

Locking plates in veterinary orthopaedics

Beierer LH*, Glyde M

*Corresponding author

College of Veterinary Medicine, School of Veterinary and Life Science, Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia; L.Beerer@murdoch.edu.au

ABSTRACT

Locking bone plates are now being used in veterinary orthopaedics. They reflect an evolution in the principles of application, design and biomechanics from the traditional dynamic compression plate. Locking plates have replaced dynamic compression plates in human orthopaedic surgery as they offer significant biomechanical and biological advantages over standard compression plates. There are multiple locking plate systems available in the veterinary market including several veterinary procedure-specific designs. This paper reviews the biomechanics and application of locking plates relevant to veterinary orthopaedic surgery and compares three of the commonly available veterinary locking plate systems. *Aust Vet Pract* 2013;43(3):483-487

INTRODUCTION

Bone plates are utilised for osteosynthesis in the management of fractures, corrective osteotomies, osteoarthritis and oncologic surgery (Table 1).¹⁻⁴ The dynamic compression plate (DCP) has long been the standard for these procedures in both veterinary and human orthopaedic surgery. The DCP was developed and tested in animals and subsequently used in fracture management in people with the first published reports in 1969.⁵ Since then, the understanding of the biomechanics and biological impact of plate design and application has developed and resulted in the advent of locked plate designs.⁶

Locking plates were developed to address some of the problems associated with the use of DCPs in people.⁶ These problems included loss of fixation in osteoporotic bone, compression-induced resorption of bone and loss of fracture reduction when the plate was not perfectly contoured to the bone surface.^{6,7}

The aim of this review is to alert the practitioner to the availability, biomechanics, application, advantages and limitations of locking plates in veterinary orthopaedic surgery. The evolution from DCP to the locking plate design will also be described.

DYNAMIC COMPRESSION PLATE

Dynamic compression plates stabilise bone segments by converting the torque applied during screw insertion into a compression force creating high frictional resistance between the plate and the bone segment (Figure 1).⁵ Maintenance of plate compression against the bone depends on maintenance of an effective interface between the screw threads and the bone.⁸ Any decrease in bone quality that affects the integrity of the thread-bone interface can lead to loss of plate compression against the bone, loss of effective frictional contact with the bone and primary loss of fixation and instability.⁸

While maintenance of DCP compression against the bone surface is essential for maintenance of fracture stability, it has a number of detrimental effects. Compression of the DCP against the bone has been shown to compromise periosteal blood supply and cause consequent bone resorption under the plate.⁹ Compression of an imperfectly contoured DCP plate can also lead to translation or angulation of bone fragments and intraoperative loss of fracture reduction.¹⁰

Dynamic compression plates are biomechanically more suited to load-sharing fracture repairs, where physiologic fracture forces are relatively low, rather than load-bearing repairs where physiologic loads are high (Figure 1).⁶ Load-sharing is achieved

Table 1. Definitions of selected terms

Term	Definition
Biomechanics	Study of the structure and function of biological systems utilising mechanical principles
Force	A mechanical disturbance or load, and is equal to mass times acceleration
Inter-fragmentary compression	Compression of two fracture ends, often only possible in transverse fractures or osteotomies, leading to improved anatomic reconstruction and load-sharing
Load-bearing (bone)	Complete resistance of weight bearing forces across the bone plate with no load transfer to the bone column
Load-sharing (bone)	Anatomic reconstruction of the bone column enables sharing of weight bearing loads between the reconstructed bone column and the bone plate
Osteosynthesis	Fixation of a bone fracture with implantable devices to promote bone healing and union
Torque	A force that twists a structure along its longitudinal axis

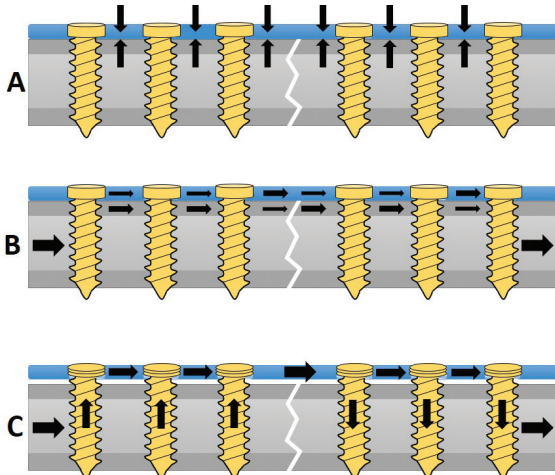


Figure 1. **A.** Conventional screws applied in a dynamic compression plate result in compression of the plate against the bone, generating friction to produce stability; **B.** As loading forces are transmitted across the bone, both the dynamic compression plate and the fracture share the force; **C.** During loading of a locked plate there is no compression of the plate against the bone, consequently the loading forces are transmitted directly from the bone into the plate via the screws resulting in a load bearing implant. This is akin to an external fixator.

when anatomic reconstruction of the bone column enables sharing of weight bearing loads between the reconstructed bone column and the bone plate.¹⁰ A load-bearing repair requires complete resistance of weight bearing forces across the bone plate with no load transfer to the bone column.

While there are obvious mechanical benefits to anatomic reconstruction, under certain fracture configurations this is not possible and when performed, can be associated with significant damage to the blood supply to the fracture site.¹¹ The damage caused to the local tissues and blood supply during anatomic reduction will prolong fracture healing and increase the likelihood of non-union.¹¹

The limited contact dynamic compression plate (LC-DCP) was introduced in the 1990's and represents a modification to the DCP design.⁸ The LC-DCP has a scalloped under-surface (Figure 2) that is proposed to allow better periosteal perfusion underneath the plate due to less contact, more evenly distributes stiffness along the plate length and permits longitudinal screw angulation of up to 80°. The DCP and LC-DCP both permit inter-fragmentary compression which maximises the mechanical properties of fractures repaired with anatomical reconstruction.¹⁰

LOCKING BONE PLATES

Unlike DCPs, locking plates do not rely on screw torque to generate and maintain compression of the plate against the bone in order to produce stability.¹² Stability in locked plates is achieved by rigid fixation of the screw to the plate.⁶ This gives rise to the term locked internal fixator (LIF) as the biomechanics of locked plates are similar to external skeletal fixators.^{13,14} This single feature of rigid fixation of the screw to the plate is the key difference between the DCP and locking plates and resolves several of the limitations of DCPs. Plate-screw stability in LIF's is most commonly achieved by thread fixation of the screw to

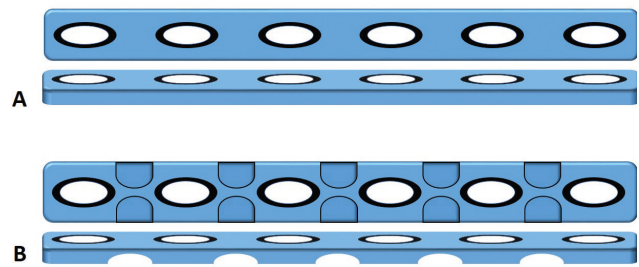


Figure 2. Underside (top) and profile (bottom) image of the dynamic compression plate and limited-contact dynamic compression plate. **A.** The dynamic compression plate is a solid length implant with holes along its length for screw placement. **B.** The limited contact-dynamic compression plate is designed with a scalloped under surface that allows better periosteal perfusion and has a more uniform stiffness than the dynamic compression plate.

the plate hole, however several other mechanisms are utilised in products available on the veterinary market.¹³

Some of the locking plate systems described in the veterinary literature include the Locking compression plate (LCP) (Synthes, Oberdorf, Switzerland), String of pearls (SOP) (Orthomed UK Ltd, Halifax, UK), Fixin (TraumaVet, Rivoli, Italy), Polyaxial Locking Plate System (PAX) (Securos, Fiskdale, MA, USA), ComPact UniLock (Synthes, Oberdorf, Switzerland) and Advanced Locking Plate System (ALPS) (Kyon, Zurich, Switzerland).¹⁵⁻¹⁷ Fixing of the screw head to the plate occurs by various methods including a matching thread between the screw head and plate hole (LCP, ComPact UniLock), matching of the screw shaft thread with the plate hole (ALPS, SOP), through a morse taper design between the conical screw head and plate hole (Fixin)¹⁸, and by a stronger screw thread (titanium alloy) cutting a thread into the weaker (pure titanium) plate hole (PAX).¹⁶

The benefits and limitations between various locking plate designs extend beyond the locking mechanism and include:

Cost and system compatibility

There is a great discrepancy between inventory costs of different systems and their compatibility with standard instrumentation. Some systems are compatible with standard compression screws and drill bits while other systems require a completely refurbished inventory.

Screw direction, dimensions and inter-fragmentary compression

Not all locking plate designs have the ability to achieve inter-fragmentary compression. Note that compression can be desirable in stabilization of corrective osteotomies and reconstruction of some fractures. The placement of angled screws is only possible with some systems. There is considerable variability in screw dimensions available in the different systems (both shaft and thread diameter) which has a direct impact on the resistance of screws to failure shear stress.¹⁹

Plate sizes and shapes

Several of the plate manufacturers supply a range of procedure-specific plates (tibial plateau leveling osteotomy, double pelvic osteotomy, arthrodesis) which can simplify application as they are of specific size and shape designed for the procedure. A range of plate sizes (length and thickness) and screw configurations are also available for various fracture configurations and animal size.

Material type

Variations in screw and plate material types (eg. stainless steel versus titanium) affects both the mechanical behaviour as well the tolerance to plate contouring.

LOCKING BONE PLATES

The most commonly used systems in veterinary orthopaedics are discussed below. Table 2 summarises the key features of several locking plate systems currently available.

Locking Compression Plate (LCP)

The LCP permits use of angled conventional (compression) screws and fixed-angle locked screws through its patented combi-hole design (Figure 3). The combi-hole is a combination of a DCP hole and a locking hole allowing the surgeon to place either a compression or a locked screw. This versatility allows the surgeon to use the LCP as a LIF, as a standard compression plate, or as a combination of both. When locked screws are placed in the LCP, they must be aligned perpendicular to the plate hole and behave as a rigid internal fixator.²⁰

String of Pearls (SOP)

The SOP system is unique as it can be contoured in six planes whereas the standard bone plate only permits bending in four planes (Figure 4). Standard cortical screws are used in all plate

holes (Figure 3). While screws must be placed perpendicular to the thread of the screw hole, angled locked screw placement through the bone is possible with precise plate contouring.²¹ Interfragmentary compression is not possible with the SOP.

Advanced Locking Plate System (ALPS)

The ALPS accepts perpendicular locked screws and angled unlocked screws but does not permit interfragmentary compression except by use of a non-locked lag screw through a plate hole.^{17,22} There is no compatibility between standard screws and the titanium ALPS plate holes (Figure 5).

POTENTIAL BENEFITS OF LOCKING PLATES OVER COMPRESSION PLATES

Locking plates do not rely on bone-to-plate friction for stability and consequently are considered to be more tolerant to higher loads than fractures repaired with a DCP. This feature also obviates the need for accurate plate contouring against the bone. The obviated need for plate contouring simplifies plate application, can reduce surgical time and facilitates the use of LIF's for minimally invasive osteosynthesis techniques. Furthermore, the absence of periosteal compression by the plate may better preserve periosteal blood supply than a compression plate.

As a general guide, fewer screws per fracture fragments are required with locking plates than with compression plates,¹⁴ which may reduce surgical time and inventory cost. When using locking plates, comminuted, diaphyseal long bone fractures can be repaired with as few as two screws per fracture fragment which would be considered high risk with a DCP repair without additional support (Figure 6).¹³ Because the plates act as a LIF, monocortical screw placement is acceptable in locking plate designs compared to their limited usefulness in a self-compressing (DCP, LC-DCP) plate design.

Table 2. Size, composition and screw availability of locking bone plates used in small animal orthopaedics

Locking System	Plate size	Plate Composition	Screw size		Screw composition
			Thread (mm)	Core (mm)	
LCP	2.0	316L SS	2.0	1.5	316L SS
	2.4		2.4	1.8	
	2.7	CP Ti	2.7	2.0	CP Ti
	3.5		3.5	2.9	
SOP	2.0		2.0	1.5	
	2.7		3.5	2.0	
	3.5		3.5	2.4	
ALPS	5/6.5	CP Ti	Standard: 1.5	Standard: 1.1	Ti-6Al-4V
	8/9		Locking: 2.4	Locking: 1.7	
	10/11		Standard: 2.4	Standard: 1.8	
			Locking: 3.2	Locking: 2.4	
			Standard: 2.7	Standard: 1.9	
			Locking: 4.0	Locking: 3.0	

LCP = Locking compression plate, SOP = String of Pearls, ALPS advanced locking plate system, 316L SS = 316L stainless steel, CP Ti = commercially pure titanium (grade 4), Ti-6Al-4V = titanium alloy (grade 5) chemical composition includes 6% aluminium, 4% vanadium

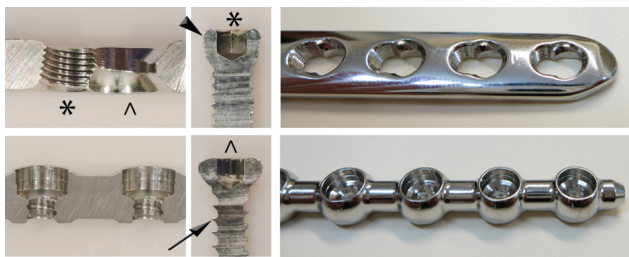


Figure 3. A view of the locking compression plate (top) and string of pearls (bottom) implants after axial sectioning. The locking compression plate has combi-hole design which permits placement of a locked screw (*) with a threaded head (arrow head) or a conventional compression screw (^). Whereas the shaft thread (arrow) of a conventional screw locks into the corresponding thread of the string-of-pearls implant.

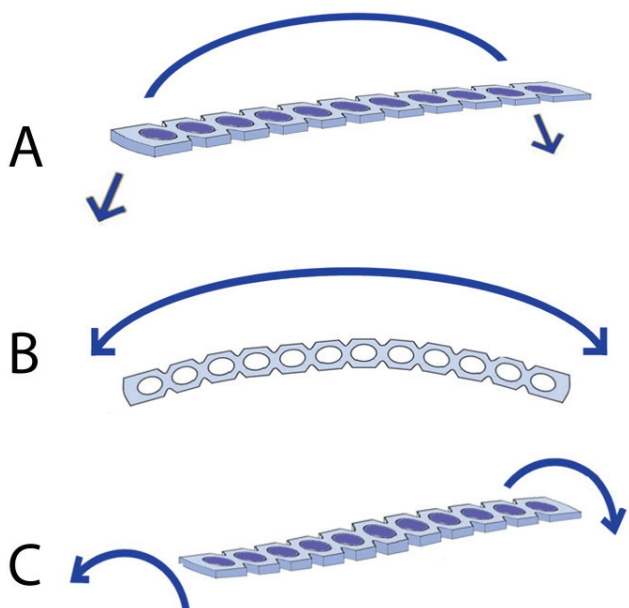


Figure 4. Various planes of contouring possible with a bone plate. **A.** Longitudinal bending around the R-S axis; **B.** Longitudinal bending around the P-Q axis; **C.** Twisting around the X-Y axis. A standard dynamic compression plate allows contouring in four planes (A,C) whereas a string of pearls plate permits contouring in all six planes.



Figure 5. The under surface of an Advanced Locking Plate System (ALPS) plate with a locking (green) and compression (yellow) screw. The shaft thread of the locking screw merges with the thread of the plate to produce a locked construct.

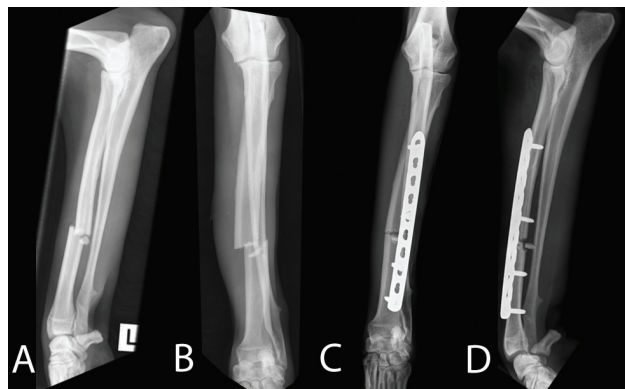


Figure 6. Pre- and post-operative medial-lateral (A) and cranio-caudal (B) radiographs of repair of a comminuted left radial fracture in a two-year-old Irish setter. A 10 hole 3.5mm narrow locking compression plate with two locked, bicortical screws per fracture fragment was placed using a minimally invasive plate osteosynthesis approach (C,D).



Figure 7. Medio-lateral (A-left) and ventro-dorsal (A-right) radiographs of repair of a comminuted left acetabular fracture in a two-year-old poodle mixed breed dog. A four hole 2.7mm string-of-pearls plate has been contoured to the dorsal aspect of the acetabulum and secured with four bicortical screws (B). The ability to bend the string-of-pearls plate in six planes was advantageous in contouring the plate to this location. Pin and wire fixation is visible following a trochanteric osteotomy for exposure during fracture repair.

APPLICATIONS

Locking plates can be used in the same circumstances that DCPs have been used. In many situations they provide significant advantages over standard compression plates. However, a thorough understanding of the differences in application of each system is important for their successful use.

Repair of long bone diaphyseal fractures is a common indication for the use of LIFs (Figure 6). They can also be implanted in the stabilisation of axial skeleton fractures (Figure 7). The improved stability of locked screws in thin and poor quality bone makes LIFs particularly useful in pelvic, spinal and scapula stabilisation. In fractures where limited bone stock is present such as juxta-articular or highly comminuted configurations, the improved biomechanical behaviour of LIFs and use of fewer screws per fracture fragment compared with compression plating is an obvious advantage.

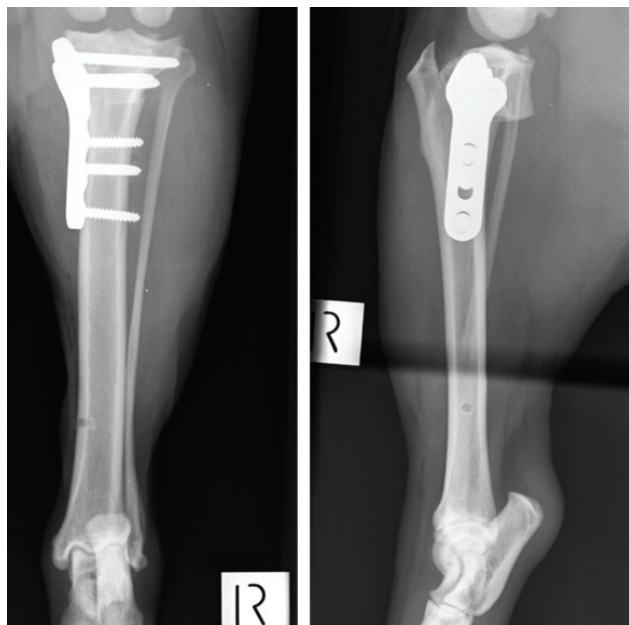


Figure 8. Cranio-caudal (left) and medial-lateral (right) radiographs of a tibial plateau levelling osteotomy in a two-year-old Staffordshire bull terrier. A 3.5mm narrow TPLO locking compression plate with four locked bicortical screws and two compression screws has been used to stabilise the osteotomy. The plate is manufactured with a contour proximally to permit placement against the medial aspect of tibia and has angled proximal screw holes to prevent intra-articular screw placement. The 4th and 6th screws are standard compression screws and have a different thread and pitch ratio compared to the 5th screw which is a locked design.

The use of procedure specific locking plates in tibial osteotomies during the surgical management of cranial cruciate ligament instability is probably the most common application and may be associated with increased stability when compared to traditional plates (Figure 8).²³

CONCLUSION

Locking bone plates are now standard implants in human orthopaedics and their use is becoming more commonplace in veterinary orthopaedics. Locked internal fixators offer several operative, mechanical and biological advantages over standard compression plates. Various locking systems are currently available in Australia. Practitioners should recognise the advantages and disadvantages of the various systems and be familiar with the specific requirements of the systems they use.

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