabilization Devices

Category and Trade Name	Key Features
Pedicle screws and artificial ligaments	
Dynesys (Dynamic Neutralization System for the Spine); Zimmer Spine, Warsaw, Ind (18)	Semirigid artificial ligament system composed of titanium alloy pedicle screws and polycarbonaturethane spacers connected by polyester cords (artificial ligaments) that are placed under tension
Graf ligament; Surgicraft, Redditch, England (19)	Nonelastic polyester ligament looped around pedicle screws and placed under tension to prevent rotation while allowing some flexion; if tension is too high, hyperlordosis, foraminal narrowing, and nerve root impingement may result
IsoBar; Scient'x USA, Maitland, Fla	Includes a mobile joint within metal rods
M-Brace; Applied Spine Technologies, New Haven, Conn	Implanted by using a minimally invasive technique
Stabilimax NZ; Applied Spine Technologies	Utilizes a dual spring mechanism
Dynamic Soft Stabilization System (20)	Elliptical metal coil connecting adjacent pedicle screws
Inter–spinous process decompression systems	
Wallis ligament; Abbott Spine, Austin, Tex (21)	Inter–spinous process distraction device composed of a spacer held between spinous processes with Dacron tape
X STOP; St Francis Medical Technologies, Concord, NH (22)	Titanium device in two pieces, placed between adjacent spinous processes to hold spine in flexion; can be inserted by using a minimally invasive approach with a local anesthetic and is thus useful in elderly patients with degenerative spinal stenosis
Diam; Medtronic Sofamor Danek, Memphis, Tenn	H-shaped silicone device held in place by a mesh band and suture
Coflex; Paradigm Spine, New York, NY	U-shaped device that controls flexion and extension
Posterior element replacement systems	
Total Facet Arthroplasty System; Archus Orthopedics, Redmond, Wash	Consists of a sphere that slides along a curved plate anchored by pegs passing into the vertebral body
Total Posterior System; Impliant, Princeton, NJ	Posterior elements are removed and a plastic device is implanted and anchored with devices similar to pedicle screws

Note.—Some of the devices listed may not yet have been approved by the FDA for clinical use.

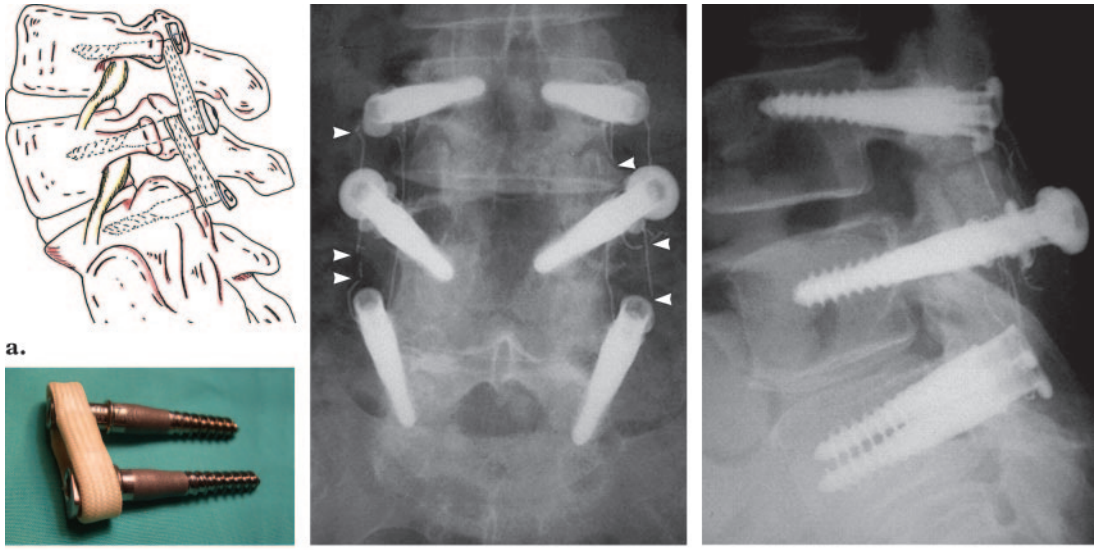


Figure 21. Graf artificial ligament system. **(a)** Diagram provides a lateral view of correct positioning of the device in the lumbar spine. **(b)** Photograph shows the device, which consists of two metallic pedicle screws around which a polyester band is looped. **(c, d)** Anteroposterior **(c)** and lateral **(d)** radiographs show the use of Graf artificial ligaments for dynamic stabilization at two levels (L3 through L4 vertebrae and L4 through L5 vertebrae). The fracture of wire markers within the polyester bands (arrowheads in **c**) is often mistaken for band failure but is actually of no consequence.

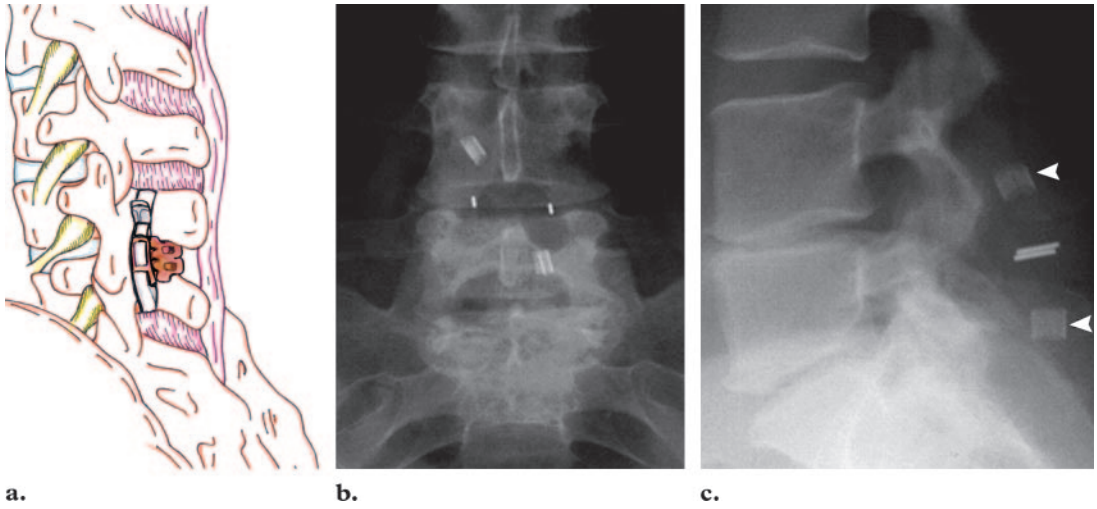


Figure 22. Wallis stabilization system. **(a)** Diagram provides a lateral view of the correct positioning of the device in the lumbar spine. **(b, c)** Anteroposterior **(b)** and lateral **(c)** radiographs show the device positioned at the level of the L4 through L5 vertebral processes. Radiopaque markers within an interbody spacer in the L4–5 disk space also are visible in **b**. The spacer is anchored in position by tape, which is wrapped around the adjacent spinous processes and is under tension. Metal bands (arrowheads in **c**) help secure the tape.

ligament [Fig 21]), *(b)* inter–spinous process decompression devices (eg, Wallis system [Figs 3, 22], X STOP), and *(c)* posterior element replacement systems. Inter–spinous process devices cannot be used at the level of L5 through S1 because of the lack of a distal anchorage point.

Conclusions

Various fixation devices may be implanted during lumbar spine fusion procedures to prevent segmental motion while bone fusion occurs; total disk replacement may be performed as an alternative to fusion in certain situations; and dynamic stabilization devices may be implanted to provide stability while allowing limited movement. An understanding of the types of devices used in these different procedures is necessary, as is a familiarity with normal postoperative appearances, if complications are to be recognized at imaging. In addition, knowledge about the type of device and the constituent materials facilitates the choice of an appropriate modality for imaging of the postoperative spine.

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RadioGraphics

Lumbar Spine Fusion and Stabilization: Hardware, Techniques, and Imaging Appearances

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Page 1738
The instrumentation used in fusion surgery is not designed to replace the bony elements of the spine, but to stabilize them during fusion, and it is generally accepted that instrumentation without intact osseous fusion will fail.

Page 1741
Lumbar spinal fusion involves the insertion of bone graft material with or without one or more interbody spacers and other devices to provide additional support and stability.

Page 1745
A vertebral body replacement may be necessary after a resection (corpectomy) because of a tumor, infection, or major trauma.

Page 1745
Total disk replacement is performed in patients whose pain is believed to originate primarily from disk degeneration without nerve root involvement, rather than from spinal stenosis or spondylolisthesis.

Page 1746
Dynamic stabilization may be an alternative to fusion in some patients with low back pain originating from chronic degeneration of the lumbar spine. By altering load bearing and controlling abnormal motion, stabilization helps limit the stress placed on the segment adjacent to the level of fusion and thus helps prevent progressive degeneration.