Locked Plating in Practice: Indications and Current Concepts

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Locked plating technology has continued to evolve since its introduction into orthopaedic fracture care just over fifteen years ago. Initial indications for these new fixed angle devices included poorly mineralized bone, situations where there was significant bone loss, or in areas of structurally weaker bone such as the metaphysis. Increasing usage of these plates has pushed the indications of their application and potentially compromised the fundamental principles of fracture fixation. Biomechanical and clinical studies have helped to provide evidence for where locked plating may be most appropriate. In addition, the concepts of hybrid plating and far cortical locking have been introduced to address the concern that fracture fixation with a locked plate is too stiff and does not allow for adequate micromotion at the fracture site. Further investigation into these techniques and the types of fractures best treated with a locking plate is still needed to define the role of fixed angle locked plating in the treatment of fractures.

Why use a locked plate?

The increasing use of locked plates in fracture care has raised concern that the appropriate usage of these plates is being lost with lack of adherence to some of the basic principles of fracture fixation. The development of locking plate technology has introduced a new and exciting dimension to fracture fixation but they should be applied with specific intent and indications; as such their role is continuously being redefined. The creation of a construct where a fixed angle relationship is created at the plate-screw interface allows these devices to be used essentially as internal-external fixator. Fracture fixation therefore does not rely on the frictional forces between the undersurface of the plate and the bone created by screw purchase, as it does with a conventional plate and screw construct[1], but rather deforming forces are transferred from the bone through the plate as each screw is "locked" into the plate[2]. This eliminates screw toggle and decreases motion at the fracture site[3]. Because of these mechanical advantages, fractures can often be transfixed with less hardware placement and soft tissue dissection especially in the zone of injury. In addition, the periosteal blood supply can be preserved to a greater degree since, unlike conventional plates, compression to bone is not necessary to achieve stability[4].

Locked plates were developed in response to a need to adequately stabilize fractures where there was poor bone quality—mechanically weaker metaphyseal bone or bone effected by osteoporosis, osteomalacia or comminution—where standard bicortical screws were unable to gain sufficient purchase for maintenance of the plate-bone relationship. For example, extra-articular metaphyseal fractures with short peri-articular segments are ideal for locked-angle plating[3]. In some areas, such as the distal femur, angled blade plates and dynamic condylar screws had proven successful[6,7,8], but these devices are not appropriate for all anatomic regions and are not as successful at capturing all necessary segments of the bony injury. Early attempts at increasing fixation of conventional plates to compromised bone included injection of cement into an area where screws were to be placed and placement of a threaded washer/nut (Schuhli nut) around a conventional screw to provide angular support[9,10]. The development of the Less Invasive Stabilization System (LISS) by Synthes (Paoli, PA) in 1995 and the Locking Compression Plate (LCP) in 2000 brought the use of locking plate technology into routine fracture care[11,12,13,14,15]

The indications and uses for locking plate technology continue to be defined. One important problem to avoid is the creation of an over-stiff construct by placing locked screws when not needed (or more than what is needed). The resultant relative lack of motion at the fracture site can, in some situations, be too stiff to allow fracture healing. This has led some to refer to locking plates as "nonunion generators."[16] Thus, the indications and correct utilization of locking plates is important to understand so they are not used inappropriately and compromise fracture healing. In addition, newer techniques such as "hybrid" plating (use of both locking and nonlocking screws in a single construct) and far cortical locking (obtaining purchase in far cortex while bypassing proximal cortex) have evolved to combat these problems sometimes seen with locking plates.

Examples of current use.

Locked plating has found increasing utilization in select fractures where their use is theoretically or philosophically advantageous. From a practical standpoint, biomechanical and clinical studies continue to evaluate their benefit in a number of different fracture types and anatomic areas. Several illustrative examples of where locked plating has found wide-spread use (proximal humerus, distal radius, distal femur) are presented and discussed.

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Proximal Humerus

Fractures of the proximal humerus are the third most common fracture seen in patients older than 65 years of age[17] and are often affected by either osteopenia or osteoporosis[18]. Nearly 80% of such fractures can be treated non-operatively but when severe comminution or displacement is encountered, functional outcomes are poor without surgical intervention[19]. When arthroplasty is not indicated, locked plates allow for establishment of a fixed angle construct within the metaphyseal osteoporotic bone of the proximal humerus. Retrospective and prospective studies alike have shown favorable outcomes with use of these plates[20,21,22]. Biomechanical data has also shown that locked plates have greater axial stiffness than nonlocking plates[23]. Unfortunately, the complication of plate cutout can be seen in over 11% of all proximal humerus fractures fixed with a locked plate[24,25,26]. Loss of fixation and angulation into varus is thought to be more likely without adequate restoration of the medial "calcar"—e.g. either unreconstructable due to comminution or malreduction—a phenomenon that cannot be reliably precluded by the use of a locked plate[27]. Because of this, some have advocated use of an internal strut (e.g. fibular allograft to "replace" the injured calcar) in combination with a locking plate[28]. As locked plating is not a panacea in this area, other options such as percutaneous pinning or replacement should be carefully considered and may provide superior outcomes in select cases[29,30].

Distal Radius

In the distal radius, volar locked plating has become the most common fixation method for both intraarticular and periarticular fractures. Because a fracture of the distal radius most often occurs as an elderly fragility fracture[31], the use of locked plating provides practical and mechanical benefits in the fixation of compromised and weaker metaphyseal bone. Fixed angle screws support the articular surface, with screws placed ideally beneath the stronger subchondral bone. Use of a fixed angle plate also allows for maintenance of the soft tissue envelope around the fracture and often alleviates the need to bone graft areas of comminution[32]. Several biomechanical studies have shown that fixed angle plates provide superior strength when tested in axial compression[33] and clinical data exists which show that locking plates may restore and maintain radial length when compared to external fixation with or without supplemental pinning[34]. However, the majority of randomized clinical trials have not demonstrated the superiority of locked plating with respect to clinical outcomes when compared to other modes of fixation including external fixation[35,36]. Due to the increased stability of the construct, some have proposed that an added benefit of locked plating is the safety of early motion in their post-operative rehabilitation and possible long term improvement in overall function[37]. Successful surgical treatment of distal radius fractures can still be obtained by a variety of means and more comparative studies are needed to answer some of the questions that still remain regarding best treatment.

Distal Femur

The distal femur is an area where less invasive locked plating has found considerable use. In these areas, maintenance of periosteal blood supply can be achieved through percutaneous placement of a locked plate and screws. In a highly comminuted distal femur fracture where an intramedullary implant cannot address a short distal segment or achieve adequate reduction, a locked plate can be used with reliable success and has been proven to absorb more deforming energy than its ancestor, the angled blade plate[38,39]. Clinical evidence supports the use of locked plates to treat distal femoral fractures, including periprosthetic fractures above a total knee arthroplasty[40,41,42]. Recently, advancements in the design of locked plates now allow a certain degree of variability in the screw trajectory taken by the screws placed into the plate[43]. This allows the plates to adjust to variations in anatomy, fracture pattern and obstacles such as a knee or hip prostheses.

One can appreciate the many different areas where locked plating has found clinical relevance. This discussion is not meant to be all-inclusive (with fractures in the tibia and calcaneus also being frequently treated with a locked plate and screw devices), but rather illustrative of their use in situations where poor bone quality necessitates improved construct strength to maintain adequate fixation. As noted, even in areas where they have found greater use, one must be judicious in their application as complications can occur and not every fracture is best treated with such a device.

Hybrid plating

The utilization of both non-locking and locking screws within a single plate construct is termed hybrid plating. This practice was initially discouraged since it was thought that a plate should function as either a non-locked or locked device, but not both. As reviewed, results examining the use of locked plates versus non-locked plates in different fractures produced location specific results. Hybrid plating attempts to merge the two principles in order to optimize fracture reduction and promote healing. The overall principles of fracture reduction and fixation are unchanged. Following reduction, non-locking screws can be used to compress the plate to bone (or decrease bone-plate distance) and in some cases, help provide interfragmentary compression. Then, locking screws are placed which alter the overall stiffness of the construct and can create a fixed angle component to the system thus changing its response to biomechanical stress. There are a number of studies that have looked at this technique, some of which are highlighted here.

One of the earliest reports of hybrid construct testing in an osteoporotic model that was presented in the Journal of Bone and Joint Surgery in 2006 by Gardner et al[44]. They divided their specimens up into three groups: one group used all non-locking screws, another all locking screws used and the third group non-locking screws bracketed by locking screws. All constructs transfixed identical osteotomy sites and were tested in cyclical torsion only. They found that both the locked and hybrid constructs behaved similarly with the outlier being the non-locked group. The authors' conclusion was that hybrid plating did not compromise the construct's strength and that the technique may have economic advantages because of the higher cost of locking screws. However, they were unable to report a mechanical benefit of hybrid plating over locked plating. Similarly, Estes et al. used cadaveric tibia and compared a hybrid plate construct to an all-locked construct and tested their specimens in axial loading. They too found no significant difference between the two groups in vertical subsidence or deflection, concluding that in these types of fractures, either construct could be used reliably[45].

In another biomechanical study performed by Doornink et al., which looked at the strength of a single hybrid plate construct in comparison to a single locked plate construct, they found that the hybrid technique was significantly stronger in torsional testing[46]. The hybrid plate was also found to be stronger to resisting a 4-point bending moment but this difference was not significant. When axial loads were applied to the constructs, the hybrid plate was shown to be significantly weaker in compression. The results of this study provided some evidence to support that a hybrid construct was not uniformly stiffer or stronger than a locked plate construct. Clinically this is relevant as fractures, after fixation, are subject to different deforming forces depending on the location and weight bearing responsibility of the bone. Therefore, a hybrid technique may be appropriate in some locations, and not ideal in others.

The axial and torsional stability of hybrid fixation was tested in a diaphyseal composite sawbone model and an intra-articular distal femur cadaveric model (Stoffel et al)[47]. Their results showed that under axial compression, the internal fixation (all-locked) construct and the hybrid construct were similar to each other, and that both were superior to compression (non-locked) plating in this scenario. However, the authors' use of a steel plate with their non-locked construct and a titanium plate in both their hybrid and locked plate construct made unambiguous interpretation difficult. Interestingly they found that the non-locked specimens had less plastic deformation and a higher load to failure in both fracture models than the hybrid or locked plate construct. These mixed results led the authors to conclude that hybrid plating may have a role in the fixation of intra- or extra-articular fractures with metaphyseal comminution.

More recently, Freeman et al. investigated multiple constructs in an osteoporotic bone model and tested them in torsion to determine which pattern of screw placement yielded the stiffest construct[48]. In addition, they examined screw removal torque after testing to determine if the arrangement of screws affected this variable as well. They concluded that when using a hybrid plating technique, the utilization of three bicortical locked screws on either side of a fracture (with a plate with four plus screw per side) optimizes fatigue strength. In addition, placing a locking screw immediately inside (nearest the fracture) of a non-locking screw increases the torque needed to remove that non-locking screw, thus "protecting" it from loosening and loss of fixation.

Despite biomechanical evidence, there is no compelling clinical data in the literature that helps to define the indications or superiority of hybrid fixation over locked plating. That said, experimental studies support their use in osteoporotic fractures or fractures which have metaphyseal comminution, especially with regard to resisting torsional stress. Further documentation from human trials will help further elucidate their true clinical utility.

Far cortical locking

The concept of far cortical locking (FCL) has gained attention recently because of the continued concern that locking plates can inhibit the formation of fracture callus formation in secondary bone healing. Nonunion rates as high as 19% have been reported with some periarticular locking plates[48]. As compared to hybrid plating, where the type of screw used within the plate is locked, or non-locked; FCL refers to the technique by which the far cortex but not the near cortex is engaged by the screw—either by technique (overdrilling the near cortex) or by design (screw only has threads to engage far cortex).

Bottlang et al. recently published a review of the current biomechanical clinical research which has addressed the following questions: 1) is the stiffness of a locked construct detrimental to callus formation and fracture healing and 2) can FCL improve callus formation by providing a more flexible environment?[49] With regard to the first question, their biomechanical testing indicated that locked plates were not significantly stiffer than non-locked plates when tested under an axial load. It should be noted though that their testing did not use an osteoporotic bone model or fracture pattern/location where locking plates are routinely used. Their clinical series looked at 75 patients with fractures of the distal femur (AO 32A or 33A, B or C) who were treated with a standard locked lateral plate[50]. They reported a nonunion rate of 19% with minimum 6 months follow-up with 37% of their fractures showing very little or no callus formation. They also noted a paucity of callus formation on the lateral side of the femur, near the plate, where interfragmentary motion was most inhibited.

When the FCL construct was tested against the locking construct in a femoral diaphysis surrogate, the FCL construct was found to be 88% less stiff than the locking construct in axial loading tests[51]. In torsion and bending, the stiffness of the FCL construct was 58% and 29% less than the locking construct, respectively. In addition, they found that inter-fragmentary motion at both the near and far cortices was nearly identical and not asymmetric as in the locked plate construct. Finally, the load-displacement curve exhibited a biphasic pattern with an increase in stiffness of the FCL construct as the amount of displacement had reached a certain distance. Gardner et al. similarly compared fixation of an osteoporotic surrogate with two different fixation constructs[52]. The test construct had a slotted hole created in the proximal cortex to allow 1mm of total screw deflection in the axial plane. This was compared to locking screws placed in the usual fashion. Testing in their

FCL construct also showed no difference in fixation stability but a significant decrease in construct stiffness.

The FCL construct was also tested in a human cadaveric model with a calculated femoral osteotomy to simulate a distal femur fracture[48]. Samples had identical distal fixation but were fixed proximally in the diaphysis with locking or FCL screws. The samples were then loaded in a "quasi-physiologic" manner along the mechanical axis to assess stiffness and interfragmentary motion. Again, a significantly lower stiffness was seen with the FCL samples and similar interfragmentary motion was seen. When the samples were tested to failure, the FCL construct was as strong and as durable as the locked plates. This last aspect was important to be defined, as decreased stiffness in this situation did not mean that the FCL construct would fail earlier when tested at near maximal loads.

Finally, to test this proposed benefit of FCL in a biologic model, the authors used an ovine tibial osteotomy to test fracture healing when fixed with a locked plate or a FCL construct[53]. The animals were sacrificed at 9 weeks and callus volume and density were assessed. In addition, the mechanical strength of the healed osteotomy was tested in torsion to determine the energy required to induce failure. The researchers found that the FCL model showed significantly more callus (36%) and 44% more bone mineral content at 9 weeks. There was symmetric callus formation in the FCL group where the locked plating group showed significantly less bone mineral content (49%) at the near cortex. Finally, the FCL group was 54% stronger when tested to failure. These results were quite supportive of FCL and the ability of a construct to allow greater, and more symmetric, healing of fractures as compared to standard locking plates.

The result of this recent work on FCL has created interest from not just orthopaedic surgeons but also industry. Recently, Zimmer (Warsaw, IN) released their MotionLoc screw for the Non-Contact Bridging (NCB®) plate system[54]. In this system the screws are designed to bypass the near cortex and obtain locking screw fixation in the far cortex. They can then be locked into the plate to function like the FCL constructs which were tested in the abovementioned studies.

As with hybrid plating, much research still needs to be done to determine the role for this technology in patient care. Clinical studies will need to examine whether the results seen in the animal model can be reproduced in human subjects and the context in which (what fracture types) such a construct is most beneficial. Until then, conversation and controversy will continue to surround this new theory.

Conclusion

Locking plate technology has provided a new dimension to fracture fixation. There are certain fractures where a fixed angle construct can provide an advantage over traditional plating techniques. The proximal humerus, distal radius, and distal femur are several of the locations where use of locked plating has found support in the literature—both in biomechanical and clinical testing. Two areas of study that will need further development and support from clinical studies are hybrid plating and far cortical locking. Both techniques are concepts that build from the belief that in some situations, locked plating may be too stiff and that some motion is desirable in order to stimulate secondary callus formation. Future studies need to build upon the biomechanical framework already in place and help define the parameters of optimal fracture fixation.

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