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**Publisher Information**

The Journal of Bone and Joint Surgery
20 Pickering Street, Needham, MA 02492-3157

www.jbjs.org
Selected Instructional Course Lectures

The American Academy of Orthopaedic Surgeons

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Editor, Vol. 57

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Locking Plates: Tips and Tricks

By Wade R. Smith, MD, Bruce H. Ziran, MD, Jeff O. Anglen, MD, and Philip F. Stahel, MD

An Instructional Course Lecture, American Academy of Orthopaedic Surgeons

Locking plates are fracture fixation devices with threaded screw holes, which allow screws to thread to the plate and function as a fixed-angle device. These plates may have a mixture of holes that allow placement of both locking and traditional nonlocking screws (so-called combi plates). The first locking plates were introduced about two decades ago for use in spinal and maxillofacial surgery. In the late 1980s and into the 1990s, experimentation with various types of internal fixation devices led to the development of locking plates for fracture care. The initial emphasis was on developing stable fixation that would not require extensive soft-tissue stripping or disruption. The clinical care impetus for development of these plates has been a combination of factors, including the increasing survival of patients with high-energy injuries, aging Western European and North American populations with an increasing rate of fragility fractures, and dissatisfaction of patients and surgeons with the outcomes of treatment of specific periarticular fractures. Nonclinical factors likely include a push by industry for new technology and new markets as well as the general interest of the public in "minimally invasive" surgery.

While locking plates have been used for years in specialized research trials, they have been available in North America for general orthopaedic applications only in the last six or seven years. Currently, numerous companies offer a variety of locking plate systems for treatment of extremity fractures. Many of these systems have been on the market for only a couple of years. Given the increased expense of these plates compared with that of traditional nonlocking equipment and the short time that they have been available for general use, it would seem fair to ask: What are the advantages and disadvantages of locking plates? What are the indications and contraindications? How do we use them effectively? How can failures be avoided? The objective of this review will be to address these questions and provide practical information and tips for the practicing orthopaedic surgeon.

**What is a Locking Plate?**

Any plate that allows the insertion of fixed-angle/angular-stable screws or pegs can be used as a locking plate. The main biomechanical difference from conventional plates is the fact that the latter require compression of the plate to the bone and rely on friction at the bone-plate interface. With increasing axial loading cycles, the screws can begin to toggle, which decreases the friction force and leads to plate loosening. If this occurs prematurely, fracture instability will occur, leading to implant failure. Thus, the more difficult it is to achieve and maintain tight screw fixation (as for example, in metaphyseal and osteoporotic bone), the more difficult it is to maintain stability.

In contrast, locking plates follow the biomechanical principle of external fixators and do not require friction between the plate and bone. They are con-
considered to be internal fixators from a biomechanical standpoint since the angular-stable interface between the screws and the plate allows placement of the plate without any contact to the bone \(^1,3,14,15,17\). In essence, however, locking plates can be considered to be external fixators placed underneath the skin envelope, although they are more stable as a result of the shorter distance between the plate and the bone. Many conventional plates now have locking counterparts. There is an increasing trend by manufacturers to supply anatomy-specific plates with locking options. Examples include anatomically pre-shaped plates for the proximal and distal parts of the femur, proximal and distal parts of the tibia, proximal and distal parts of the humerus, and calcaneus\(^18-22\). In many cases, the design of the plate allows substantially less contact between the plate and bone, in an attempt to preserve the periosteal blood supply and bone perfusion. Increasingly, locking plate systems have special features such as outriggers, jigs, and blunted ends to enhance the surgeon’s ability to pass the plate in a submuscular or subcutaneous manner for minimally invasive application\(^23-27\) (Fig. 1).

**Principles of Locking Plate Fixation**

Comminuted intra-articular fractures, such as bicondylar tibial plateau and distal femoral fractures, are highly unstable. After an anatomic joint reduction is achieved, the articular segment must be reconnected to the shaft while appropriate alignment is maintained. Achieving adequate stability for fracture-healing is difficult in the presence of metaphyseal or metaphyseal-diaphyseal comminution. An additional medial buttress in the form of a plate or an external fixator may be required when a conventional laterally based plate is used. Locking plates potentially provide increased stability in these cases to a degree that a second plate is not required. The increased stability is the result of the difference in the mechanics of conventional plate and locking plate fixation\(^3,14,17,28-30\). As mentioned above, locking plates do not depend on the bone-plate interface. Stability is maintained at the angular-stable screw-plate interface. As a result of this stable monoblock of the locking internal fixator, the pullout strength of locking head screws is substantially higher than that of conventional screws\(^3,14,17,28-30\). Because the screws are locked to the plate, it is difficult for one screw to pull out or fail unless all adjacent screws fail.

The increase in stability provided by locking plates is most helpful to surgeons treating a fracture in poor-quality bone, a comminuted bicondylar fracture, or any highly unstable fracture for which a single plate may not provide adequate stability. Also, since only a single plate is needed and the plate does not depend on a tight fit to the bone for stability, substantially less soft tissue dissection may be required, thus preserving the local blood supply and enhancing fracture-healing\(^12,28,31\).

The biomechanical and biological advantages of locking plate systems, compared with conventional plates, have led to a widespread use of these new implants in recent years\(^23,26,32-41\). However, the effective and successful use of locking plates and of minimally invasive techniques remains highly challenging and is associated with a substantial learning curve. The uncritical use of locking plates for a broad range of undifferentiated indications is associated with substantial pitfalls and has led to new patterns of failure of fracture fixation in recent years\(^42-46\). Thus, the surgeon working with locking plates must be well aware of the indications and contraindications, technical tricks, advantages and limitations, and typical pitfalls and adverse events associated with these new implants\(^23,24,26,47\).

**Disadvantages of Locking Plates**

Locking plates are substantially more expensive than conventional plates. They are also unnecessary for many fractures. Locking plates are more difficult to use to help achieve an adequate...
reduction. Particularly with specialty plates, which have only locking holes, fracture reduction must be achieved primarily, before plate fixation. Once a locking screw has been placed through the plate into bone, this particular bone segment can no longer be manipulated by insertion of additional screws or by using compression devices. This makes the sequence of screw placement critical in order to avoid fracture malreduction (Fig. 2). Surgeons who use locking plates need a variety of reduction techniques such as “no-hands” traction, femoral distractors, and percutaneous clamps”. The surgeon must keep in mind that, despite the “advanced technology” of expensive locking plates, they do not improve the fracture reduction and cannot help a poorly reduced fracture to heal. For example, if the final fracture construct is too stiff, particularly when a bridging technique is used, nonunion may occur. The combination of a stiff plate, stiff screws, and fracture distraction is a formula for nonunion (Fig. 3).

**Indications**

Most fractures undergoing operative treatment do not require a locking plate. The majority heal with conventional plates or intramedullary nails, provided that the principles of safe surgery are followed. There are specific fractures, however, that are associated with a higher risk of loss of reduction and plate or screw failure with subsequent nonunion. These are often termed “unsolved” or “problem” fractures and include comminuted intra-articular fractures, short-segment perarticular fractures, and fractures in osteopenic bone. These injury patterns represent the typical spectrum of indications for locking plates.

However, decision-making regarding the use of a locking plate must include precise preoperative consideration of the exact principle by which the locking plate will be used. (“What’s your plan?”) The main indications for the use of a locking plate include four different “classic” principles: (1) the compression principle, for osteoporotic diaphyseal fractures; (2) the neutralization principle, also for osteoporotic diaphyseal fractures; (3) the bridging principle (“locked internal fixator” principle), for comminuted diaphyseal or metaphyseal extra-articular fractures; and (4) the combination principle (“combi plate” principle), for comminuted metaphyseal intra-articular fractures.

The surgeon using a locking plate for fracture fixation must be well aware of the exact indication, according to these four different principles, for which the angular-stable implant will be used (Table I). For simple, noncomminuted diaphyseal fractures in osteoporotic bone requiring an open reduction and rigid internal fixation, locking plates offer the advantage of increased pullout resistance of the locking head screws compared with that of conventional screws. Thus, for these fractures, locking plates can be applied according to the compression principle through eccentric placement of screws in the dynamic compression unit of the “combi hole” or by the use of a compression device after initial placement of one locking head screw on the other side of the fracture. On the basis of the same rationale, locking plates can also be used according to the neutralization principle to protect a lag screw in osteoporotic bone, with increased pullout resistance of the locking head screws. However, it is crucial to understand that locking head screws can never provide...
interfragmentary compression. Compression can be achieved only by the use of a compression device or by eccentric placement of conventional screws in the “combi hole” of a combination locking plate (lag first, then lock).\(^5,28,30,47\)

The classic and ideal indications for fracture fixation with locking plates are represented by the bridging principle and the combination principle (Table I). Both concepts apply to fixation of fractures with substantial comminution—either high-energy fractures in young patients or low-energy osteoporotic fractures in elderly patients. The bridging principle is typically represented by the concept of minimally invasive percutaneous plate fixation (also referred to as the “MIPO” or “MIPPO” technique), whereby the angular-stable plate is used as an internal splint that bridges the comminuted fracture. With this method, indirect reduction is performed by ensuring adequate axial alignment, length, and rotation of the extremity while the fracture fragments are not exposed or directly reduced. In contrast to the compression and neutralization principles, which provide absolute rigid stability leading to primary (direct) fracture-healing, the bridging concept provides relative, elastic fixation that leads to secondary (indirect) fracture-healing by callus formation. For adequate bridge plate fixation, three or four holes of the plate should be left empty at the level of the fracture, as discussed below (in the Tips, Tricks, and Pitfalls section).

The combination principle refers to a biomechanical mixture of compression and bridging with only one implant. Although the original locking plates available for fracture fixation, such as the point contact fixator (PC-Fix) and the less invasive stabilization

<table>
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<tr>
<th>Indication</th>
<th>Biomechanical Principle</th>
<th>Technique</th>
<th>Bone Quality</th>
<th>Typical Anatomic Location</th>
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</thead>
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<tr>
<td>Comminuted shaft fractures</td>
<td>Bridging</td>
<td>Locked internal fixator</td>
<td>Normal or osteopenic</td>
<td>Femur, tibia, humeral shaft</td>
</tr>
<tr>
<td>Comminuted metaphyseal intra-articular fractures</td>
<td>Combination</td>
<td>Combined (lag screws for articular fixation, locking head screws for metaphyseal bridging)</td>
<td>Normal or osteopenic</td>
<td>Distal part of femur, distal part of tibia</td>
</tr>
<tr>
<td>Short-segment metaphyseal fractures</td>
<td>Bridging or combination</td>
<td>Locked internal fixator</td>
<td>Normal or osteopenic</td>
<td>Proximal part of humerus, distal part of radius, distal part of tibia</td>
</tr>
<tr>
<td>Simple fractures in osteoporotic bone</td>
<td>Compression</td>
<td>Dynamic compression with eccentric screw placement or a compression device, locking head screws for shaft; tension device with locking head screws only</td>
<td>Osteopenic</td>
<td>Osteoporotic forearm</td>
</tr>
<tr>
<td>Simple fractures in osteoporotic bone</td>
<td>Neutralization</td>
<td>Conventional lag screw, locking head screws for neutralization plate</td>
<td>Osteopenic</td>
<td>Osteoporotic ankle</td>
</tr>
</tbody>
</table>

Fig. 3
Locking plate fixation of a simple fracture of the radial shaft, leading to nonunion. The use of locking plates is contraindicated for simple fractures that require interfragmentary compression. In this case, three locking head screws were used on each side of the fracture (arrows in panel C), whereas the dynamic compression holes of the combi plate were left empty. This stiff construct led to a nonunion within a few months after the surgery.
system (LISS), provided all of the innovative biomechanical and biological properties of angular-stable devices, surgeons expressed the desire to use a combination of both concepts, locking and compression plate fixation, with only one implant. This option was made available for the first time in the early twenty-first century by the locking compression plate (LCP), which was designed by Robert Frigg (Bettlach, Switzerland) on the basis of an idea from Prof. Michael Wagner (Vienna, Austria)\(^4,5,15,28\).

The combination technique is indicated for fixation of fractures with a simple pattern (e.g., an intra-articular split) at one level and comminution (e.g., metaphyseal-diaphyseal comminution) at a different level. Under these circumstances, the plate can be used to achieve interfragmentary compression of the simple fracture pattern by means of a dynamic compression technique or placement of a lag screw through the dynamic compression unit of the plate. Thereafter, the plate can be used as a

<table>
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<tr>
<th>Contraindication</th>
<th>Wrong Technique</th>
<th>Example</th>
<th>Expected Adverse Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple fractures</td>
<td>Locked internal fixator</td>
<td>Simple forearm or humeral shaft fracture</td>
<td>Nonunion</td>
</tr>
<tr>
<td>Simple fractures</td>
<td>Minimally invasive percutaneous plate fixation</td>
<td>Simple distal tibial fracture</td>
<td>Nonunion</td>
</tr>
<tr>
<td>Displaced intra-articular fractures</td>
<td>Locked internal fixator</td>
<td>Tibial pilon fracture</td>
<td>Malunion, arthritis</td>
</tr>
</tbody>
</table>

Fig. 4
Typical patterns of failure of locking plate fixation of proximal humeral fractures. Although the locking plate technique has revolutionized the surgical fixation of this fracture in recent years, typical failure patterns occur with locking plates whenever basic concepts and technical principles are not respected. Secondary loss of reduction with varus collapse can occur as a result of use of screws of inadequate length in the humeral head fragment and inappropriate fixation of locking head screws in the plate (arrows in panels A and B). The interfaces between the locking head screws and the threaded plate holes should not fail if the screws are inserted at the perfect angle and attached with a torque-limiting screw driver. Increased strain in a construct with too much stiffness and exposure to high rotational forces will lead either to breakage of the plate in the dynamic compression part of the combination hole, which is the weakest part of this construct (panels C and D) or, more rarely, to a failure at the screw-plate interface with breakage of the screws (asterisks in panel B). If the locking screws in the head part of the fracture are too long, they may protrude into the glenohumeral joint, since locking head screws cannot recede backward, as conventional screws can. This failure pattern is particularly frequent if the fracture is malreduced in varus, as demonstrated in panel E.
locked internal fixator to align the articular fragment to the shaft in a bridging manner. The combination principle is feasible only with plates that allow placement of both locking head screws and conventional compression screws in one implant.

**Contraindications**

Despite the widespread use of locking plates and their wide range of indications, a few contraindications must be acknowledged and respected (Table II). The uncritical use of locking plates may lead to failure of fixation and to nonunion, particularly if the above-mentioned standard principles for use of locking plates are violated. A typical contraindication to the use of a locking plate as a locked internal fixator is a simple fracture pattern that requires interfragmentary compression. For example, simple diaphyseal fractures of the forearm fixed with a plate with a locked internal fixation technique are prone to nonunion (Fig. 3). Similarly contraindicated is percutaneous locking plate fixation of simple fractures with use of a minimally invasive technique. This concept violates the principle of the fracture gap width in relation to strain and thus leads to nonunion, as described in an excellent review article by Stephan Perren. Finally, indirect reduction and locking-plate fixation are contraindicated for displaced intra-articular fractures, since these injuries require anatomic open reduction and rigid interfragmentary compression.

Because of their cost, locking plates are relatively contraindicated for fractures that can be stabilized satisfactorily with conventional plates. For example, diaphyseal forearm fractures have healing rates in excess of 90% with conventional plates. While there are some claims that, theoretically, the use of unicortical locking plates should increase healing rates because of the lack of soft-tissue stripping, this has not been validated in any type of controlled trial, to our knowledge. Overuse of these plates in some health-care systems may negatively impact overall patient care by consuming resources that could be better used elsewhere.

**Tips, Tricks, and Pitfalls**

Successful use of locking plates depends on adherence to established principles of operative fracture care and learning the tricks of the specific technology. Gautier and Sommer recently presented prudent guidelines that may improve the individual learning curve of surgeons who are less familiar with these new implants.

In general, successful use begins with a formal preoperative drawing. The advent of digitized radiography at many centers requires that digital templates be available. If plain radiographs are used, utilization of tracing paper is still the most effective way to draw a preoperative plan. The sequence of screw placement, the length and position of the plate, and the surgical approach are all critical to success. A precise preoperative plan reduces the guesswork and increases the likelihood of technical success. The preoperative plan also ensures that the surgeon will have all necessary implants available at the time of surgery.

Correct positioning of the patient is vital, particularly if the plan calls for minimally invasive or percutaneous insertion of the implant. The surgeon should ensure that all necessary images are obtainable prior to preparation and draping of the patient. A radiolucent table is very helpful. Tightly rolled bumps of different sizes fashioned prior to the operation can aid in fracture reduction as well as visualization, particularly in the lateral plane. Fracture reduction can be challenging with locking plates because the locking screws do not pull the plate to the bone in the manner of conventional screws. Therefore, it is essential that the surgeon have a preoperative plan for fracture reduction. Combinations of traction to correct length and
alignment in the anteroposterior plane and placement of bumps under the extremity to correct lateral plane deformities can successfully permit reductions with minimal direct manipulation of the fracture fragments. Specialized reduction clamps can be used judiciously with percutaneous long-bone and periarticular reductions. Conventional screws or “whirlybird” push-pull types of devices can be used to pull the bone to the plate initially to secure fracture reduction. Once the fracture is reduced, then locking screws can be added as needed to provide stability.

Effective use of locking plates requires an understanding of the potential pitfalls of usage. Locking holes offer minimal opportunity for screw angulation. More than 5° of angulation between the screw and the locking hole can cause the screw to eventually fail. Careful technique is necessary to ensure that the screw is perfectly lined up with the axis of the screw threads in the plate. This may be quite difficult in a minimally invasive procedure. Malaligned screw threads can lead to loose screws and loss of reduction (Fig. 4).

The weakest part of the combi locking plate (e.g., the LCP) is the dynamic compression unit. This is the part of the plate that should be used for bending, if required, and it is the part that breaks when there is increased stress concentration and strain on the plate. For this reason, when a bridge plate is used to fix a comminuted fracture, at least three or four plate holes should be left empty at the level of the fracture, in order to achieve a larger area of stress distribution on the plate (Fig. 5). In contrast to conventional plates, which fail at the interface between the screws and the plate—often leading to breakage of conventional screw heads—the interface of the locking head screw with the threaded locking hole is the strongest part of the locking plate system. Locking screw heads are less likely to break since the difference between the core diameters of the screw shaft and head is much smaller than it is with conventional screws. Nevertheless, locking head screws can break in cases of chronic instability and increased strain as a result of rotational forces, as is exemplified by proximal humeral nonunion shown in Figure 4 (panel B).

Locking plates allow the use of both bicortical and unicortical locking head screws. The choice of screw type (self-drilling/self-tapping or self-tapping only) and screw length (unicortical or bicortical) needs to be based on defined principles in order to avoid complications. As a general rule, self-drilling/self-tapping screws, as are used in minimally invasive locking plates (such as the LISS), should be employed exclusively in a unicortical fashion. The main reason is that self-drilling screws have sharp tips that may cause neurovascular and/or soft-tissue damage across the far cortex. Furthermore, drilling of the far cortex with self-drilling/self-tapping screws may lead to simultaneous disruption of the tapped thread in the near cortex and thus reduce the overall purchase of the locking head screws. Similarly, a pitfall with unicortical placement of self-tapping screws is the selection of an inadequate screw length. If the screw is too short, the threads in the near cortex will not have enough purchase and the locking monoblock frame is prone to failure by pullout with cyclic loading (Fig. 6). In contrast, if the unicortical screw is slightly too long, the nondrilling screw tip will push off from the far cortex, thus destroying the tapped thread in the near cortex.

The pullout resistance of unicortical locking head screws is almost identical to that of similar-diameter bicortical conventional screws and about 70% of that of bicortical locking head screws. Thus, how much pullout strength is needed? There is no way to objectively judge this, nor is it necessarily important, because these constructs rarely fail through pullout per se. Two factors are essential for decision-making with regard to the use of unicortical or bicortical locking head screws. These are, first, the quality of the cortical bone and, second, the extent of rotational forces applied to the fractured bone. Cortical thickness is of great importance in determining the adequacy of the working length of unicortical screws. The working length of a unicortical screw in good-quality cortical bone usually provides sufficient pullout resistance equaling the pullout strength of a bicortical conventional screw, as mentioned above. In contrast, in metaphyseal bone and osteoporotic cortical bone, the cortex is usually very thin, thus rendering the working length of unicortical screws insufficient. This reduction in pullout strength is of par-

<table>
<thead>
<tr>
<th>Screw Placement</th>
<th>Bone Quality</th>
<th>Fracture Location</th>
<th>Working Length</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unicortical</td>
<td>Normal</td>
<td>Diaphysis</td>
<td>Adequate</td>
<td>Except for fractures exposed to high rotational forces; e.g., in humerus</td>
</tr>
<tr>
<td>Bicortical</td>
<td>Normal and osteopenic</td>
<td>Diaphysis and metaphysis</td>
<td>Adequate</td>
<td>Use self-tapping but not self-drilling screws for bicortical fixation</td>
</tr>
<tr>
<td>Unicortical</td>
<td>Normal</td>
<td>Metaphysis</td>
<td>Inadequate</td>
<td>Except for minimally invasive use of self-drilling/self-tapping screws or short-segment metaphyseal fractures (e.g., in proximal part of humerus)</td>
</tr>
<tr>
<td>Unicortical</td>
<td>Osteopenic</td>
<td>Diaphysis and metaphysis</td>
<td>Inadequate</td>
<td>Contraindication for unicortical screws</td>
</tr>
</tbody>
</table>
ticular importance when osteoporotic bone is mainly loaded by torsional forces such as occurs in the humerus. Under these conditions, an adequate working length must be achieved by using bicortical locking head screws, as outlined in Table III.

For these reasons, bicortical fixation is recommended for osteoporotic bone in general and for metaphyseal fractures in bone of normal quality. Also, unicortical screws should not be used in anatomic locations exposed to high rotational forces, such as the humeral shaft. In fact, the only advantage of using unicortical screws may be the lack of penetration of the bone and periosteum on the far side of the bone, and this advantage is highly debatable as far as its true impact on fracture-healing. Additionally, unicortical screws are less stiff than bicortical locking screws. unicortical screws are indicated for periarticular fractures in which the screws are placed in the direction of an articular surface, such as in the proximal part of the humerus.

Locking head screws have some peculiar differences from conventional screws. While these differences may seem intuitively obvious, they have implications with regard to clinical application. The first difference is that a torque-limiting screwdriver is useful during placement of the locking head screw. The advantage of the use of a torque-limiting device is that, as long as the screw is centered in the hole, the thread cannot be stripped or overtightened. Deformation of the screw heads by overtightening or cross-threading (“cold-welding”) into the plate can make hardware removal very difficult. This happens more often with the minimally invasive technique, which can result in stripping of the screw heads and angulation of the screws because of the difficulty in judging orientation without direct visualization. In contrast to the situation with conventional screws, the purchase of the screw in the bone cannot be felt, since locking head screws always feel tight. Unfortunately, the tight feel is deceptive. Many fracture surgeons, through years of experience and training, have developed a tactile feedback loop based on how the screw “feels” as it tightens down. The fixation can still fail despite “tightness” of the screws, particularly if there is substantial malreduction (Fig. 2) or if the screws are cross-threaded or not adequately locked in the plate (Fig. 4, panels A and B).

One strategy that is used to overcome this problem is to carefully place perpendicular 2.0-mm Kirschner wires in the most distal and proximal plate holes prior to screw insertion. To ensure that the wires are truly perpendicular, they should be placed through the locking drill guides. Alignment can then be checked by looking for the round “bull’s-eye” of the drill guide in the locking hole on the lateral radiograph. These wires will maintain length and can also serve as a reference for subsequent placement of screws. Alternatively, a drill bit can be left in place through the drill sleeve to hold the plate in place temporarily, until an adequate reduction is achieved.

Although minimally invasive techniques have been improved in recent years by the introduction of locking plates, achieving and maintaining an adequate reduction remain sources of pitfalls and failures. Sliding any minimally invasive plate in the submuscular plane along the bone can be challenging. There are a number of strategies for aligning the plate along the bone percutaneously. Kirschner wires can be inserted manually just anterior and posterior to the bone to mark the boundaries for plate passage. The plate

Fig. 6
Inappropriate use of unicortical locking head screws. Several errors in concept and technique led to failure of the fixation of this simple humeral shaft fracture. The plate was used as a bridging locked internal fixator, holding the fracture in distraction and rendering it prone to nonunion (A). Furthermore, the fracture was fixed by only two unicortical locking head screws on each side, which is insufficient for fixation of a humeral shaft fracture exposed to high rotational forces (Table II). Finally, some unicortical screws that were placed without sufficient purchase in the near cortex had no pullout resistance at all (C). This inadequate locking plate fixation failed early after the surgery (B) and was revised with use of a conventional compression plate. The fracture healed fully within three months. It is important to emphasize that locking plates usually fail as a monoblock if the locking head screws are properly attached to the threaded plate holes, as depicted in panel D.
is then passed between the wires, and the wires will prevent posterior or anterior deviation of the plate. Another tactic is to make 4 to 6-cm incisions at the proximal and distal sites of the plate. With use of blunt dissection down to bone, the plate can be directly visualized as it passes into the wound. Locking drill sleeves should be attached to the most proximal and distal holes of the plate to form a frame for easier positioning of the plate on the bone as depicted in Figure 1. This way, the plate can be centered on the bone at each end and anchoring screws can be placed under direct visualization. If the fracture is well reduced with regard to length, alignment, and rotation, then the plate will be appropriately positioned along the entire length of bone when it is centered at each end. The plate must be held to the bone by first placing a conventional screw or a “whirlybird” tool, since the placement of a self-drilling/self-tapping screw will push the plate away from the bone and may cold-weld the screw head to the plate. Since the incisions are distant to the fracture site, the principle of minimally invasive fixation is preserved, as the fracture fragments and soft-tissue attachments are undisturbed.

Locking plates, particularly the specialized so-called all-locking plates, require an approach to fracture reduction that is completely different from what most of us have practiced. When one begins to use locking plates, a good approach is to “start easy.” One should consider initially using combination plates that permit the use of traditional reduction techniques. Lost in the current enthusiasm for this new technology is the recollection that ten years ago almost no surgeons in the world were using locking plates routinely. Most of the current high-volume experts in this field started by practicing on Sawbones and attending workshops. This is a good approach for anyone starting to use these techniques.

Malreduction can result in failure regardless of whether the plate is conventional or locking. Common problems include varus in the proximal part of the humerus and distal part of the femur and distraction in diaphyseal fractures (Figs. 2, 3, and 4). In many cases, locking plates are used as bridge plates in the presence of substantial comminution. Plates that are very stiff or stiff fracture constructs with too many screws can lead to nonunion and eventually plate failure (Fig. 5). Bridge plates must be longer, and fewer screws are needed. For the treatment of periarticular fractures, few screws are needed in the diaphysis but more screws may be required near the articular surface. The precise length of the bridge plate and the number of screws needed for a specific fracture remain controversial. In general, the length of the plate should be more than two times the length of the fracture zone. Screws should be spread evenly, and ideally there should be at least one empty hole between each pair of holes filled with screws. As mentioned above, when the bridging principle is used, three or four screw holes should be left empty at the level of the fracture to avoid a local stress concentration, which may lead to breakage of the plate. The even distribution of force over a long working plate length with relatively few screws appears to provide a stable stimulus for indirect bone-healing and callus formation.

**Overview**

Locking plate technology offers improved fixation stability in osteopenic bone and for comminuted and periarticular fractures. The additional stability per screw compared with that of conventional nonlocking fixation enhances the application of minimally invasive fracture techniques such as use of bridge plates and percutaneous fracture stabilization. The application of locking plates is somewhat more difficult than the placement of conventional plates. Fracture reductions are often done indirectly, the locking screw must be carefully aligned along the axis of the receiving hole to ensure proper tightness, and the length of the plate must be selected carefully. Despite the necessity of mastering these nuances, the use of locking plates will likely increase, particularly with the increasing prevalence of fragility fractures in our aging population and the increase in high-energy fractures in younger patients surviving severe trauma. While a substantial amount of biomechanical and animal data have been published, few series have validated the long-term advantages of fixation with locking plates. The initial results in series that included a variety of fractures are encouraging, although it is increasingly apparent that failures do occur. The causes of failure should be examined carefully in both the literature and one’s own practice in order to learn from mistakes and refine our techniques.

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**References**


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