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Current Concepts of Internal Plate Fixation of Fractures

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Abstract. This paper presents a review of the literature related to the current concepts of internal plate fixation of fractures. Papers selected for this review were drawn from peer review orthopaedic journals. All selected papers specifically discussed plate and screw used to fracture fixation. PubMed search terms were: plates and screws, DCP, LC-DCP, PC-Fix, LCP, LISS, MIPO, and fracture fixation. We review basic plate and screw function, discuss the design rationale for the new implants.

Locked plates and conventional plates rely on completely different mechanical principles to provide fracture fixation and in so doing they provide different biological environments for healing. Locked plates may increasingly be indicated for indirect fracture reduction, diaphyseal/metaphyseal fractures in osteoporotic bone, bridging severely comminuted fractures, and the plating of fractures where anatomical constraints prevent plating on the tension side of the bone. Conventional plates may continue to be the fixation method of choice for periarticular fractures which demand perfect anatomical reduction and to certain types of nonunions which require increased stability for union.

Keywords: fracture stabilization, locked plates, conventional plates.

Bone plating has been used as a method of fracture management since the late 1800's. Stabilization of the fracture using plate requires contact surfaces between implant and bone. The first metal plate used for fractures fixation (Lane, 1895) indicated initial shortcomings such as corrosion, insufficient strength, malunion or nonunion, or a poor return to function.

Danis in 1949 recognized the need for compression between the fracture fragments. He achieved this goal using a plate he called the *coapteur*, which suppressed interfragmentary motion and increased the stability of the fixation. It led to a mode of healing he called *soudure autogène* (autogenous welding), a process now known as primary bone healing (Danis, 1949). His revolutionary concept influenced all subsequent plate designs.

Dynamic Compression Plate (DCP).

In 1958 Bagby and Janes described a plate with specially designed oval holes to provide interfragmentary compression during screw tightening. Müller *et al.* in 1965 presented another design that permitted interfragmentary compression by tightening a tensioner that was temporarily anchored to the bone and the plate. The use of the tensioner was eventually abandoned in favor of oval holes with a design similar to that of the Bagby plate.

This new design was called a dynamic compression plate (DCP). The advantages of the DCP included low incidence of malunion, stable internal fixation, and no need for external immobilization. The disadvantages of the DCP included delayed union, persistence of a microscopically detectable fracture gap that acted as a stress riser after plate removal. Cortical bone loss under the plate was another disadvantage (Uhthoff *et al.*, 2006).

Limited Contact-Dynamic Compression Plate (LC-DCP)

In 1958, a group of Swiss orthopaedic surgeons formed the Arbeitsgemeinschaft fur osteosynthesefragen (AO), also known as the Association for the Study of Internal Fixation (ASIF). The principles for fracture management developed by the AO group defined the standard of care for fracture.

The Swiss group developed a new plate design intended to reduce the plate's interference with cortical perfusion and thus decrease cortical porosis. The design was called the limited contact-dynamic compression plate (LC-DCP), which was claimed to reduce bone-plate contact by approximately 50% (Gautier and Perren, 1992). The subsequent development of the point contact fixator, PC-fix, reduced bone-plate contact to the point where it was essentially negligible and the conical screws holes that allowed the screw heads to be effectively locked into plate (Perren and Buchanan, 1995; Schutz and Sudkamp, 2003; Tepic and Perren, 1995).

The basic principles of an internal fixation procedure using a DCP or LC-DCP plate and screw system (compression method) are direct, anatomical reduction and stable internal fixation of the fracture. Wide exposure of the bone is usually necessary to gain access to and provide good visibility of the fracture zone to allow reduction and plate fixation to be performed. This procedure requires pre-contouring of the plate to match the anatomy of the bone. The screws are tightened to fix the plate onto the bone, which then compresses the plate onto the bone. The actual stability results from the friction between the plate and the bone. Anatomical reduction of the fracture was the goal of conventional plating technique (Wagner).

Only one published study has reported on actual measurements of the plate-bone contact area of the DCP and LC-DCP. Field *et al.* (1997) measured the bone-plate contact area for both DCPs and LC-DCPs fixed to cadaveric bone and found "no apparent differences in interface contact area attributed to bone plate design". This contradicts the assertion by Gautier and Perren (1992) that the LC-DCP reduces the contact area by 50%.

Jain *et al.* (1999) measured cortical blood flow with laser Doppler flowmetry of canine tibias fixed with a DCP or LC-DCP. They found no difference in cortical blood flow between the two groups supporting the findings of Field *et al.* (1997). They also reported on the biomechanical properties of the tibia and found no difference between the two groups. Jain *et al.* (1999) and Kregor *et al.* (1995) concluded that "the LCDCP is not advantageous in fracture healing or restoration of cortical bone perfusion to devascularized cortex."

Locking Compression Plate (LCP)

Most recently, based on the principle of the point contactor fixator, the locking compression plate (LCP) has been developed (Schutz and Sudkamp, 2003). The newly developed, so-called locked internal fixators consist of plate and screw systems where the screws are locked in the plate. This locking minimizes the compressive forces exerted by the plate on the bone. This method of screw-plate fixation means that the plate does not need to touch the bone (Keller *et al.*, 2005; Schwandt and Montanov, 2005; Wagner and Frigg, 2006; Wagner, 2003). Precise anatomical contouring of a plate is no longer necessary thanks to these new screws and because the plate does not need to be pressed on to the bone to achieve stability. The basic locked internal fixation technique aims at flexible elastic fixation to initiate spontaneous healing, including its induction of callus formation (Aguila *et al.*, 2005; Ahmad *et al.*, 2007; Ruedi *et al.*, 2007; Schutz and Sudkamp, 2003; Weiss *et al.*, 2008).

With reference to the mechanical, biomechanical and clinical results, the new AO LCP with combination holes can be used, depending on the fracture situation, as a compression plate, a locked internal fixator, or as an internal fixation system combining both techniques. The LCP with combination holes can also be used, depending on the fracture situation, in either a conventional technique (compression principle), bridging technique (internal fixator principle), or a combination technique (compression and bridging principles). A combination of both screw types offers the possibility to achieve a synergy of both internal fixation methods. If the LCP is applied as a compression plate, the operative technique is much the same as conventional technique, in which existing instruments and screws can be used. The internal fixator method can be applied through an open but less invasive or an Minimal Invasive Percutaneous Osteosynthesis (MIPO) approach. An indirect closed reduction is necessary when using the LCP in the internal fixator method bridging the fracture zone. A combination of both plating techniques is possible and valuable, depending on the indication. It is important to command knowledge of both techniques and their different features (Egol *et al.*, 2004).

Less Invasive Stabilization System (LISS)

Recent advancements in fracture repair within the human medical field have focused on minimally invasive fracture stabilization (Baumgaertel *et al.*, 1998; Field and Törnkvist, 2001). Based on the experience gained with the PC-Fix and LCP, a new technologies has been introduced in human orthopaedics: Less Invasive Stabilization System (LISS) and/or Minimal Invasive Percutaneous Osteosynthesis (MIPO) (Farouk *et al.*, 1998; Farouk *et al.*, 1999; Haas *et al.*, 1997; Krettek *et al.*, 2001; Schavan *et al.*, 1998).

The Less Invasive Stabilisation Systems (LISS) combine a new concept of implant with instruments for the treatment of metaphyseal fractures of long bones (Krettek *et al.*, 2001; Schavan *et al.*, 1998). The implant consists of a plate-like device and locking screws which together act as an internal fixator. An internal fixator is a construct where the screws (pins), which are the principal load-transferring elements, are locked in the plate (or frame). The forces are transferred from the bone to the fixator across the screw neck. Therefore, the blood supply of the bone under the plate is preserved as basically no (or only little) contact between the plate and the bone is needed. For stability and soft tissue reasons, the internal fixator will be placed very close to the bone. The plates are therefore pre-shaped. Special instruments and insertion guides allow the plates to be slid under the muscle. The screws are inserted percutaneously via small stab incisions, in a technique similar to that used for Bridge Plating and for Minimally Invasive Plate Osteosynthesis (MIPO). Fracture reduction and fixation proceed in two distinct steps. First, the reduction of the fracture has to be performed. Anatomical reduction is mandatory in articular fractures. In the metaphysis and shaft area, the indirect reduction is preferred. However, care has to be taken to ensure that length, rotation, and axial alignment of the main fragments are correct. The reduction must then be securely held to allow the reduced fragments to be bridged with the LISS fixator. The first LISS was developed for the treatment of distal femoral fractures (LISS-DF) (Schavan *et al.*, 1998).

Minimally Invasive Percutaneous Plate Osteosynthesis (MIPO)

A new method of bone plating has evolved that allows a plate to be applied through small incisions made remote from the fracture site. This technique conforms to the principles of biological osteosynthesis since the fracture site in not exposed and only minimally disturbed (Palmer, 1999; Perren, 2002 36). The technique has been termed minimally invasive percutaneous plate osteosynthesis (MIPO), and has also been referred to as percutaneous plating (Hudson *et al.*, 2009; Krettek *et al.*, 2001; Miclau and Martin, 1997; Redfern *et al.*, 2004; Tong and Bavonratanvech, 2007).

Percutaneous plating involves the application of a bone plate, typically in a bridging fashion, without making an extensive surgical approach to expose the fracture site (Ruedi *et al.*, 2007; Wagner and Frigg, 2006). The bone segments are reduced using indirect reduction techniques (Borg *et al.*, 2004; Hudson *et al.*, 2009). Small plate insertion incisions are made at each end of the fractured bone and an epiperiosteal tunnel connecting the incisions is created. The plate is inserted through one of the insertion incisions and slid through the tunnel along the periosteal surface of the bone, spanning the fracture site. Screws are applied at the proximal and distal ends of the plate through the insertion incisions, or if necessary, through additional stab incision.

As with most techniques, there are both advantages and disadvantages associated with MIPO. Operative time is reduced compared to anatomic reconstruction once familiarity with the procedure is developed (Schmokel *et al.*, 2003; Schmokel *et al.*, 2007). Minimally invasive procedures carry a lower risk of bacterial infection in comparison to open reconstruction procedures due to shorter duration of surgery, limited iatrogenic soft tissue trauma, and decreased potential for intra-operative contamination of the fracture site (Arens *et al.*, 1999; Aron *et al.*, 1995; Eugster *et al.* 2004; Hudson *et al.*, 2009; Wagner and Frigg, 2006). The preservation of the fracture trauma haematoma during surgery may contribute to an increased rate of callus formation. Mizuno et al demonstrated in a rat model that the fracture haematoma possesses inherent osteogenic properties (Mizuno *et al.*, 1990). Cadaveric studies showed that perforating arteries are preserved to a much greated extent when using MIPO techniques in comparison to conventional plating, resulting in conservation of the periosteal blood supply, which in turn may contribute to an increased rate of fracture healing (Borrelli *et al.*, 2002; Farouk *et al.*, 1998; Farouk *et al.*, 1999). The results of these studies, however, should be interpreted cautiously as none of these studies evaluated periosteal blood flow under in vivo conditions. Fractures stabilized with MIPO should heal in a similar manner to fractures stabilized with external skeletal fixation applied in a closed fashion (Claes *et al.*, 1999), but the former would require less patient and fixator care in the post-operative convalescence period (Aron and Dewey, 1992, Hudson *et al.*, 2009; Marcellin-Little, 1999). There are several studies that provide support for the hypothesis that the healing of fractures managed by MIPO is more rapid than with conventional plating techniques. In a femoral fracture model study performed in sheep, biological plating techniques yielded shorter times to union than fractures stabilized with anatomic reconstruction and plating (Baumgaertel *et al.*, 1998). Furthermore, a retrospective study evaluating fracture repairs in 35 dogs found that bridging plate fixation resulted in a significantly shorter time to union than anatomic reconstruction and plate fixation (Johnson *et al.*, 1998). A clinical trial in human patients with displaced intra-articular radial fractures demonstrated that indirect reduction and precutaneous plate osteosynthesis resulted in a more rapid return to function and a better functional outcome than management of fractures with open reduction and internal fixation (Kreder *et al.*, 2005). Also, pain may be reduced during the post-operative period compared to traditional plating because of the limited skin incision and manipulation of bone segments required during MIPO (51).

There are some obvious disadvantages associated with MIPO (Cabassu, 2001; Lau *et al.*, 2007; Post *et al.*, 2008; Sarraun *et al.*, 2007). The technique can be technically challenging to learn and apply (Hudson *et al.*, 2009; Pozzi *et al.*, 2008). Minimally invasive plate osteosynthesis may be less suitable for simple and articular fractures that require precise anatomic reduction and interfragmentary compression (Hudson *et al.*, 2009; Schatyker, 1995; Wagner and Frigg, 2006). Minimally invasive plate osteosynthesis does not allow direct observation of the fracture fragments; therefore, access to intra-operative fluoroscopy or radiography greatly facilitates the surgical procedure. Unfortunately, the use of fluoroscopy has greatly in creased the amount of radiation exposure for the surgery team and the patient (Hudson *et al.*, 2009; Ruedi *et al.*, 2007).

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REFERENCES

1. Aguila, A. Z., J. M. Manos, A. S. Orlansky *et al.* (2005). In vitro biomechanical comparison of limited contact dynamic compression plate and locking compression plate. Vet. Comp. Orthop. Traumatol. 18:220-226.

2. Ahmad, M., R. Nanda, A. S. Bajwa *et al.* (2007). Biomechanical testing of the locking compression plate: When does the distance between bone and implant significantly reduce construct stability?. Injury. 38:358-364.

3. Arens, S., C. Kraft, U. Schlegel *et al.* (1999). Susceptibility to local infection in biological internal fixation. Experimental study of open vs minimally invasive plate osteosynthesis in rabbits. Arch. Orthop. Trauma Surg. 119:82-85.

4. Aron, D. N. and C.W. Dewey (1992). Application and postoperative management of external skeletal fixators. Vet. Clin. North Am. Small Anim. Pract. 22:69-97.

5. Aron, D. N., R. H. Palmer and A. L. Johnson (1995). Biologic strategies and a balanced concept for repair of highly comminuted long bone fractures. Comp. Cont. Edu. Small Anim. 17:35-47.

6. Bagby, G. W. and J. M. Janes (1958). The effect of compression on the rate of fracture healing using a special plate. Am. J Surg. 95:761–71. doi: 10.1016/0002-9610(58)90625-1. [PubMed]

7. Baumgaertel, F., M. Buhl and B. Rahn (1998). Fracture healing in biological plate osteosynthesis. Injury. 29(Suppl 3):C3-6.

8. Borg, T., S. Larsson and U. Lindsjo (2004). Percutaneous plating of distal tibial fractures. Preliminary results in 21 patients. Injury. 35:608-614.

9. Borrelli, J., W. Prickett, E. Song *et al.* (2002). Extraosseous blood supply of the tibia and the effects of different plating techniques: a human cadaveric study. J. Orthop. Trauma. 16:691-695.

10. Cabassu, J. P. (2001). Elastic plate osteosynthesis of femoral shaft fractures in young dogs. Vet. Comp. Orthop Traumatol. 14:40-45.

11. Claes, L., U. Heitemeyer, G. Krischak *et al.* (1999). Fixation technique influences osteogenesis of comminuted fractures. Clin. Orthop. Relat. Res. 365:221-229.

12. Danis, R. (1949). Théorie et pratique de l'ostéosynthèse. Masson, Paris.

13. Egol, K. A., E. N. Kubiak, E. Fulkerson *et al.* (2004). Biomechanics of locked plates and screws. J. Orthop. Trauma. 18:488-493.

14. Eugster, S., P. Schawalder, F. Gaschen *et al.* (2004). A prospective study of postoperative surgical site infections in dogs and cats. Vet. Surg. 33:542-550.

15. Farouk, O., C. Krettek, T. Miclau *et al.* (1998). Effects of percutaneous and conventional plating techniques on the blood supply to the femur. Arch. Orthop. Trauma. Surg. 117:438-441.

16. Farouk, O., C. Krettek, T. Miclau, P. Schandelmaier, P. Guy and H. Tscherne (1999). Minimally invasive plate osteosynthesis: does percutaneous plating disrupt femoral blood supply less than the traditional technique? J. of Orthopaedic Trauma. 13:401-406.

17. Field, J. R., T. C. Hearn and C. B. Caldwellm (1997). Bone plate fixation: an evaluation of interface contact area and force of the dynamic compression plate (DCP) and the limited contact-dynamic compression plate (LC-DCP) applied to cadaveric bone. J. Orthop. Trauma. 11:368–373.

18. Field, J. R. and H. Törnkvist (2001). Biological fracture fixation: a perspective. Vet. Comp. Orthop. Traumatol. 14:169-178.

19. Gautier, E. and S. M. Perren (1992). Die limited contact dynamic compression plate (LC-DCP): Biomechanische Forschung als Grundlage des neuen Plattendesigns. Orthopade. 21:11–23.

20. Haas, N. P. *et al.* (1997). LISS – a new internal fixator for distal femoral fractures. "(in German)". O. P. Journal. 13:340–344.

21. Hudson, C. C., A. Pozzi and D. D. Lewis (2009). Minimally invasive plate osteosynthesis: Applications and techniques in dogs and cats. Vet. Comp. Orthop. Traumatol. 3:175-182.

22. Jain, R., N. Podworny, T. M. Hupel, J. Weinberg and E. H. Schemitsch (1999). Influence of plate design on cortical bone perfusion and fracture healing in canine segmental tibial fractures. J. Orthop. Trauma. 13:178–86.

23. Johnson, A. L., C. W. Smith and D. J. Schaeffer (1998). Fragment reconstruction and bone plate fixation versus bridging plate fixation for treating highly comminuted femoral fractures in dogs: 35 cases (1987-1997). J. Am. Vet. Med. Assoc. 213:1157-1161.

24. Keller, M. A., K. Voss and P. M. Montanov (2005). The ComPact UniLock 2.0/2.4 system and its clinical application in small animal orthopedics. Vet. Comp. Orthop. Traumatol. 18:83-93.

25. Kreder, H. J., D. P. Hanel, J. Agel *et al.* (2005). Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: a randomised, controlled trial. J. Bone Joint Surg. Br. 87:829-836.

26. Kregor, P. J., D Senft, D. Parvin, C. Campbell, S. Toomey, C. Parker, T. Gillespy and M. F. Swiontkowski (1995). Cortical bone perfusion in plated fractured sheep tibiae. J. Orthop. Res. 13(5):715-724.

27. Krettek, C., M. Muller and T. Miclau (2001). Evolution of minimally invasive plate osteosynthesis (MIPO) in the femur. Injury. 32(Suppl 3):C14-23.

28. Lane, W. A. (1895). Some remarks on the treatment of fractures. B. M. J. 1:861–863. doi: 10.1136/bmj.1.1790.861. [PubMed]

29. Lau, T. W., F. Leung, C. F. Chan *et al.* (2007). Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures. Int. Orthop. 32:697-703.

30. Marcellin-Little, D. J. (1999). Fracture treatment with circular external fixation. Vet. Clin. North Am. Small Anim. Pract. 29:1153-1170.

31. Miclau, T. and R. E. Martin (1997). The evolution of modern plate osteosynthesis. Injury. 28(Suppl 1):A3-6.

32. Mizuno, K., K. Mineo, T. Tachibana *et al.* (1990). The osteogenetic potential of fracture haematoma. Subperiosteal and intramuscular transplantation of the haematoma. J. Bone Joint Surg. Br. 72:822-829.

33. Müller, M. E., M. Allgöwer and H. Willenegger (1965). Technique of internal fixation of fractures. P. 47–51. In: Compression fixation with plates. Springer, Berlin.

34. Palmer, R. H. (1999). Biological osteosynthesis. Vet. Clin. North Am. Small Anim. Pract. 29:1171-1185, vii.

35. Perren, S. M. and J. S. Buchanan (1995). Basic concepts relevant to the design and development of the point contact fixator (PC-Fix). Injury. 26(Suppl 2):S-B-1–4.

36. Perren, S. M. (2002). Evolution of the internal fixation of long bone fracture. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J. Bone Joint Surg. Br. 84:1093-1110.

37. Post, C., T. Guerrero, K. Voss *et al.* (2008). Temporary transarticular stabilization with a locking plate for medial shoulder luxation in a dog. Vet. Comp. Orthop. Traumatol. 21:166-170.

38. Pozzi, A., C. C. Hudson and D. D. Lewis (2008). Minimally invasive plate osteosynthesis: Initial clinical experience in 16 cases. Proceedings of the Annual Conference of the Veterinary Orthopaedic Society. 9-14.

39. Redfern, D. J., S. U. Syed and S. J. Davies (2004). Fractures of the distal tibia: minimally invasive plate osteosynthesis. Injury 35:615-620.

40. Ruedi, T.P., R. Buckley, and C. G. Moran (2007). AO principles of fracture management, p. 199-210. In: volume 1-Principles. 2nd ed. Clavadelerstrasse, AO Publishing.

41. Sarraun, S., F. Meige and A. Autefage (2007). Treatment of femoral and tibial fractures in puppies by elastic plate osteosynthesis. A review of 17 cases. Vet. Comp. Orthop. Traumatol. 20:51-58.

42. Schatyker, J. (1995). Changes in the AO/ASIF principles and methods. Injury. 26(Suppl 2):B51- 56.

43. Schavan, R. *et al.* (1998). LISS-The Less Invasive Stabilization System for Metaphyseal Fractures of Femur and Tibia. O.T.A. Poster #1. Vancouver B.C.

44. Schmokel, H. G., K. Hurter and P. Schawalder (2003). Percutaneous plating of tibial fractures in two dogs. Vet. Comp. Orthop. Traumatol. 16:191-195.

45. Schmokel, H. G., S. Stein, H. Radke *et al.* (2007). Treatment of tibial fractures with plates using minimally invasive percutaneous osteosynthesis in dogs and cats. J. Small Anim. Pract. 48:157-160.

46. Schutz, M. and N. P. Sudkamp (2003). Revolution in plate osteosynthesis: new internal fixator systems. J. Orthop. Sci. 8:252-258.

47. Schwandt, C. S. and P. M. Montanov (2005). Locking compression plate fixation of radial and tibial fractures in a young dog. Vet. Comp. Orthop. Traumatol. 18:194-198.

48. Tepic, S. and S. M. Perren (1995). The biomechanics of the PC-Fix internal fixator. Injury. 26(Suppl 2):S-B5–10.

49. Tong, G. and S. Bavonratanvech (2007). AO manual of fracture management: minimally invasive plate osteosynthesis (MIPO). Clavadelerstrasse: AO Publishing. 3-7.

50. Uhthoff, H. K., P. Poitras and D. S. Backman (2006). Internal plate fixation of fractures: short history and recent developments. J. Orthop Sci. 11(2):118-126.

51. Wagner, M. and R. Frigg (2006). AO manual of fracture management, internal fixators: concepts and cases using LCP and LISS. Clavadelerstrasse: AO Publishing. 1-57.

52. Wagner, M. (2003). General principles for the clinical use of the LCP. Injury. 34 Suppl 2:B31-42.

53. Weiss, D. B., S. G. Kaar, E. P. Frankenburg *et al.* (2008). Locked versus unlocked plating with respect to plate length in an ulna fracture model. Bull. N.Y.U. Hosp. Jt. Dis. 66:5-8.