# Fixation of Osteoporotic Fractures in the Upper Limb with a Locking Compression Plate

## Stabilizace osteoporotických zlomenin horní končetiny pomocí úhlově stabilní uzamykatelné dlahy (LPC) – přehled současných přístupů

**NEUHAUS, V., KING, J. D., JUPITER, J. B.**

Hand and Upper Extremity Service, Massachusetts General Hospital, Orthopaedic Surgery, Boston, Massachusetts, USA

## SUMMARY

Locking Compression Plate (LCP) has the advantageous feature that screws can be locked in the plate leaving an angular stable construct. There is no need to have contact between the plate and the bone to achieve stability resulting from friction of the plate-bone-construct. Therefore the plate does not need to be contoured exactly to the bone and the healing bone's periosteal blood supply is not affected. The LCP is used as a bridging plate to gain relative stability in multi-fragmentary, diaphyseal or metaphyseal fractures. Depending on the fracture, the combination hole can also allow the LCP to achieve absolute stability similar to conventional fixation techniques.

Osteoporotic fractures have significant impact on morbidity and mortality. Proximal humeral and distal radius fractures are typical examples. These osteoporotic and often comminuted fractures are ideal settings/indications for LCP utilization in the upper extremity. However, the data quality is due to mostly small study populations not so powerful. Unquestionably there has been a clear and fashionable trend to choose operative treatment for these fractures, because the angular stability allows stable fixation and early functional mobilization.

**Key words:** concepts, current, fractures, Locking Compression Plate, osteoporotic, review.

## INTRODUCTION

Reconstruction of complex fractures and nonunions in the upper limb in the elderly patient with underlying osteoporosis and prior to the development of the Locking Compression Plate (LCP) was challenging (20, 23). The development of LCP in the last ten years has dramatically changed the treatment not only of distal radius and proximal humeral fractures, but also of complex fractures and nonunions (Fig. 1a–f). This article will present an overview about the principles of LCP and the current concepts utilizing LCP in treating osteoporotic upper extremity fractures.

## LCP

Locking Compression Plate (LCP) has the advantageous feature that screws can be locked easily in the plate achieving an angular stable construct. There is no need to have contact between the plate and the bone to get stability resulting from friction of the plate-bone-construct (42). As a consequence the plate does not need to be contoured as exactly as possible to the bone. Another advantageous aspect of this technique is that the healing bone's periosteal blood supply is not affected. The LCP is broadly used as a bridging plate to gain relative stability in multi-fragmentary diaphyseal or metaphyseal fractures (12). An open approach is possible, but a less invasive, as in MIPO (minimal invasive plate osteosynthesis), is preferred and affords less harm to the soft-tissue coverage. The reduction is mostly achieved by indirect means. Yet there are important features to be considered according to Gauthier and Sommer (12). First the plate must be of appropriate length. The proportion of plate length and fracture length has to be considered. They concluded that the plate length should be 2 to 3 times the fracture length in comminuted fractures and 8 to 10 times in simple fractures. Second the plate must be positioned well, so that all the screws can be adequately positioned in the bone to maximize anchorage of the bicortical screws. Third the appropriate number of screws is needed, usually three on each main frag-
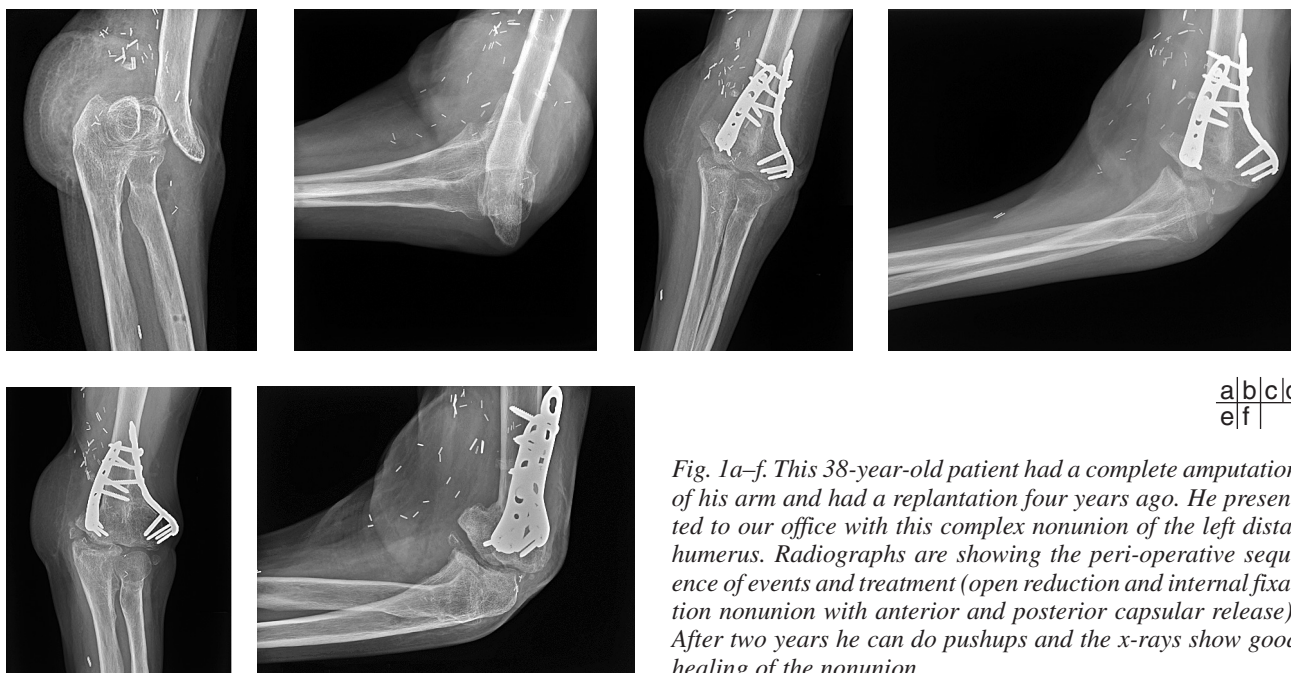
a|b|c|d
e|f

*Fig. 1a–f. This 38-year-old patient had a complete amputation of his arm and had a replantation four years ago. He presented to our office with this complex nonunion of the left distal humerus. Radiographs are showing the peri-operative sequence of events and treatment (open reduction and internal fixation nonunion with anterior and posterior capsular release). After two years he can do pushups and the x-rays show good healing of the nonunion.*

ment. One last issue is the complete loss of the surgical feeling of the quality of the bone during screw insertion and tightening.

Depending on the fracture, the combination hole can allow the LCP to achieve absolute stability similar to conventional open reduction and internal fixation techniques using Low Contact Dynamic Compression Plates (LC-DCP). The main indications therefore are articular fractures or simple diaphyseal (AO type A) fractures (42). However, a precise contouring is mandatory in this situation. In osteoporosis the loss of reduction is often encountered with conventional plate-screw-

bone-constructs due to the thin bone cortex and consecutively short working length of the screws in the cortex (12). This leads to malalignment and in the case of instability to nonunion. A combination of conventional and locking screws is possible and is showed in diagram 1. Anatomical reduction is achieved with the precise contoured plate and conventional screws. Supplemental locking head screws improve the pullout forces of the osteosynthesis and the resistance against bending and torsion.

Another example of the combination of conventional and locking screws is the use of absolute and relative
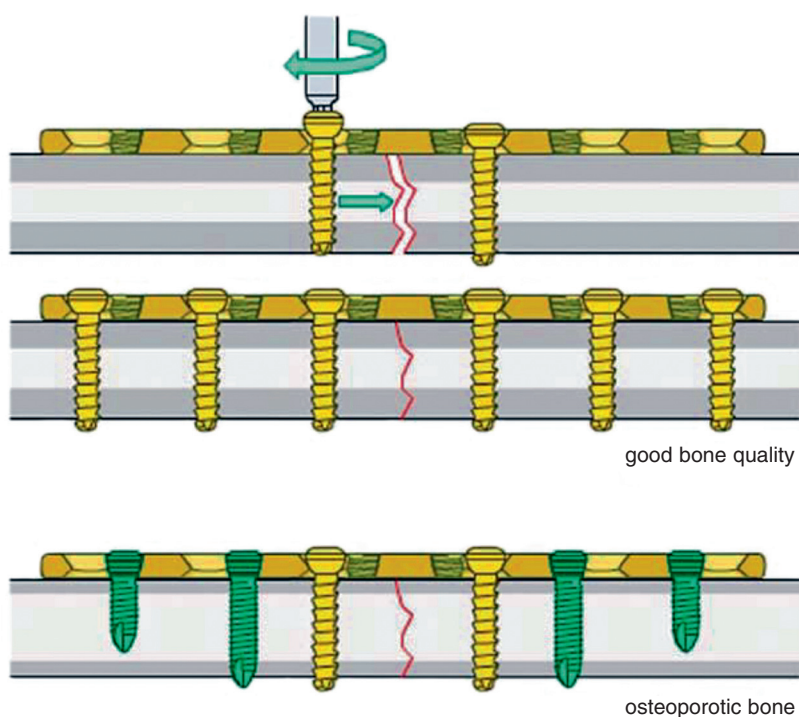


good bone quality

osteoporotic bone

*Diagram 1. In osteoporosis loss of reduction is often encountered with conventional plate-screw-bone-constructs due to the thin bone cortex and consecutively short working length. A combination of conventional and locking screws is possible. (Reprinted from Injury, Int. J. Care Injured, Vol 34, Michael Wagner, General principles for the clinical use of the LCP, Page No. S-B35, Copyright (2003), with permission from Elsevier).*

stability in articular fractures with extension into the diaphysis (42). The articular component can be fixed with absolute stability using conventional screws whereas the metaphyseal / diaphyseal part is bridged (relative stability) while adhering to the locking compression technique.

LCP is mainly used in proximal humeral, distal radius, distal ulna, peri-articular metacarpal, phalangeals, osteopenic, or comminuted / multifragmentary diaphyseal fractures, and reconstructions in case of nonunion and malunion (37). In the next section we focus on a few of these topics

## Osteoporotic fractures

Osteoporotic fractures have significant impact on morbidity and mortality as well as social and economic implications (2, 10, 14, 44). Patients with osteoporotic fractures have also an increased risk having a second fracture in the future (10). Typical osteoporotic fractures of the upper extremity are proximal humeral and distal radius fractures. The lifetime risk of suffering a proximal humeral fracture is nearly 14% in a standard European city (25). The risk for distal forearm fractures (22%) is higher in women while the risk in men is usually lower than 6%. The prevalence of osteoporosis in women with distal radius fractures can be as high as 34% (31). Because it is considerably higher compared to control groups it may therefore be seen as a risk factor for these fractures. These fractures occur classically in elder patients after a fall and subsequently from the direct fracturing impact (32). Due to the growing numbers of older and active people, treating physicians are more often confronted with these osteoporotic fractures.

Elderly patients are best served by rapid, definitive fracture care allowing mobilization. The fixation of these osteoporotic bones may therefore call for modifications of plate fixation (longer plates, blade modification, cement, 6.5 mm cancellous screws, or allograft struts)
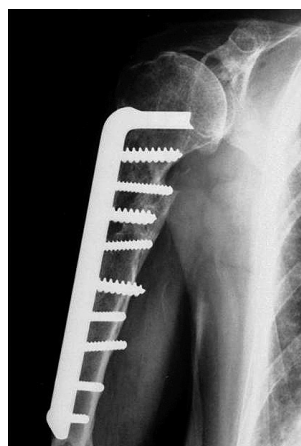
(Fig. 2a–e). Especially osteoporotic and often comminuted fractures are ideal indications for LCP in the upper extremity (40) (Fig. 3a–c). LCP therefore has greatly influenced the treatment of these fractures. Because of the angular stability it allows stable fixation and early functional mobilization.

Osteoporosis, the stability of the osteosynthesis in osteoporotic fractures, soft tissue quality, comorbidities, and the age of these patients can impair bone healing (5, 13). Bisphosphonates (up to 5 years) and calcium-supplements are therapeutic and preventive in osteoporosis. Therefore they can reduce the overall risk of fractures, however the effect on bone healing is controversial. In addition, long-term bisphosphonates can promote atypical femoral fractures as recently published data shows, but the absolute risk is small (38, 39). There are so far no atypical fractures reported in the upper extremity.

### *Proximal humeral fractures*

Hertel emphasized the main difficulties in proximal humeral fractures as there being a weak bone, a tendency towards comminuted fractures, and reduced patient's compliance (17). These issues are ideal indications for locking plates as discussed earlier.

Neer distinguished fractures with no or minimal displacement (Neer I) versus displaced fractures (displaced more than 1 cm or angulated more than 45 degrees). The displaced fractures are - based on the fracture localization and the amount of segments - further subdivided (Neer II - VI) (29). As a basic principle non or minimally displaced proximal humerus fractures can be treated non-operatively with excellent or good results in nearly 90% (11). In contrast, conservative treatment of displaced proximal humeral fractures can lead to a worse outcome. Therefore the number of fragments and their displacement influences the decision to proceed with operative treatment. The indication for operative treat-
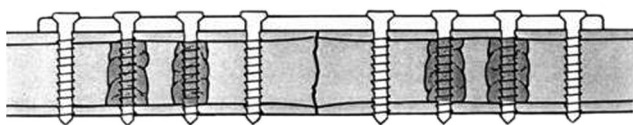


a|b|c|d
e|

*Fig. 2a–e. The fixation of fractured osteoporotic bones may call for modifications of plate fixation: longer plates, blade modifications, 6.5 mm cancellous screws, allograft struts, or cement.*
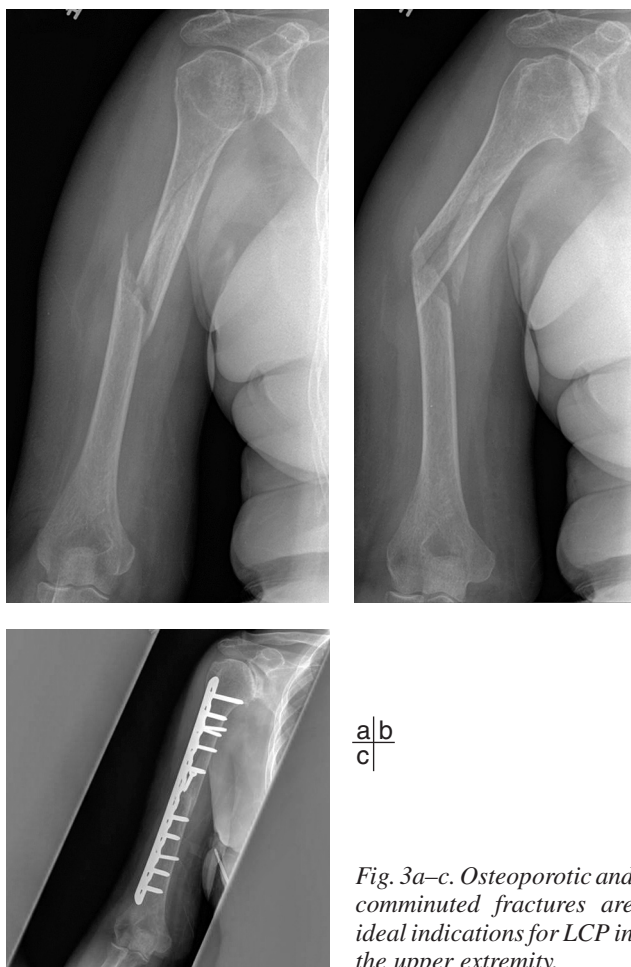
*Fig. 3a–c. Osteoporotic and comminuted fractures are ideal indications for LCP in the upper extremity.*

ment not only depends on these criteria, but also on many other factors not limited to but including the existence of osteoporosis, the predictors of humeral head perfusion (Hertel criteria), and the preference of the surgeon or institution. However, the quality of published studies is due to mostly small study populations sometimes not ideally powered (15).

Open reduction and internal fixation is the most popular surgical method, whereas percutaneous pinning is not widely used (34). Internal fixation can be achieved via conventional or locking techniques. The delto-pectoral approach is mostly used. Worse outcome can result from loss of reduction, malunion or even nonunion due to loosening of conventional screws and plates. In contrast, angular-stable implants have biologic and biomechanical advantages as well as fewer complications compared to conventional fixation techniques (33). In many biomechanical studies the angular-stable plates showed significantly greater stiffness, higher load before failure and significantly less displacement at higher loads than conventional plates (4, 35). An excellent or good functional outcome can therefore be achieved in 92% of patients with two or three part fractures treated with LCP after an average time to union of 18 weeks (40). Patients attained nearly 90% range of motion compared with the uninjured shoulder in a recently published long-term follow-up study (18).

However, the reoperation rate was 29%. This high reoperation rate is consistent with other studies (16, 18, 43). Screw penetration, varus fracture collapse, subacromial impingement, and loosening of implant were mentioned as indications for revision surgery (33, 34, 40). Screw penetration in 16% was the major complication in a retrospective analysis. We agree with the authors that the appropriate number and length of screws are of great importance (8). More displaced fractures, initial varus fracture configuration and reduced head vascularity were the main risk factor for failure (16). In addition to the high reoperation rate, up to 18% can demonstrate a fair result due do pain or restricted abduction. The most predictive factors for these insufficient results were revision surgery and increasing age (18). Additionally, studies from Norway and Sweden showed no functional benefit after one year of operative treatment even in displaced proximal humeral fractures (9, 45).

As a result, the complication and reoperation rates need to be estimated in every patient. The indication to proceed with surgery is crucial and as mentioned by Yang et al. that larger study cohorts are needed to better crystallize the ideal indications (43).

Hemiarthroplasties are usually indicated in non-restorable situations (complex head split fractures, osteoporosis, avascular head) and as a salvage option. One study compared the 2-years results of hemiarthroplasty versus non-operative treatment of displaced 4-part proximal humeral fractures in elderly patients. The quality of life was significantly higher in the hemiarthroplasty group due to less pain, but the range of motion was similar (30).

### Distal radius fractures (Fig. 4a–f)

Distal radius fractures have a great impact on functional independence in elderly patients. Casting of distal radius fractures affected functional outcome in older patients more than in younger patients. The functional outcome as well as the satisfaction - but not the x-ray - were yet similar for open reduction and internal fixation vs. casting in unstable distal radius fracture in elderly people after a follow-up period of one year (1).

To proceed with the ideal treatment, it is fundamental to understand the fracture pattern as well as the patient. Different classification-systems evolved over time and greatly help us to improve the comprehension of these fractures and their stability. The fracture stability and reduction, the presence of associated injuries and patient factors mainly guide the treatment (19). However the treatment is debatable, the trials lack adequate power and the indication to operate is beyond the focus of this review (21, 27). Unquestionably there has been a clear trend towards operative treatment of distal radius fractures.

Before the development of LCP the dorsal approach was preferred for dorsally displaced distal radius fractures. The conventional plate was used as a buttress plate. Additionally a dorsal incision of the joint capsule allowed visualizing the adequacy of the open reduction of

*Fig. 4a–f. A comminuted distal radius fracture in a 52-year-old woman with osteoporosis. Pre- and postoperative anteroposterior and lateral radiographs after volar locking plate fixation as well as after one year.*

intra-articular fractures. However, the positioning of the plate can cause tendinitis and tendon ruptures and are therefore often removed typically after six months (26). Currently, the dorsal approach is rarely used and the main indications are displaced dorso-ulnar fragments, need for repair of carpal ligaments, and articular surface reconstructions. For the volar approach, the incision is made between the flexor carpi radialis and the radial artery, then the pronator elevated and the fracture identified, reduced, and fixed.

A biomechanical study showed superiority of volar locked plating versus dorsal non-locked plating in distal radius fracture (3). These results are more distinct in osteoporotic fractures (24). A recent study comparing volar versus dorsal approach and internal fixation with locking plates in 305 patients revealed an earlier and better functional outcome in the volar group (27). However, the complication rate in the volar treated group was considerably higher (15% vs. 5%). Mostly transient soft tissue / wound problems were encountered. Loss of reduction and fracture healing problems were seen in less than 2%. A multicenter prospective case series in 125 patients treated with open reduction and internal

fixation with a volar 2.4 mm locking plate showed good-to-excellent outcomes with low complication rates (22). Motion, grip strength, satisfaction, Gartland and Werley score, and DASH-score were measured as outcome variables. Loss of reduction, malunion, and nonunion were encountered in less than 3%.

The choice of the plate most likely does not affect the outcome. A study comparing a titanium 2.4 mm pre-contoured plate with that of a stainless-steel oblique 3.5 mm T-shaped plate revealed similar results (41).

The main goal in operative treatment is definite and stable fixation of the fracture. The most important provider of stability in volar plate fixation remains yet the subchondral positioning of the screws (6). More screws seem also more stable in osteoporotic bones. Loss of volar tilt as a consequence of malpositioned screws can cause reduced range of motion, incongruity of the distal radioulnar joint as well as flexor tendon ruptures due to the more prominent plate (7, 36). A volar plate should therefore not overlap the Watershed line. A second plate right-angled to a volar plate as well as bone substitute (allograft and cement) may improve further the stability.

As a summary, Mudgal and Jupiter stated that locking plate fixation of distal radius fractures can have satisfying outcome even in the face of osteoporosis (28). In the active elderly population there is an acceptable complication rate to justify open reduction and internal fixation for appropriate fractures. Osteoporotic bone does not preclude internal fixation. And they usually have good (functional) outcomes.

## References

1. ARORA, R., LUTZ, M., DEML, C., KRAPPINGER, D., HAUG, L., GABL, M.: A prospective randomized trial comparing nonoperative treatment with volar locking plate fixation for displaced and unstable distal radial fractures in patients sixty-five years of age and older. J. Bone Jt Surg., 93-A: 2146–2153, 2011.

2. CALVO, E., MORCILLO, D., FORURIA, A. M., REDONDO-SANTAMARIA, E., OSORIO-PICORNE, F., CAEIRO, J. R.: Nondisplaced proximal humeral fractures: high incidence among outpatient-treated osteoporotic fractures and severe impact on upper extremity function and patient subjective health perception. J. Shoulder Elbow Surg., 20: 795–801, 2011.

3. CAPO, J. T., KINCHELOW, T., BROOKS, K., TAN, V., MANIGRASSO, M., FRANCISCO, K.: Biomechanical stability of four fixation constructs for distal radius fractures. Hand (N Y), 4: 272–278, 2009.

4. CHUDIK, S. C., WEINHOLD, P., DAHNERS, L. E.: Fixed-angle plate fixation in simulated fractures of the proximal humerus: a biomechanical study of a new device. J. Shoulder Elbow Surg., 12: 578–588, 2003.

5. DIMITRIOU, R., JONES, E., McGONAGLE, D., GIANNOUDIS, P. V.: Bone regeneration: current concepts and future directions. BMC Med., 9: 66, 2011.

6. DROBETZ, H., BRYANT, A. L., POKORNY, T., SPITALER, R., LEIXNERING, M., JUPITER, J. B.: Volar fixed-angle plating of distal radius extension fractures: influence of plate position on secondary loss of reduction--a biomechanic study in a cadaveric model. J. Hand Surg. Am., 31: 615–622, 2006.

7. DROBETZ, H., KUTSCHA-LISSBERG, E.: Osteosynthesis of distal radial fractures with a volar locking screw plate system. Int. Orthop., 27: 1–6, 2003.

8. EGOL, K. A., ONG, C. C., WALSH, M., JAZRAWI, L. M., TEJWANI, N. C., ZUCKERMAN, J. D.: Early complications in proximal humerus fractures (OTA Types 11) treated with locked plates. J. Orthop. Trauma, 22: 159–164, 2008.

9. FJALESTAD, T., HOLE, M. O., HOVDEN, I. A., BLUCHER, J., STROMSOE, K.: Surgical treatment with an angular stable plate for complex displaced proximal humeral fractures in elderly patients: A randomized controlled trial. J. Orthop. Trauma, 26: 98–106, 2012.

10. FOOTE, J. E., ROZENTAL, T. D.: Osteoporosis and upper extremity fragility fractures. J. Hand Surg. Am., 37: 165–167, 2012.

11. GAEBLER, C., McQUEEN, M. M., COURT-BROWN, C. M.: Minimally displaced proximal humeral fractures: epidemiology and outcome in 507 cases. Acta Orthop. Scand., 74: 580–585, 2003.

12. GAUTIER, E., SOMMER, C.: Guidelines for the clinical application of the LCP. Injury, 34 Suppl 2: B63–76, 2003.

13. GIANNOUDIS, P., TZIOUPIS, C., ALMALKI, T., BUCKLEY, R.: Fracture healing in osteoporotic fractures: is it really different? A basic science perspective. Injury, 38 Suppl 1: S90–99, 2007.

14. GREENDALE, G. A., BARRETT-CONNOR, E., INGLES, S., HAILE, R.: Late physical and functional effects of osteoporotic fracture in women: the Rancho Bernardo Study. J. Am. Geriatr. Soc., 43: 955–961, 1995.

15. HANDOLL, H. H., GIBSON, J. N., MADHOK, R.: Interventions for treating proximal humeral fractures in adults. Cochrane Database Syst. Rev., CD000434, 2003.

16. HARDEMAN, F., BOLLARS, P., DONNELLY, M., BELLEMANS, J., NIJS, S.: Predictive factors for functional outcome and failure in angular stable osteosynthesis of the proximal humerus. Injury, 43: 153–158, 2012.

17. HERTEL, R.: Fractures of the proximal humerus in osteoporotic bone. Osteoporos Int., 16 Suppl 2: S65–572, 2005.

18. HIRSCHMANN, M. T., FALLEGGER, B., AMSLER, F., REGAZZONI, P., GROSS, T.: Clinical longer-term results after internal fixation of proximal humerus fractures with a locking compression plate (PHILOS). J. Orthop. Trauma, 25: 286–293, 2011.

19. ILYAS, A. M., JUPITER, J. B.: Distal radius fractures-classification of treatment and indications for surgery. Orthop. Clin. North Am., 38: 167–173, 2007.

20. JUPITER, J. B.: The management of nonunion and malunion of the distal humerus a 30-year experience. J.Orthop. Trauma, 22: 742–750, 2008.

21. JUPITER, J. B., MARENT-HUBER, M.: Operative management of distal radial fractures with 2.4 millimeter locking plates. A multicenter prospective case series. J. Bone Jt Surg., 91-A: 55–65, 2009.

22. JUPITER, J. B., MARENT-HUBER, M.: Operative management of distal radial fractures with 2.4 millimeter locking plates: a multicenter prospective case series. Surgical technique. J. Bone Jt Surg., 92-A: Suppl 1 Pt 1: 96–106, 2010.

23. JUPITER, J. B., WYSS, H.: Stable fixation of osteoporotic fractures and nonunions in the upper limb – life before the „locking plate". Acta Chir. orthop. Traum. čech., 77: 361–364, 2010.

24. KANDEMIR, U., MATITYAHU, A., DESAI, R., PUTTLITZ, C.: Does a volar locking plate provide equivalent stability as a dorsal nonlocking plate in a dorsally comminuted distal radius fracture?: a biomechanical study. J. Orthop. Trauma, 22: 605–610, 2008.

25. KANIS, J. A., JOHNELL, O., ODEN, A., SEMBO, I., REDLUND-JOHNELL, I., DAWSON, A., DE LAET, C., JONSSON, B.: Long-term risk of osteoporotic fracture in Malmo. Osteoporos Int., 11: 669–674, 2000.

26. KELLER, M., STEIGER, R.: The pi plate: an implant for unstable extension fractures of the distal radius in patients with osteoporotic bone. Tech. Hand Up Extrem Surg., 8: 212–218, 2004.

27. MATSCHKE, S., WENTZENSEN, A., RING, D., MARENT-HUBER, M., AUDIGE, L., JUPITER, J. B.: Comparison of angle stable plate fixation approaches for distal radius fractures. Injury, 42: 385–392, 2011.

28. MUDGAL, C. S., JUPITER, J. B.: Plate fixation of osteoporotic fractures of the distal radius. J. Orthop. Trauma, 22: S106–115, 2008.

29. NEER, C. S., 2nd: Displaced proximal humeral fractures. I. Classification and evaluation. J. Bone Jt Surg., 52-A: 1077–1089, 1970.

30. OLERUD, P., AHRENGART, L., PONZER, S., SAVING, J., TIDERMARK, J.: Hemiarthroplasty versus nonoperative treatment of displaced 4-part proximal humeral fractures in elderly patients: a randomized controlled trial. J. Shoulder Elbow Surg., 20: 1025–1033, 2011.

31. OYEN, J., BRUDVIK, C., GJESDAL, C. G., TELL, G. S., LIE, S. A., HOVE, L. M.: Osteoporosis as a risk factor for distal radial fractures: a case-control study. J. Bone Jt Surg., 93-A: 348–356, 2011.

32. PALVANEN, M., KANNUS, P., PARKKARI, J., PITKAJARVI, T., PASANEN, M., VUORI, I., JARVINEN, M.: The injury mechanisms of osteoporotic upper extremity fractures among older adults: a controlled study of 287 consecutive patients and their 108 controls. Osteoporos Int., 11: 822–831, 2000.

33. PARNES, N., JUPITER, J. B.: Fixed-angle locking plating of displaced proximal humerus fractures. Instr. Course Lect., 59: 539–552, 2010.

34. RING, D.: Current concepts in plate and screw fixation of osteoporotic proximal humerus fractures. Injury, 38 Suppl 3: S59–68, 2007.

35. RODERER, G., GEBHARD, F., KRISCHAK, G., WILKE, H. J., CLAES, L.: Biomechanical in vitro assessment of fixed angle plating using a new concept of locking for the treatment of osteoporotic proximal humerus fractures. Int. Orthop., 35: 535–541, 2011.

36. ROZENTAL, T. D., BLAZAR, P. E.: Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. J. Hand Surg. Am., 31: 359–365, 2006.
37. RUCHELSMAN, D. E., MUDGAL, C. S., JUPITER, J. B.: The role of locking technology in the hand. Hand Clin., 26: 307–319; 2010.
38. SCHILCHER, J., MICHAELSSON, K., ASPENBERG, P.: Bisphosphonate use and atypical fractures of the femoral shaft. N. Engl. J. Med., 364: 1728–1737, 2011.
39. SHANE, E., BURR, D., EBELING, P. R., ABRAHAMSEN, B., ADLER, R. A., BROWN, T. D., CHEUNG, A. M., COSMAN, F., CURTIS, J. R., DELL, R., DEMPSTER, D., EINHORN, T. A., GENANT, H. K., GEUSENS, P., KLAUSHOFER, K., KOVAL, K., LANE, J. M., MCKIERNAN, F., MCKINNEY, R., NG, A., NIEVES, J., O'KEEFE, R., PAPAPOULOS, S., SEN, H. T., VAN DER MEULEN, M. C., WEINSTEIN, R. S., WHYTE, M.: Atypical subtrochanteric and diaphyseal femoral fractures: report of a task force of the American Society for Bone and Mineral Research. J. Bone Miner. Res., 25: 2267–2294, 2010.
40. SIWACH, R., SINGH, R., ROHILLA, R. K., KADIAN, V. S., SANGWAN, S. S., DHANDA, M.: Internal fixation of proximal humeral fractures with locking proximal humeral plate (LPHP) in elderly patients with osteoporosis. J. Orthop. Traumatol., 9: 149–153, 2008.
41. SOUER, J. S., RING, D., MATSCHKE, S., AUDIGE, L., MAREN-HUBERT, M., JUPITER, J.: Comparison of functional outcome after volar plate fixation with 2.4 mm titanium versus 3.5 mm stainless-steel plate for extra-articular fracture of distal radius. J. Hand Surg. Am., 35: 398–405, 2010.
42. WAGNER, M.: General principles for the clinical use of the LCP. Injury, 34 Suppl 2: B31–42, 2003.
43. YANG, H., LI, Z., ZHOU, F., WANG, D., ZHONG, B.: A prospective clinical study of proximal humerus fractures treated with a locking proximal humerus plate. J. Orthop. Trauma, 25: 11–17, 2011.
44. ZIADE, N., JOUGLA, E., COSTE, J.: Population-level impact of osteoporotic fractures on mortality and trends over time: a nation wide analysis of vital statistics for France, 1968–2004. Am. J Epidemiol., 172: 942–951, 2010.
45. ZYTO, K., AHRENGART, L., SPERBER, A., TORNKVIST, H.: Treatment of displaced proximal humeral fractures in elderly patients. J. Bone Jt Surg., 79-B: 412–417, 1997.

**Corresponding author:**
Prof. Jesse B. Jupiter, M.D.,
AO Professor of Orthopedic Surgery Hand and Upper
Extremity Service,
Yawkey Center, Suite 2100,
Massachusetts General Hospital,
55 Fruit Street, Boston, MA 02114, USA
E-mail: jjupiter1@partners.org