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Cervical Spine Fusion Using Dynamic Ventral Cervical Plating

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SUMMARY OF KEY POINTS

- Stress shielding refers to implant-induced reduction of bone healing.
- Wolff's law states that bone heals optimally under compressive forces.
- Rigid plates may stress-shield bone graft and result in pseudarthrosis.
- Dynamic implants allow for load sharing and can be classified into rotational and translational types of plates.
- Clinical outcomes and fusion rates are generally comparable between dynamic cervical plates and constrained and semiconstrained plates.

The benefits of rigid implants (i.e., internal fixation) in the axial skeleton include rigid stabilization, maintenance of alignment, minimal postoperative immobilization, earlier return to function, and potentially enhanced fusion rates.[1] A potential shortcoming of rigid implants is that they may stress-shield the bone graft and result in nonunion, implant failure, or both. *Stress shielding* refers to an implant-induced reduction of bone healing–enhancing stresses and loads, resulting in stress reduction osteoporosis or nonunion (Fig. 63-1). This hypothesis is in keeping with Wolff's law, which postulates that the form and function of bone is a result of changes in the internal architecture according to "self-ordered" mathematical rules.[2] In contemporary terms, skeletal morphology is substantially controlled by mechanical function, and bone remodeling, both locally and throughout the skeleton, is influenced by the level and distribution of the functional strains within the bone.[3,4] A corollary to Wolff's law is that bone heals optimally under compressive, as opposed to tensile, forces. Experimental studies in the thoracolumbar spine show that a 70% or greater axial load should be transmitted through the spine, not the implant, optimally to enhance arthrodesis and provide acute stability.[5]

In an attempt to improve on the shortcomings of rigid implants, there has been a resurgence of interest in dynamic implants, particularly for use in the cervical spine. The concept of dynamic implants is not new. Dynamic hip arthroplasties have been employed successfully for femoral neck fractures. These dynamic implants allow for the femoral neck to shorten or collapse along its axis so that the bone is subject to optimal bone-healing compressive forces.[6] Advocates of dynamic implants hypothesize that implants that permit a limited and controlled type of deformation may be desirable. Some experts have termed this *controlled dynamism*. In the spine, allowing for some axial deformation but not angular deformation (kyphosis) may be optimal. Occasionally, the failure of a rigid implant may permit fusion because the bone graft and vertebral bodies are subsequently exposed to the appropriate bone healing–enhancing forces. In this case, the implant has "dynamized by failing" (Fig. 63-2).

The first ventral cervical plate and screw system was introduced by Bohler[7] in 1964. This system ultimately culminated in the development of the Caspar (Aesculap, Center Valley, PA) and Orozco (Synthes, West Chester, PA) plate systems in the early 1980s. These early ventral cervical plates were dynamic implants and are classified as having unrestricted backout properties (i.e., nonlocking and nonrigid) because of a lack of fixation at the screw-plate interface. These implants permit a significant transfer of load through the bone graft, increasing the likelihood of fusion. The nonfixed moment arm nature of the screw caused degradation of the screw-bone interface with cyclic loading. This effect can be minimized with bicortical screw purchase, which requires C-arm fluoroscopy. The main disadvantage of these plates is that the nonlocking and nonrigid (i.e., variable angle) screws led to high rates of screw backout and screw breakage with graft subsidence (Fig. 63-3).

The next generation of ventral cervical plates included the CSLP (DePuy Synthes, Raynham, MA) and Orion (Medtronic Memphis, TN). The CSLP was developed by Morscher in Europe in the early 1980s and introduced in the United States in the early 1990s. The major advantage of this generation of devices is that they do not require bicortical screw purchase. The CSLP uses a titanium expansion screw that rigidly secures the screw to the plate, greatly reducing the incidence of screw backout. In contrast to the Caspar plate where screw angulation could be varied, the CSLP has a predetermined (rigid) screw trajectory, which is perpendicular at the caudal end and 12 degrees rostrally. It has been suggested that these types of restricted, constrained plate-screw configurations are preferable in trauma cases, in which immediate stability is desired; however, this concept remains unproved.

One concern with rigid plates such as the CSLP and Orion is that they were thought to stress-shield the bone graft by reducing the compressive forces that the bone graft experiences and result in increased rates of nonunion (pseudarthrosis).[8] This concern led to interest in the design of dynamic implants. These newer-generation dynamic implants improved on the Caspar plate design by preventing screw backout while allowing for some movement at the plate-screw interface. This dynamism allowed for compressive forces to be shared between the implant and the bone graft—so-called load sharing. Dynamic cervical plates can be classified into rotational or translational, depending on the type of movement that is permitted at the plate-screw interface. The translational dynamic plates also can be subdivided further into internally and externally dynamized plates.

ROTATIONAL TOGGLE DYNAMIC PLATES

The original Codman plate system, now called Skyline (Depuy, Johnson & Johnson, Raynham, MA), uses screws that "toggle"

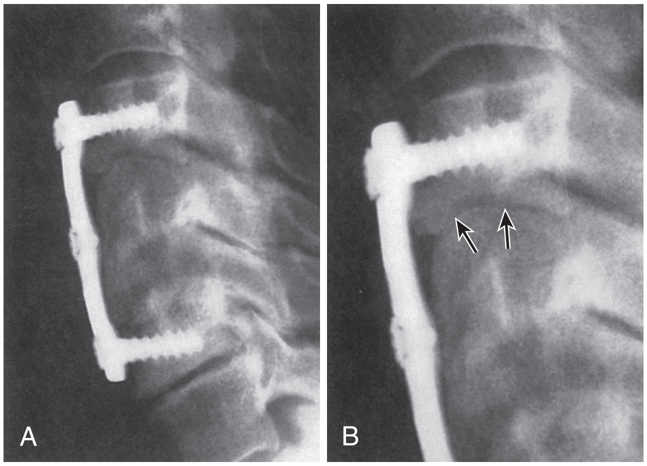

Figure 63-1. A ventral rigid cervical implant caused stress shielding. This resulted in nonunion (pseudarthrosis) in a patient with preexisting osteoporosis, as depicted. *Arrows* indicate the location of the nonunion (pseudarthrosis). **A,** Lateral radiograph; **B,** close-up. *(From Benzel EC:* Biomechanics of spine stabilization, *Rolling Meadows, IL, 2001, American Association of Neurological Surgeons.)*

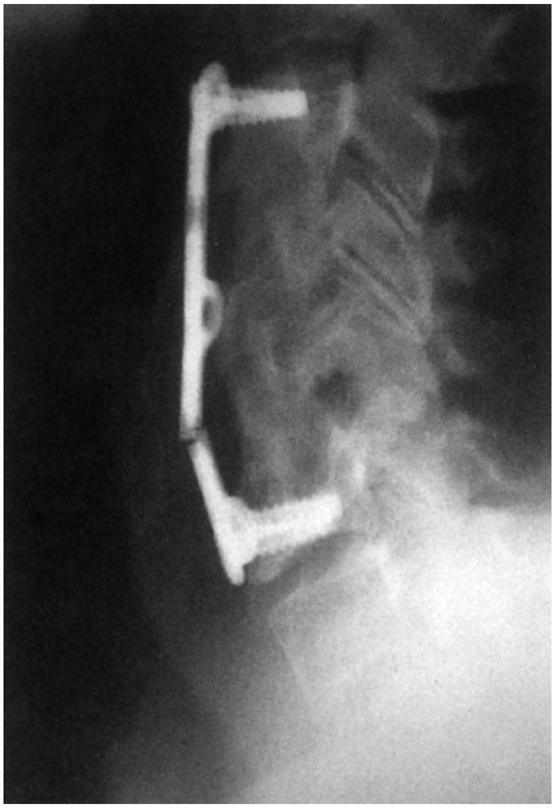

Figure 63-2. Failure of an implant (by fracture) may allow fusion to occur. In a sense this implant, dynamized by failure, as depicted, allows the bone graft to see bone healing–enhancing compression forces. *(From Benzel EC:* Biomechanics of spine stabilization, *Rolling Meadows, IL, 2001, American Association of Neurological Surgeons.)*

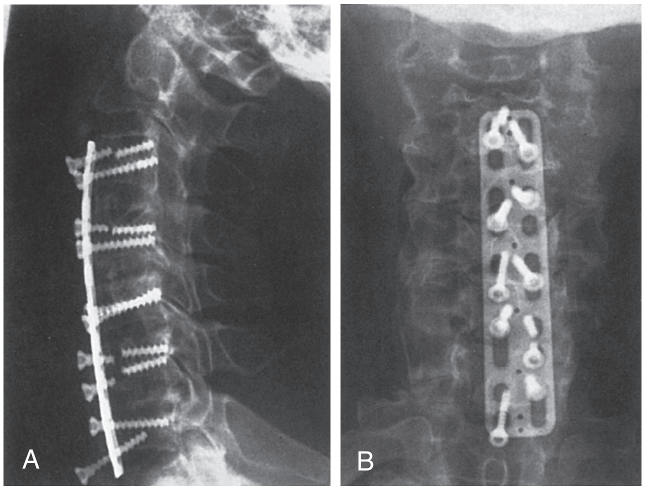

Figure 63-3. Screws may fracture as a result of excessive stresses placed on them by the subsiding spine, as depicted. **A,** Anteroposterior radiograph. **B,** Lateral radiograph. The screws positioned in holes fractured; they could not axially subside. The screws positioned in slots maintained fixation while dynamizing, permitting, and encouraging fusion. *(From Benzel EC:* Biomechanics of spine stabilization, *Rolling Meadows, IL, 2001, American Association of Neurological Surgeons.)*

at the screw-plate interface, increasing the load on the graft and allowing for controlled subsidence. As with the Caspar plate, variable screw trajectories can be used; however, a built-in cam-locking mechanism restricts the screws from backout.[9,10] The Atlantis cervical plating system (Medtronic, Memphis, TN) features a floating washer design that prevents screw backout. The Atlantis plate incorporates the most beneficial aspects of several types of cervical plate design. It uses either a variable (i.e., nonfixed) angle cantilever screw or a fixed-angle cantilever screw (Fig. 63-4). As a result of this flexibility, one can create a rigid construct (similar to the CSLP or Orion), a pivot rotational construct (similar to the Codman plate), or a hybrid construct with both fixed and rigid qualities. The fixed-angle screws using the Atlantis system are directed 12 degrees rostrally, caudally, or both and 6 degrees medially. The hybrid Atlantis construct, with fixed-angle screws inferiorly and variable angle screws superiorly, may have the advantage of allowing for "controlled subsidence," as the rostral screws are allowed to pivot, whereas the caudal screws remain fixed. In this way, the graft is subjected to compressive forces as the construct settles.

Translational dynamic plates are believed to have some biomechanical advantages over rotational or screw toggle dynamic plates. Translational dynamic plates have shown decreased pseudarthrosis and revision surgery rates compared with screw toggle (fixed hole) dynamic plates.[11]

TRANSLATIONAL EXTERNALLY DYNAMIZED PLATES

The DOC (Depuy Synthes, Raynham, MA, Johnson & Johnson) cervical system represents an axial subsidence type of dynamic implant. The screws on the DOC system are not designed to pivot but instead translate, or "slide," along a rail. The screws are rigid at the caudal end, and all cephalad screws have the potential to slide along the rail. This design provides axial subsidence and load sharing with the graft while minimizing angular subsidence (kyphosis). This configuration minimizes degradation of the bone-screw interface compared with a device in which screws toggle. This system also has been shown to be useful for ventral correction of postsurgical cervical kyphosis.

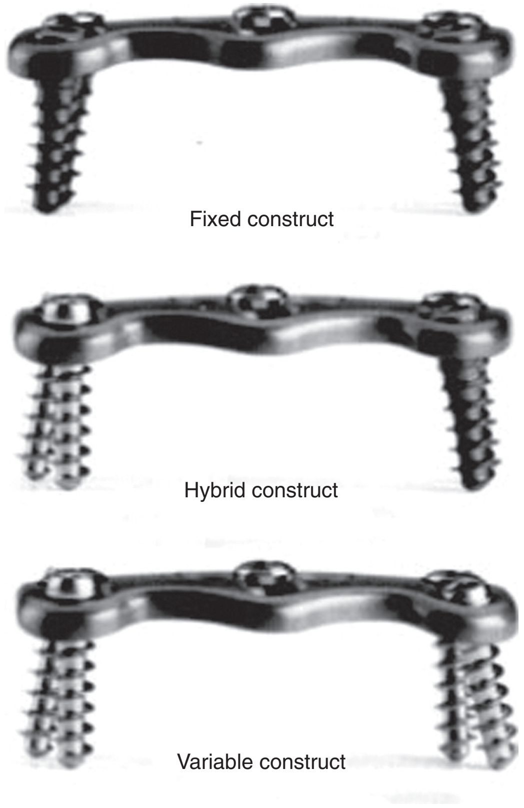

Figure 63-4. Lateral view of the three types (fixed, hybrid, and variable) of Atlantis constructs. The fixed screws at the caudal end of the hybrid plate act as a buttress, allowing for rotation only at the variable screws at the superior portion of the construct. Additionally, in the variable construct, rotation at both ends of the plate is allowed at the plate-screw interface. *(From Haid RW, Foley KT, Rodts GE, et al: The Cervical Spine Study Group anterior cervical plate nomenclature.* Neurosurg Focus *12:E15, 2002.)*

The ABC (Aesculap Inc., Center Valley, PA) and Premier (Medtronic Memphis, TN) plates allow for both subsidence and pivoting motions at the screw-plate interface. Similar to the Caspar plate, the ABC and Premier plates allow for variable-angle screw placement but are able to restrict screw backout. With both plates, screws are allowed to subside in a slot and may then pivot after maximal translation. With the ABC plate, all screws can pivot and subside. As with the DOC system, the caudal screws of the Premier plate are rigid, and the rostral screws are dynamic, although a version in which caudal and rostral screws are dynamic is also available. These externally dynamized plates can potentially accelerate adjacent segment degeneration because with subsidence the plate can translate up and impinge on the adjacent level.

TRANSLATIONAL INTERNALLY DYNAMIZED PLATES

The Dyna Tran plate (Stryker Spine, Allendale, NJ) (Fig. 63-5) is a low-profile plate. It avoids the previously mentioned adjacent segment impingement that externally dynamized plates have. Screws remain fixed in the vertebral bodies while the plate can translate. There is no screw migration. It allows for 2 mm of subsidence per level. This plate allows for potentially easier screw placement and centering compared with externally dynamized plates and allows for graft visualization.

Figure 63-5. Dyna Tran translational internally dynamized plate manufactured by Stryker Spine. This construct allows for the fixed position of screws in a vertebral body with dynamization of the plate. This prevents migration of the superior portion of the plate into the adjacent segment with subsidence and may provide for easier screw placement compared with externally dynamized translational systems. *(From Dyna Tran biomechanical review: dynamic anterior cervical plating system, Stryker Spine, Allendale, NJ.)*

UTILITY OF DYNAMIC CERVICAL FIXATION

A number of studies have found no difference in clinical outcomes between dynamic and static plates.[12-15] There have also generally been no differences in the fusion rates between dynamic and static plates.[12,13,16] Improved fusion rates and clinical outcomes have been reported with the use of dynamic plates for multilevel fusions.[17,18] Fewer implant complications and faster graft incorporation have generally been reported when dynamic plates are compared to static plates.[15,18,19] Loss of cervical alignment (lordosis) has been reported with the use of dynamic cervical plates. The loss of lordosis, resulting from subsidence with dynamic plates, does not seem to affect clinical outcome,[14,20] although there are reports of higher nonunion and implant complications associated with the use of dynamic plates and the related loss of lordosis.[13,21] With regard to adjacent level surgery (degeneration), there does not appear to be any difference between dynamic and static plates.[16] In addition, the use of a shorter plate with longer angulating screws has been shown to significantly reduce adjacent level ossification.[22]

SUMMARY

Despite the conceptual advantages provided by the use of dynamic cervical plates for cervical spine fusion, it is uncertain whether such fixation systems are clinically more beneficial over other types of cervical plates. Dynamic cervical fixation may offer some subtle advantages over static plates; however, results and clinical outcomes appear to be similar between the two classes of cervical plating systems.

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