14 Nonlocking Plate Functions 2

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Bridge Plating

Bridge plates are used for open reduction and internal fixation (ORIF) of comminuted metaphyseal and some diaphyseal fractures. Common situations include comminuted distal femur fractures with complex articular involvement, or more simple articular fractures where the plate can also be used as a reduction tool. A common misconception is that bridge plates are locking plates. It is important to realize that bridge plating is a function of the plate and not the specific type of plate.

Bridge plates are used to restore functional reduction of the metadiaphyseal fracture component. That is to say, restoration of length, alignment, and rotation are the goals of the bridge plate. Bridging thus provides relative stability to the fracture. The desired healing that ensues is secondary healing through callus formation.

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A bridge plate is ideally used to span comminuted fractures. Performing a direct reduction and using an absolute stability construct would devitalize soft tissues and periosteum that are vital to revascularization and fracture healing in the setting of comminution. Thus, an indirect reduction technique for non-articular fracture components and preservation of periosteum, fracture hematoma, and soft tissues is generally used in concert with bridge plating.

An understanding of stress and strain is necessary in order to determine which fractures are amenable to bridge plate fixation. Stress is force divided by area, while strain is defined as the motion between fracture fragments divided by the distance between fracture fragments [1]. Fractures unite through secondary bone healing in environments with low strain [1].

An appropriately placed bridge plate results in a flexible environment that allows for motion between comminuted bony fragments with physiological loading. In fracture comminution, there is a large overall distance between fracture fragments. A flexible construct in the setting of a fracture with a large overall distance between fragments results in a low overall strain (strain=motion between fragments/distance between fragments).

Three factors influence the stability of a bridge plate: length of the plate, the working length of the plate, and the density and design of the screws used [2].

B. D. Crist et al. (eds.), *Essential Biomechanics for Orthopedic Trauma*,
https://doi.org/10.1007/978-3-030-36990-3_14

Length of the Plate

Since stress is defined as force/area, longer plates will have a larger stress distribution. The ideal length of a bridge plate relative to the length of the comminuted fracture being spanned is debatable. A reasonable estimation is that a bridge plate should be three times the length of the comminution it spans [1]. If a bridge plate is used in a simple fracture pattern, it should be 8–10 times the length of the fracture in order to dissipate the strain over a longer working distance [2].

Working Length of the Plate

The working length of the bridge plate is defined as the distance between the two screws closest to either side of the fracture site. The shorter the working length, the less flexible the construct is. Although not proven clinically, a shortened working length increases strain and is thought to lead to a higher risk of nonunion.

Screw Design and Density

Any plate can be used as a bridge plate, including locking plates. When locking screws are used in bridge plating, the surgeon must be mindful of their effect on strain. Locking screws increase the stiffness of a construct, thereby increasing the strain by decreasing the allowable motion at the fracture. While this is advantageous in certain situations, a very stiff construct in bridge plate situations may lead to nonunion. One study of distal femur fractures identified that when all screws proximal to the fracture were locking screws, there was a 48.8% rate of nonunion compared to 25.0% when cortical screws were used as well (hybrid screw technique) [3]. In patients with adequate bone quality, cortical screws (nonlocking) can be placed proximal and distal to the spanned comminution, while in osteoporotic bone, locked screws may be necessary if there is poor cortical screw purchase—however, this is unlikely in the diaphysis.

Deciding on the appropriate number of screws on either side of the fracture (screw density) is crucial, as too many screws can lead to an overly stiff construct, creating a high strain environment and predisposing to nonunion. A general recommendation is to use a screw density of 0.5 [2], meaning that at least half of the screw holes of the plate are left empty in a bridge plate construct. Depending on the anatomic region and bone quality in question, screws can be placed much more sparingly.

Case 1: Bridge Plate

A patient is an 18-year-old male who was the victim of multiple gunshot wounds. One of the bullets caused a right comminuted distal humeral shaft fracture (Fig. 14.1). The patient was indicated for debridement as well as osteosynthesis given the distal extent of the fracture.

A triceps splitting approach was performed and the radial nerve was protected. After excisional debridement of the multiple bullet fragments and the bony fragments that were devoid of soft tissue, the fracture was grossly reduced, and no attempt was made to reduce additional fragments of comminution to minimize further periosteal damage. A 12-hole posterolateral extra-articular distal humeral locking plate was selected and positioned deep to the radial nerve. Four proximal cortical screws were placed in addition to two distal cortical screws. Three distal locking screws were used because it was a short segment for fixation distally, and bicortical nonlocking screws would be intra-articular at this level. Additional stability was obtained by applying an orthogonal contoured 3.5-mm reconstruction plate with three proximal and two distal cortical screws (Fig. 14.2). At 9 months postoperatively, the patient returned for follow-up and the fracture was healed (Fig. 14.3).

Why This Works

Secondary to the severe comminution and periosteal damage from the energy of the injury, bridge plating was chosen as the fixation strategy. The

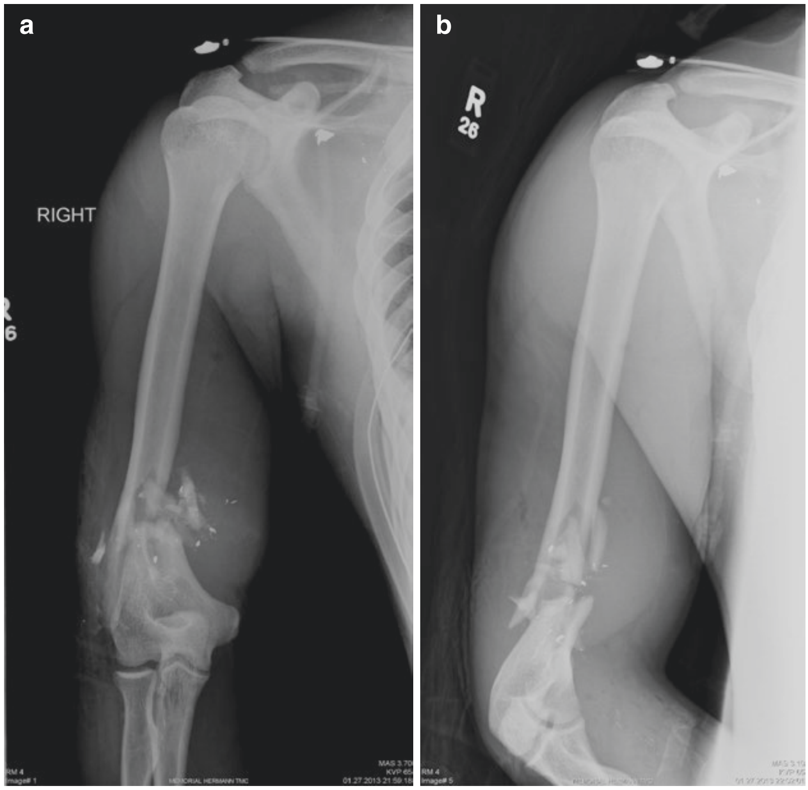

Fig. 14.1 Lateral (**a**) and anteroposterior (**b**) injury radiographs demonstrating a comminuted extra-articular distal humerus fracture

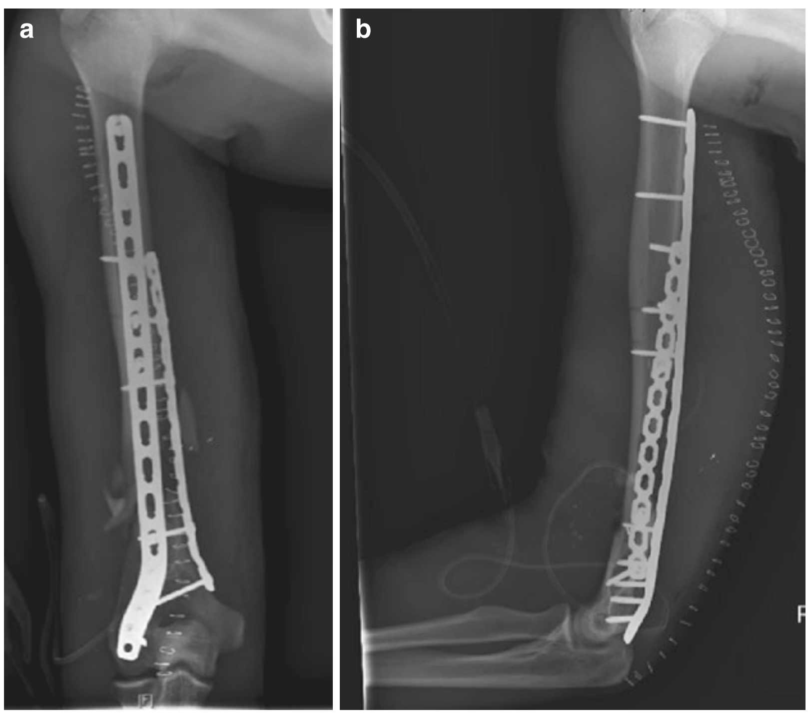

Fig. 14.2 Anteroposterior (**a**) and lateral (**b**) radiographs immediately post-fixation with bridge plating

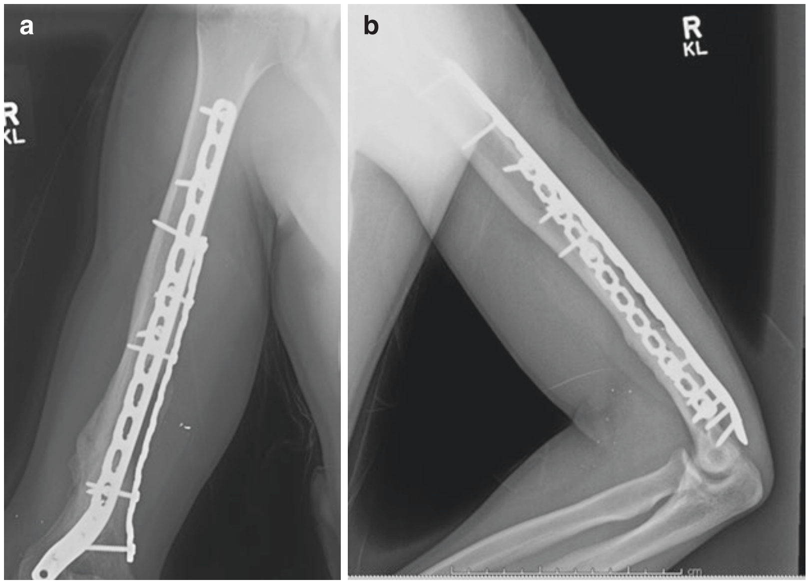

Fig. 14.3 Anteroposterior (**a**) and lateral (**b**) radiographs demonstrating secondary healing of the fracture

long posterior locking plate with both locking and cortical screws in combination with the orthogonally placed shorter reconstruction plate created a dual bridge plate construct. The orthogonal plates distributed the load over a long working distance and were strong enough to resist the torsional forces on the humeral shaft while the comminuted fracture healed.

Wave Plate

One modification of a bridge plate is the wave plate, which was originally described by Weber and Brunner in 1982 [4]. The distinctive feature of a wave plate is its central curved segment. There are three main advantages to using wave plates [5]. First, the "wave" of the plate provides improved access to the fracture or nonunion site for bone grafting. The wave also reduces the plate's contact with the bone and reduces the interruption in periosteal blood flow compared to standard plating. Finally, the wave in the plate increases the area and force distribution of the plate. As callus forms, exaggerating the convexity of the bony surface to which the wave is applied, the plate will function as a tension band, converting tension forces to compression across the fracture site. In recent literature, the wave plate has been applied successfully to long bone nonunions including the femur, humerus, ulna, and radius [6–8].

Case 2: Wave Plate

A 64-year-old polytrauma patient sustained a femoral shaft fracture in a motor vehicle collision that was initially treated at an outside institution. The patient presented 1 year following the incident with an atrophic left femoral nonunion (Fig. 14.4). After discussing treatment options, the patient elected to undergo exchange nail and augmentative wave plating. The previous nail and interlocking screws were removed, and the nail was exchanged for a larger reamed retrograde nail. Then, a lateral subvastus approach to the femur was performed. The nonunion site was identified and taken down with osteotomes and a high-speed burr. Approximately 40 cc of iliac crest bone graft was harvested. A wave plate was contoured and then applied to the nonunion site, and screws were strategically placed around the nail. The bone graft was packed underneath the wave of the plate abutting the nonunion site both anteriorly and posteriorly. At the patient's

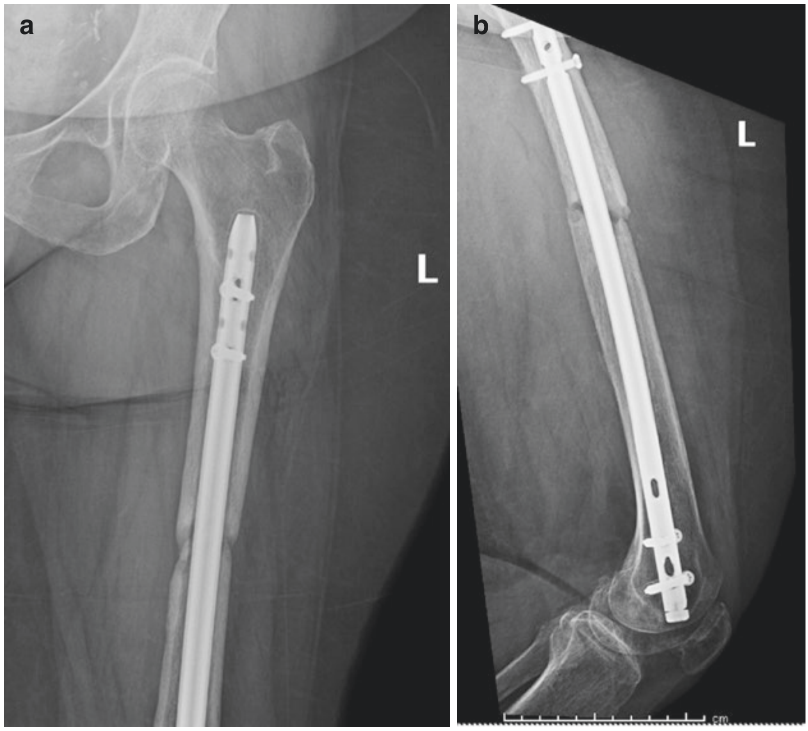

Fig. 14.4 Anteroposterior (**a**) and lateral (**b**) radiographs demonstrating an atrophic nonunion of the femoral shaft

10-month follow-up appointment, the nonunion had healed and the patient's symptoms resolved (Fig. 14.5).

Why This Works

In this case, the subtrochanteric region had already failed to heal after one attempt at intramedullary nailing. The wave plate with bone grafting was chosen as a supplement to the larger exchange nail in order to add stability to the construct as well as to capture the bone graft.

Fixed Angle Devices

A fixed angle device is any device that has a fixed angle within the implant, including blade plates, dynamic hip plates/sliding hip screws, dynamic condylar plates, and locking plates. The blade plate and the dynamic hip/condylar plate are two unique nonlocking plates that warrant additional discussion.

The blade plate was the first used fixed angle plate, and it was introduced in the 1960s [9]. The blade plate can function as a tension band, a compression plate, or a bridge plate depending on its application. The blade plate is an L-shaped plate that is fashioned from a single piece of stainless steel. The most commonly used plate has an angle of 95 degrees, but additional plates come in 110, 120, or 130 degrees. Although largely replaced by locked plating, the blade plate continues to be used in select acute fractures [10], proximal femoral osteotomies, nonunions [11], and for salvage arthrodesis [12]. The original indications of the blade plate were to treat proximal and distal femur fractures.

There is evidence of failure of proximal femoral locking plates (PFLP) that has renewed interest in blade plating [13–15]. While the PFLP are stronger biomechanically compared to blade plating [16], they have not performed as well clinically. After blade plate insertion, the articulated tensioning device (ATD) can be used to compress or "load" the fracture and perhaps further correct deformity, prior to placing shaft

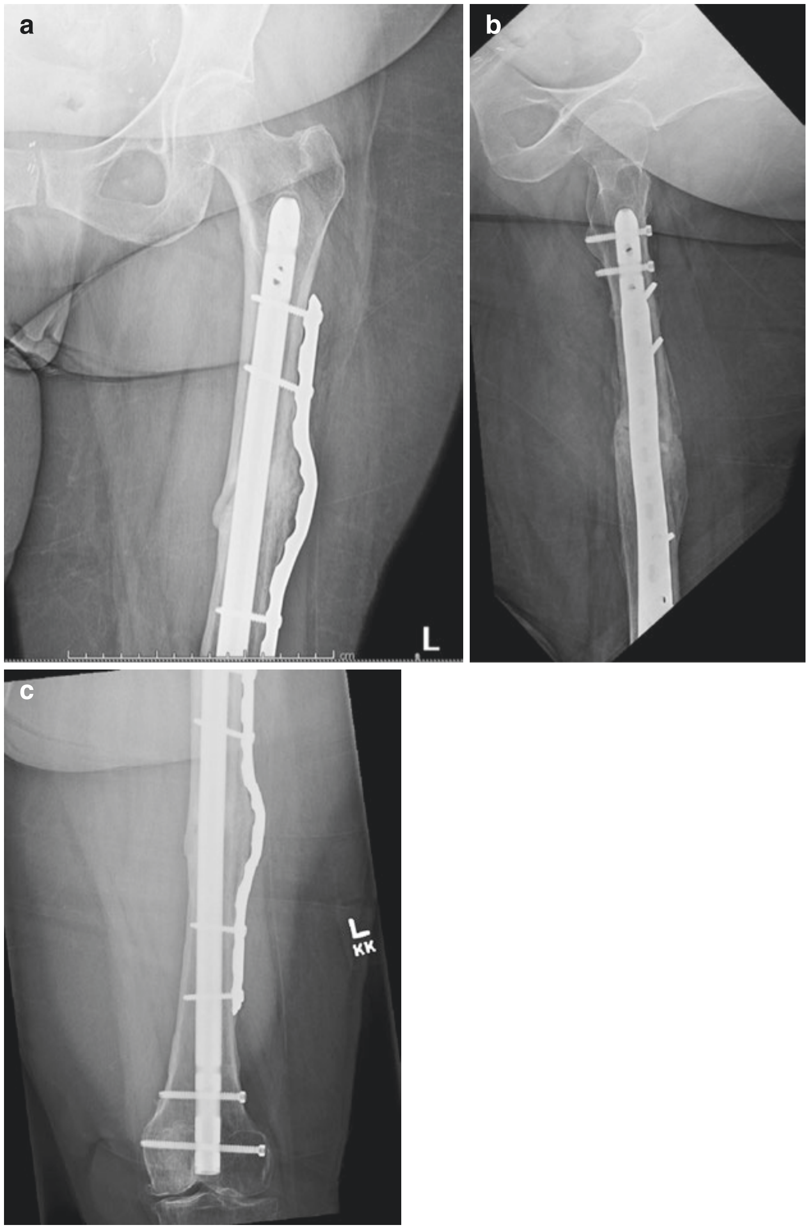

Fig. 14.5 Postoperative anteroposterior (**a**) and lateral images of the hip (**b**) and anteroposterior image of the distal femur (**c**), demonstrating healing of the femoral shaft fracture following exchange nailing with wave plating

screws. The use of the ATD and its ability to load the blade plate is one of the major advantages, and for this reason, it is particularly beneficial in fractures that are amenable to compression [10].

However, the blade plate is technically challenging because precise placement is required. Once the blade has been impacted, altering plate position will alter the reduction. Therefore, this implant requires appropriate preoperative planning and correct positioning in multiple planes and cannot be inserted in a percutaneous manner.

Case 3

A 57-year-old male was struck by a projectile from a wood chipper and sustained a complex open distal femur fracture (Fig. 14.6). There was

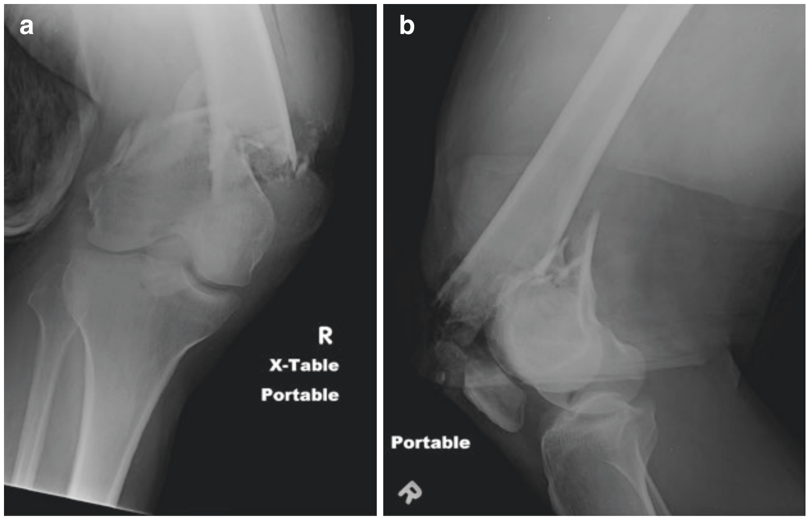

Fig. 14.6 Anteroposterior (**a**) and lateral (**b**) radiographs of the distal femur fracture

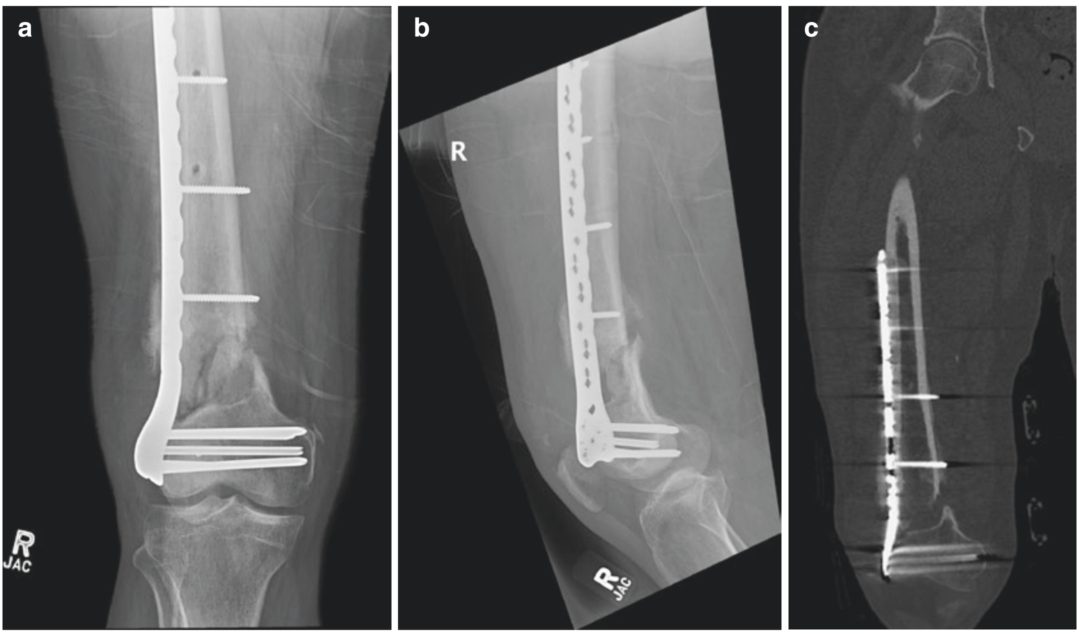

Fig. 14.7 The patient went on to nonunion of the distal femur as demonstrated on anteroposterior (**a**) and lateral (**b**) radiographs and confirmed by CT (**c**)

a large transverse wound along the anterior/distal thigh that transected his quadriceps tendon. After initial debridement and knee-spanning external fixation, definitive ORIF was performed through an anterior incision that incorporated his open wound using a distal femoral locking plate. Eight months following the initial procedure, the patient presented with continued pain and nonunion (Fig. 14.7).

A separate lateral incision was used, and a subvastus approach to the distal femur was performed. The nonunion was debrided. Then iliac crest was harvested for bone graft. The reference wire for the blade is critical and needs to be placed parallel to the joint line on the AP view (Fig. 14.8). A 95-degree blade plate was inserted. This was secured distally with cortical screws, and then the fracture was compressed with the ATD proxi-

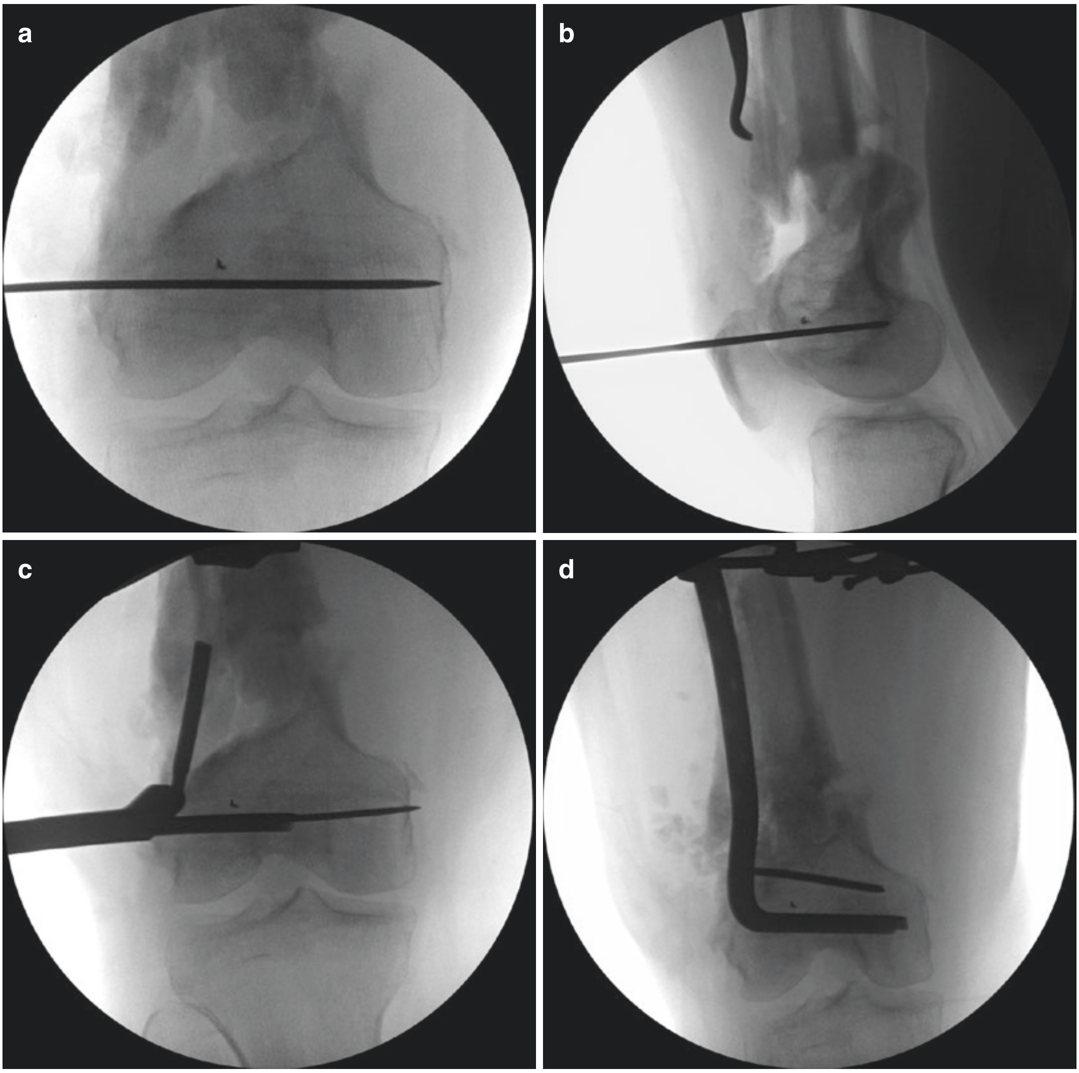

Fig. 14.8 Intraoperative images demonstrating blade plate preparation and insertion. Placement of the summation guide wire on anteroposterior (**a**) and lateral (**b**) fluoroscopy. (**c**) The chisel is introduced over the guide wire and (**d**) the blade plate is inserted

mally and then secured with additional cortical screws proximally using compression technique (Fig. 14.9). The patient returned for follow-up 9 months following nonunion repair and showed radiographic healing (Fig. 14.10).

Why This Works

This distal femoral fracture was at high risk for nonunion given the high-energy and the open nature of the injury. When the distal femoral locking plate failed, the blade plate was chosen to compress the nonunion with ATD and provide rigid, fixed angle fixation.

Similarly, the dynamic condylar screw (DCS) is a 95° fixed angle implant intended for fixation of distal femur fractures or subtrochanteric fractures that has largely been replaced by other more technically forgiving implants [17]. The DCS is traditionally considered more "forgiving" than the blade plate because once the plate is inserted, unlike the blade, it can still be adjusted in the sagittal plane to accommodate the femoral shaft. Furthermore, it can be placed percutaneously.

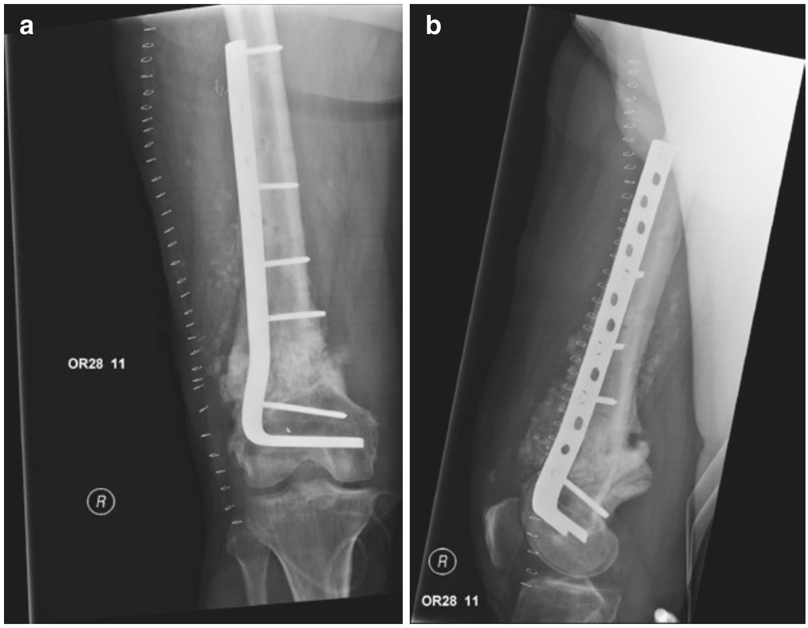

Fig. 14.9 Immediate postoperative anteroposterior (**a**) and lateral (**b**) radiographs demonstrating the final construct

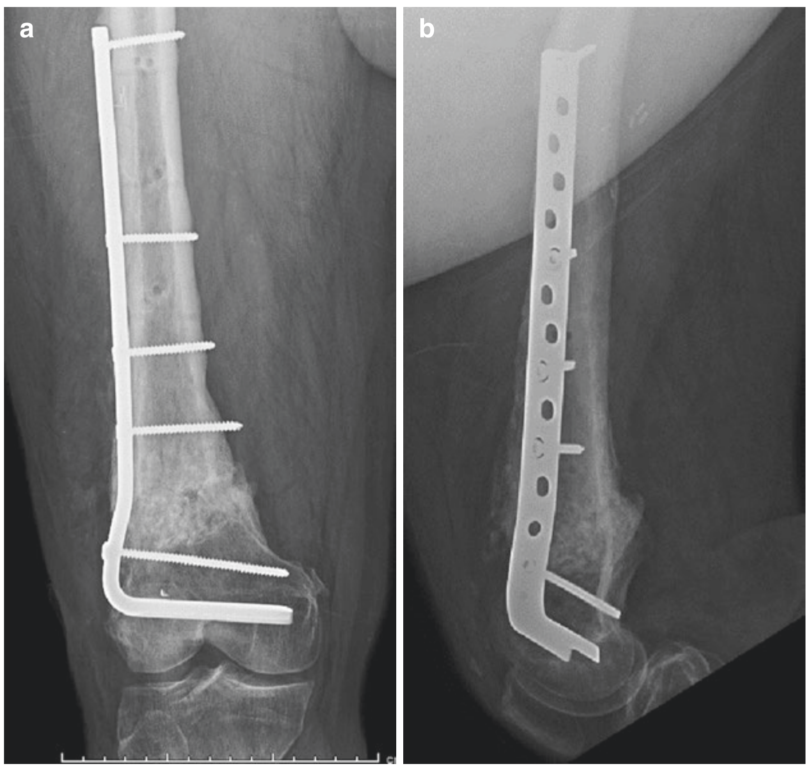

Fig. 14.10 Anteroposterior (**a**) and lateral (**b**) radiographs at 9 months following surgery

Case 4: Dynamic Condylar Screw

A 62-year-old female sustained a spiral femoral shaft fracture from a mechanical fall and subsequently underwent retrograde intramedullary nailing. At 8 weeks post-op from the retrograde nail, she was involved in a motor vehicle collision and sustained an ipsilateral unstable intertrochanteric femur fracture proximal to the previously placed nail (Fig. 14.11). A lateral approach to the hip was performed for fracture reduction. Due to the level of the retrograde nail impeding placement of a DHS, a 95° DCS implant was used to stabilize the hip fracture (Fig. 14.12).

Fig. 14.11 Intertrochanteric hip fracture proximal to a retrograde femoral nail

Why This Works

In this patient with an intertrochanteric fracture proximal to a retrograde femoral nail, preoperative templating revealed that a standard sliding hip screw would not be able to be inserted as there was interference from the nail that would block the barrel of the screw. The DCS with its 95° allowed for insertion proximal to the femoral nail. While a blade plate also could have been used, it is a more technically demanding device to insert as it cannot be rotated once inserted.

Another fixed angle plate commonly used in fracture surgery is the sliding hip screw (SHS). This is a stainless steel implant designed to treat proximal femur fractures. The device consists of a large cancellous screw that freely slides within a barrel that is attached to a side plate. The design allows for controlled collapse within a single

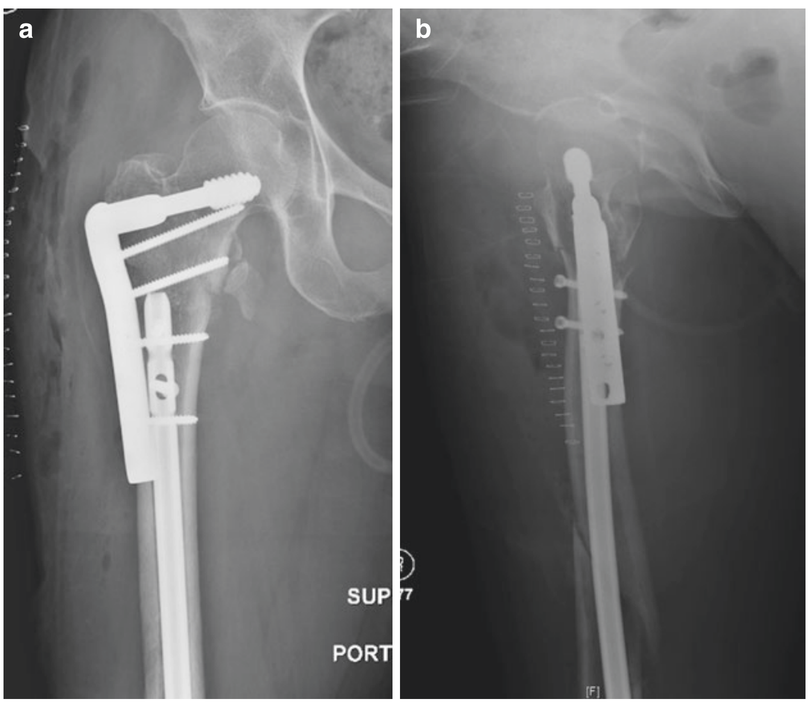

Fig. 14.12 Immediate postoperative imaging anteroposterior (**a**) and lateral (**b**) demonstrating the placement of the DCS proximal to the femoral nail

plane as the fracture heals. An anti-rotation screw can be placed prior to insertion of the SHS in order to resist rotation of the femoral head as the lag screw is inserted. However, for unstable intertrochanteric hip fractures, including reverse obliquity fractures, fractures with posteromedial comminution, subtrochanteric extension, or lateral cortex insufficiency, cephalomedullary nailing is typically chosen over SHS. These fracture patterns result in either loss of the lateral femur as a buttress or loss of resistance to medial shaft displacement. If the lateral femoral cortex is disrupted, then the sliding hip screw will fail as the telescoping along the lag screw will result in uncontrolled fracture displacement and failure.

Case 5: Sliding Hip Screw

A 62-year-old male involved in a motor vehicle collision sustained an open intertrochanteric hip fracture with an 8-cm open wound (Fig. 14.13). The wound was irrigated copiously. A subvastus lateral approach to the hip was performed. The fracture was reduced using traction and direct manipulation of fragments with large pointed reduction clamps.

A sliding hip screw with an anti-rotational screw was used for fixation (Fig. 14.14).

Fig. 14.13 Widely displaced intertrochanteric hip fracture resulting from a high-energy injury

Why This Works

The SHS, in combination with an anti-rotational screw, was successful in this high-energy intertrochanteric hip fracture as it allowed for controlled collapse along the femoral neck while maintaining fracture alignment. It should be noted that this patient had a stable, albeit high-energy, intertro-

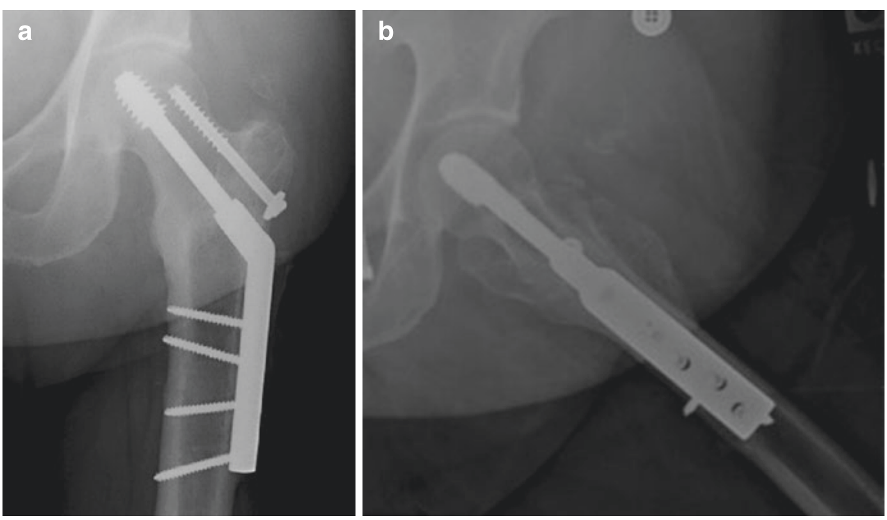

Fig. 14.14 Postoperative images including AP (**a**) and lateral (**b**) demonstrating placement of the SHS with anti-rotational screw fixation

chanteric hip fracture with an intact lateral femoral cortex that was amenable to SHS fixation. While an intramedullary device would have been another option for fixation [18], surgeons should recognize that in this high-energy patterns, closed reduction techniques are unlikely to reduce the fracture due to soft tissue injury, and open reduction will likely be necessary. Therefore, a subvastus approach was utilized to accomplish both reduction and application of fixation while providing the benefit of not violating the abductors as an intramedullary device would [3].

Conclusion

In most fractures or nonunions, surgeons have a variety of implant and techniques to choose from that can accomplish the goal of fracture healing and restoration of length, alignment, and rotation. Bridge plating can be accomplished with either locked or nonlocked plates and has the goal of providing stability while minimally disrupting soft tissues. Wave plates allow the advantage of providing access for bone grafting at fracture or nonunion sites while also providing additional stability. Fixed angle devices, including sliding hip screws, dynamic condylar screws, and blade plates, have varying degrees and ease of use, with the blade plate being the most technically challenging. They are excellent tools that orthopedic surgeons can employ and should be chosen based on the biomechanical advantages that are needed in each individual setting.

References

1. Graves M. Principles of internal fixation. In: Browner BD, Jupiter JB, Krettek C, Anderson PA, editors. Skeletal trauma: basic science, management, and reconstruction. 5th ed. Philadelphia: Elsevier; 2015. p. 221–90.
2. Gautier E. A thorough understanding of the basic concepts of fixation, the bone biology and biomechanics, remains of outstanding importance. AO Dialogue Davos Platz, Switzerland: AO Foundation. Feb 2009. https://issuu.com/aofoundation/docs/aodialogue_2009_02_14/24. Accessed 23 Oct 2019.
3. Harvin WH, Oladeji LO, Della Rocca GJ, Murtha YM, Volgas DA, Stannard JP, Crist BD. Working length and proximal screw constructs in plate osteosynthesis of distal femur fractures. Injury. 2017;48(11):2597–601.
4. Brunner CF, Weber BG. Special techniques in internal fixation. Berlin/Heidelberg: Springer; 1982.
5. Wilber JH, Baumgaertel F. Bridge plating. AO principles of fracture management. New York: Thieme; 2007. p. 287.
6. Young JP, Stover MD, Magovern B. Treatment of isolated ulnar nonunions using wave plate osteosynthesis: a report of four cases. J Orthop Trauma. 2009;23(8):595–9.
7. Ring D, Jupiter JB, Sanders RA, Quintero J, Santoro VM, Ganz R, Marti RK. Complex nonunion of fractures of the femoral shaft treated by wave-plate osteosynthesis. J Bone Joint Surg Br. 1997;79(20):289–94.
8. Ring D, Jupiter JB, Quintero J, Sanders RA, Marti RK. Atrophic unurited diaphyseal fractures of the humerus with a bony defect: treatment by wave-plate osteosynthesis. J Bone Joint Surg Br. 2000;82(6):867–71.
9. Depuy Synthes. Angled blade plate for adults. Jun 2016. Accessed 20 Oct 2018.
10. Hartline BE, Achor TS. Use of the 95-degree angled blade plate to treat a proximal femur fracture. J Orthop Trauma. 2018;32(Suppl 1):S26–7.
11. Amorosa LF, Jayaram PR, Wellman DS, Lorich DG, Helfet DL. The use of the 95-degree-angled blade plate in femoral nonunion surgery. Eur J Orthop Surg Traumatol. 2014;24(6):953–60.
12. Abebe E, Farrell DJ, Zelle B, Gruen G. Primary posterior blade plate tibiotalar arthrodesis: a salvage procedure for complex nonreconstructable pilon fractures. J Orthop Trauma. 2017;31(Suppl 3):S30–3.
13. Berkes MB, Little MT, Lazaro LE, Cymerman RM, Helfet DL, Lorich DG. Catastrophic failure after open reduction internal fixation of femoral neck fractures with a novel locking plate implant. J Orthop Trauma. 2012;26(10):E170–6.
14. Glassner PJ, Tejwani NC. Failure of proximal femoral locking compression plate: a case series. J Orthop Trauma. 2011;25(2):76–83.
15. Collinge CA, Hymes R, Archdeacon M, Streubel P, Obremskey W, Weber T, Members of the Proximal Femur Working Group of the Southeast Trauma Consortium, et al. Unstable proximal femur fractures treated with proximal femoral locking plates: a retrospective, multicenter study of 111 cases. J Orthop Trauma. 2016;30(9):489–95.
16. Crist BD, Khalafi A, Hazelwood SJ, Lee MA. A biomechanical comparison of locked plate fixation with percutaneous insertion capability versus the angled blade plate in a subtrochanteric fracture gap model. J Orthop Trauma. 2009;23(9):622–7.
17. Depuy Synthes. DHS/DCS dynamic hip screw and condylar screw system: technique guide. Westchester PA: Synthes 2012; 2018. Accessed 30 Oct 2018.
18. Niu E, Yang A, Harris AH, Bishop J. Which fixation device is preferred for surgical treatment of intertrochanteric hip fractures in the United States? A survey of orthopaedic surgeons. Clin Orthop Relat Res. 2015;473(11):3647–55.