As the philosophy for fracture management has swung away from reconstruction and rigid fixation towards preservation of fracture biology, and implants that bridge the fracture gap, it has become necessary for surgeons to understand the mechanical properties of the “bridge”, as this will impact the ability of the construct to resist a single high load and repeated lower loads, and it will influence the amount of motion that occurs in the fracture gap(s). The “span” is termed the working length, meaning the portion of the construct that must bear the load placed by the patient, without deforming or fatiguing. There have been many studies evaluating different plate types and different screw types, number and position and how they influence the ability of the construct to resist bending and torsional forces. Recognition of the weakness of the exposed span led to the concept of combining a plate and intramedullary pin (plate-rod) so that the bending strength of the construct was improved (1). Because the plate-screw-bone interaction is different for locking plates, additional studies were undertaken to examine the influence of bicortical and monocortical screws, and various combinations of locking and non-locking screws. As more minimally invasive techniques are employed, plate placement (less contouring, longer spans) and screw number and position (fewer screws located at either end of a long plate) combinations that are more compatible with those techniques have been evaluated. In some circles, plates with long working lengths were proposed based on the theory that less stiff fixation would stimulate secondary bone healing and that stress in the plate might be reduced by spreading it over the longer span. While it is true that less stiff fixation will result in greater motion between fracture fragments, the optimal amount of motion is still not known – and less stiff constructs also have a lower yield load and are, therefore, more likely to bend or fatigue.

Using surface strain measurements, Pearson and colleagues very nicely demonstrate that plate strain (and, by inference, stress) in bending is actually greater in unprotected, long working length constructs compared to shorter working length constructs (2). However, they also show that plate strain was reduced by the addition of an intramedullary pin that was 20% of the medullary diameter, and was reduced even further by pins 30% and 40% of the medullary diameter. These findings should guide plate and screw placement practices. To reduce plate stress, the working length should be minimized. Locating screws close to the fracture ends on either side of the gap will achieve this. If a long working length is present (due to fracture configuration or screw placement choices), an intramedullary pin should be placed to increase the bending strength of the construct, and reduce the possibility of plate failure.

In locking plate-rod constructs, the intramedullary pin may prevent placement of bicortical screws, particularly when a relatively large diameter pin is chosen. Using an incrementally increasing cyclic compression/bending test method that simulates the anticipated postoperative activity of a dog, Field and colleagues found that locking plate-rod constructs (with a pin of 40% medullary diameter) using only monocortical screws performed similarly to constructs with one bicortical and a range of monocortical screw numbers (3). In an earlier study, using the same cycling test method, this group showed that the stiffness of a locking plate-rod construct increased as the working length was reduced by adding screws closer and closer to the fragment ends (4). However, it is important to realize that these studies evaluated only compression/bending responses. Bicortical screws have been shown to improve resistance to torsional forces and these must be considered in the complex
loading environment of a limb (5). Working length is also a factor in resistance to torsional forces – plates with long working length will allow more shear motion at the fracture, and the intramedullary pin will not influence this property (6).

Choosing the optimal plate-screw-pin combination that will effectively support a fracture until it has healed requires a balance of understanding the loads that the patient will apply, the mechanical properties of the various components - and how they interact in combination - and the biological factors associated with each specific fracture and patient. The correct balance optimizes the functional and biological outcome for the patient.

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References