J Orthop Sci (2003) 8:252–258

Journal of
Orthopaedic Science

Instructional lectures

Revolution in plate osteosynthesis: new internal fixator systems

Michael Schütz[1] and Norbert P. Südkamp[2]

[1] Clinic for Trauma and Reconstructive Surgery, Charité, Humboldt University, Augustenburger Platz 1, 13353 Berlin, Germany
[2] Department of Traumatology, Albert Ludwig University, Freiburg, Germany

Abstract Conventional plating has been performed since the nineteenth century, and since then Lambotte, Danis, and others have developed new plate designs to restore fractured bones. At the early stage of plating, mechanical aspects were the focus, and the biology of the bone was sometimes neglected. During the 1980s the AO/ASIF group started to work on new plate designs to minimize the disadvantages of plating with respect to cortical perfusion. To overcome the negative effect of compression forces on the periosteum, a new generation of plates, or internal fixators, were created. The key to these internal fixators is the locking mechanism of the screw in the implant, which provides angular stability. This technical detail ensures that compression forces on the bone surface are not necessary to gain stability of the bone–implant construct, which improves fracture healing and provides an excellent holding force even in osteoporotic bone. The locking mechanism also makes the technique of percutaneous plating easier because, in contrast to conventional plates, the fragments are not pulled toward the implant by the locking screws. The new internal fixator systems [LISS (less invasive stabilization system) and LCP (locking compression plates)] offer new approaches to trauma surgery, especially for metaphyseal fractures.

Key words Internal fixator · LISS · LCP · Minimally invasive surgery · Fracture healing

Introduction

Since the first plate osteosyntheses reported in 1886 by the surgeon Hansmann[5] from Hamburg, plating methods and surgical techniques have changed to ensure the best possible fracture healing. During the 1950s the founders of the Swiss Association for the Study of Internal Fixation[9] standardized the use of plating systems. The first edition of the 1969 *AO Manual of Internal Fixation* noted that the main goal of fracture treatment was to restore the function of the injured limb. Stable internal fixation provides the bone with primary strength, allowing early functional mobilization. As a result, complications such as malpositioning and fracture-related disease caused by prolonged immobilization can be avoided.

With the original AO/ASIF technique, screws or tension devices achieved the compression principle. Later, the specially designed screw hole of the dynamic compression plate (DCP) allowed axial compression of the fracture zone. In a perfect application of lag screws, this principle led to primary bone-fracture consolidation with no visible callus formation. This development in plate osteosynthesis led to a surgical technique that tried to adapt even the smallest fragments exactly to the anatomy, often at the expense of bone and soft tissue vitality. Denudation of the individual fragments was the result of this traumatic surgical technique, with wide exposure of the fracture zone, ultimately causing delayed healing, nonunion, and an increased tendency to infection.

During the 1980s a greater understanding of these problems led innovators to modify the concepts of absolute stability and anatomical reconstruction in the plating treatment of shaft fractures. As a consequence, the concept of the bridging plate was implemented.[1] It consists in leaving extended multiple fractures untouched and bridging them by anchoring the plate only in the proximal and distal main fragment. To minimize the risk of additional devascularization of the bone fragments, the lag screw is no longer used. Callus healing was no longer an undesirable side effect but represented the aim of the treatment with secure fracture consolidation.

In summary, the emphasis was no longer on absolute fracture stability but on preserving the circulation of the

Offprint requests to: M. Schütz
Presented at the 75th Annual Meeting of the Japanese Orthopaedic Association, Okayama, Japan, May 18, 2002
Received: July 22, 2002

fracture zone. Thus, the terms "bridging internal fixation" and "biological plate osteosynthesis" were coined by Ganz.[3] This type of internal fixation is atraumatic, is without substantial exposure of the fracture zone, and includes indirect reduction techniques and bridging stabilization.[8]

Plate types and shapes

Conventional plating methods are based on using an adequate number of anchoring screws to press the plate with high compressive force against the bone fragments, thereby creating a stable bone–implant connection. Typically, bicortical screws have been used to obtain the best possible anchoring force.

Lüthi et al.[7] showed the danger of a high compressive force on bone by proving that the extent of the plate–bone contact influenced the disturbance of the periosteal blood circulation. Others, such as Gautier et al.,[2] Jörger,[6] and Vattalo,[16] proved that circulatory disturbances can cause bone necrosis, which can be treated only by internally transforming the bone structure via reaming the dead bone and filling the resulting space with living bone. This process can temporarily perforate the bone (osteoporosis), which initially was imputed mistakenly to the mechanical relief of the bone by the plate. To minimize cortical vascularization damage, a theoretical stage was pursued to reduce the contact surface of the plate and bone. This led to development of the limited-contact dynamic compression plate (LC-DCP) in which a special plate reduces the contact surface by more than 50% compared with the conventional DCP[10] (Fig. 1).

Even with a reduced contact surface using the LC-DCP, however, the principle of plate osteosynthesis with compressive forces acting against the bone was present. This problem can be avoided only when stabilization requires no frictional forces between implant and bone. To achieve this objective, an angular-stable connection is required between the screw head and the force carrier. Admittedly, such a stabilization method resembles a plate from the exterior, but it is a fixator in principle – and an internal fixator when placed under the surface of the skin.

The Zespol system, the first internal fixator for stabilizing long bones, was developed during the 1970s in Poland.[11] By the end of the 1980s the Association for the Study of Internal Fixation (ASIF) started to approach internal fixator systems as a further development of their plates. Today, various systems that achieve angular stability by various means are being tested.

The point contact fixator (PC-Fix) was the first version of these plate fixators in which angular stability was achieved by a conical connection between screw heads and screw holes[15] (Fig. 2). This connection did not produce extreme angular stability, as pointed contact surfaces with the bone remained. In this respect, the PC-Fix represents a combination plate and fixator. During clinical handling the slight conical inclination of the screw head produced a nearly "cold-forged" connection between the screw head and the screw hole, sometimes making it difficult to remove individual screws. These findings started the development of a new thread connection between screw head and screw hole, resulting in high angular stability (Fig. 3). With this connection, stable anchoring no longer requires contact between the force carrier and the bone. The thread connection has been applied in the new AO/ASIF internal fixator systems: the less invasive stabilization system (LISS) and the locking compression plate (LCP).[4,13] Based on this interlocking between screw head and force carrier, the original function of the screw also changes from an anchoring screw for plate osteosynthesis (which presses the force carrier against the bone) to a Schanz screw, which simply ensures the connection between the bone and the force carrier.[13]

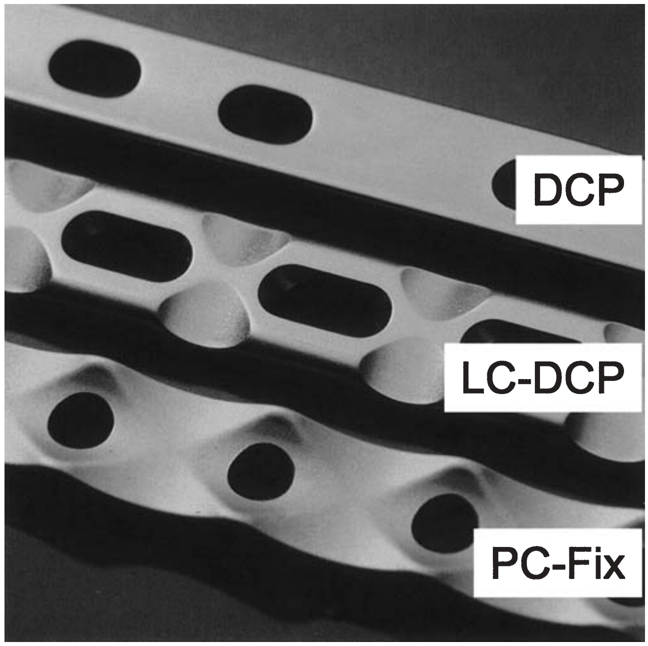


Fig. 1. Because of its special undercuts, the limited-contact dynamic compression plate (*LC-DCP*) reduced the contact surface by 50% compared to the dynamic compression plate (*DCP*). The point contact fixator (*PC-Fix*), was the first internal fixator and had point contact only on the bone surface

At the same time, the stabilization principle also changes the strain of the bone by the screw. Whereas the transverse strain of the bone remains in the classic plate osteosynthesis with axial loading, with an angular-stable system the load transfer over the screws occurs

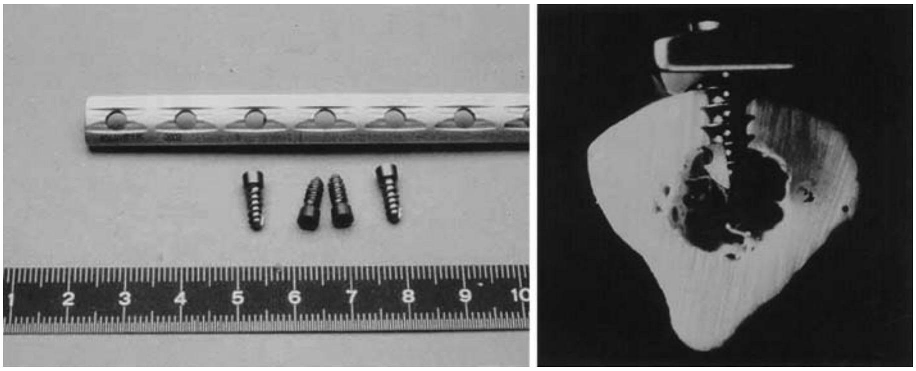


Fig. 2. In the first PC-Fix version angular stability was achieved by means of a conical screw-head/implant-hole connection. Self-tapping screws were already applied monocortically

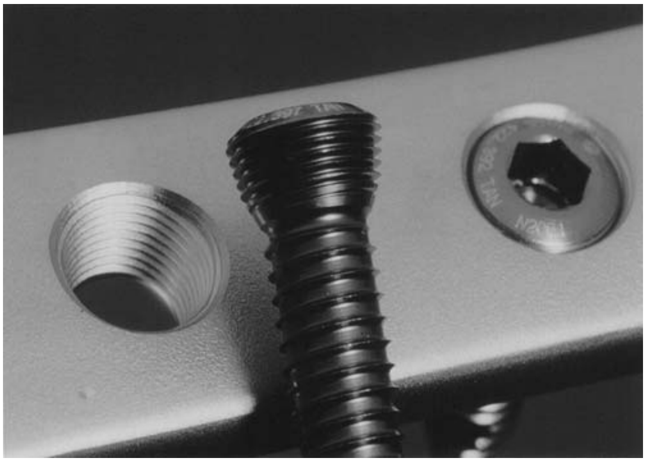


Fig. 3. Less invasive stabilization system (LISS) achieves high angular stability between the screw and the force carrier by an interlocking thread connection between screw head and internal fixator hole

along the bone axis. Initial investigations have shown that this also has a positive effect on osteoporotic bone.[12]

LISS

The LISS for management of distal femoral fractures and proximal tibial fractures features the possibility of using a minimally invasive surgical technique and the principle of angular stability. The LISS is an anatomically preshaped internal fixator that can be inserted percutaneously by means of an adaptable insertion guide (Fig. 4). This process of a "covered" surgical technique has advantages compared with the traditional open technique, especially regarding extreme soft tissue trauma. In combination with a trocar assembly, the handle serves at the same time as an aiming instrument for exact percutaneous placement of self-drilling, self-tapping screws (Fig. 5). Based on extensive anatomical studies, the orientation of the individual screws is predetermined and cannot be changed. The reason for this is the angular-stable screw–plate connection, which is achieved by an outer thread of the screw head and an inner thread of the plate hole; it does not permit a variable screw direction.

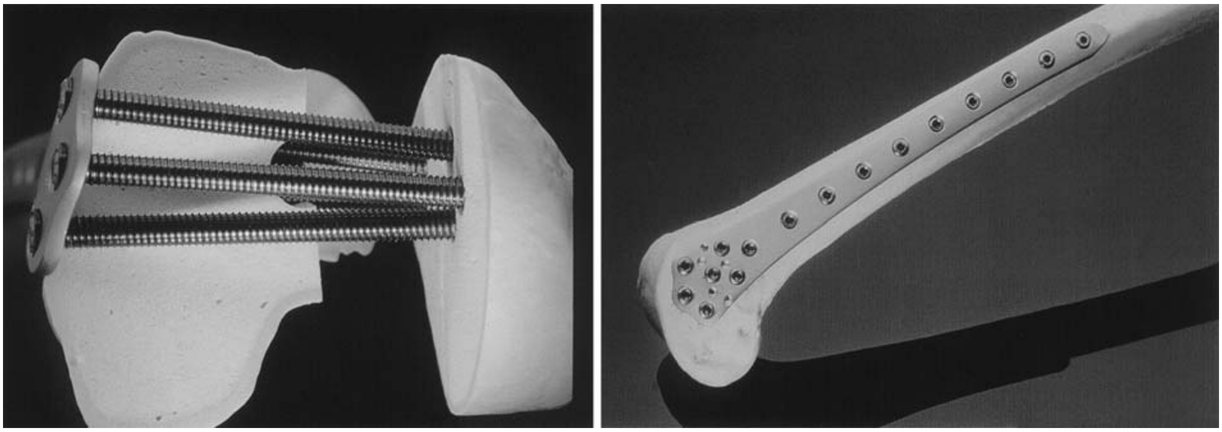
The LISS system includes three plate lengths each (5, 9, and 13 holes) for the distal femur and the proximal tibia. As the plates are preshaped, their sides are not symmetrical.

The indications for the LISS system in the distal femur and the proximal tibia include all extraarticular and intraarticular fractures that cannot be treated with screws alone. No other currently available implant can achieve this wide range of applications.[13]

Surgical procedure with LISS for distal femur and proximal tibia fractures

The surgical procedure depends basically on whether an intraarticular fracture requires open reduction. The exact anatomical reconstruction of the articular surface in question always has priority. For complex intraarticular fractures of the distal femur, select a lateral parapatellar approach that ensures an optimal overview of the articulation. For articular tibial fractures, perform a lateral arthrotomy that can be adapted to the fracture characteristics. After reconstructing the joint surface, make a temporary reduction of the articular block on the shaft taking into account the axis, length, and rotation. The use of a distractor or an external fixator is useful for this surgical step but is not absolutely necessary. An experienced user of the LISS can also perform indirect reduction directly by means of the anatomically precontoured implants.

For purely extraarticular fractures of the distal femur, make an incision approximately 8 cm long laterally toward Gerdy's tubercle and visualize the lower rim of the muscle vastus lateralis. For extraarticular fractures



a b

Fig. 4. In line with anatomical studies, the shape and screw direction of the LISS-DF (distal femur) system for managing distal femoral fractures have been adapted to this zone. Distal (**a**) and lateral (**b**) views of the distal femur

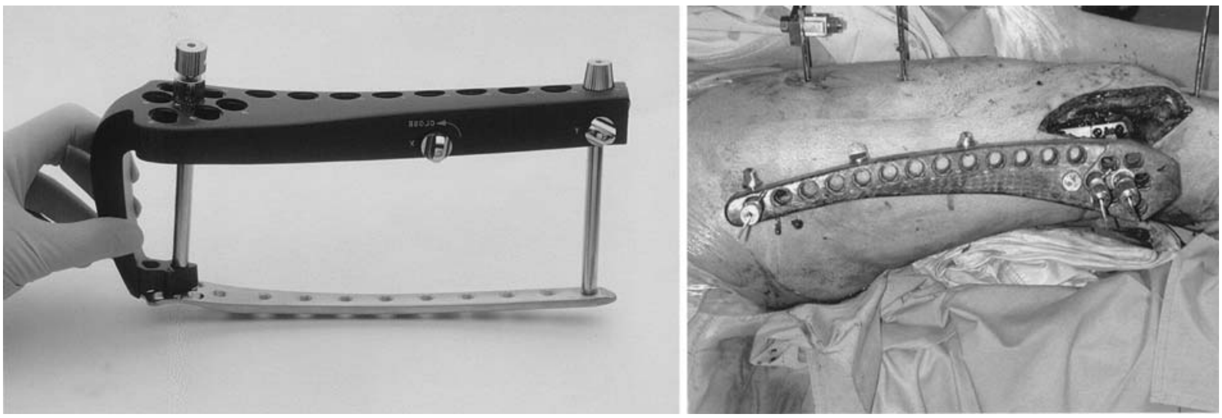


Fig. 5. Left LISS-DF with a mounted insertion guide that, together with the trocar assembly, serves also as an aiming instrument. **Right** Implant has been inserted and aligned over the insertion guide with the lateral femur

of the proximal tibia, use a lateral approach to the tibial head. Enlarge the access along the proximal contour of the tibia in the medial direction to detach the muscle tibialis anterior muscle close to the bone. It is recommended that part of the muscular fascia be left on the bone to ensure easier refixation of the muscle. Insert the LISS on the distal femur from under the muscle vastus lateralis in a proximal direction. Pay attention to the correct position in the condylar area and particularly on the femoral shaft. Use Kirschner wires to fix this position over the insertion guide and position the self-drilling, self-tapping screws over the trocar assemblies. Clinical experience recommends the use of long implants fixed with individual screws, so it results in well-balanced strain on both implant and bone. It is preferable to use monocortical screws in the shaft and long screws in the metaphyseal zone. As a rule, four screws should be securely inserted in the shaft and five or six screws in the condylar block (Fig. 6). On the tibia, insert the LISS PT from proximal to distal under the muscle tibialis of the lateral tibia and fix it in a manner similar to that described for the femur (Fig. 7).

The first clinical results of a multicenter study with the LISS to the distal femur (LISS-DF) showed that the minimally invasive method is a technique that has a learning curve.[14] Of 116 distal femoral fractures, 99 were followed until healing. No primary bone grafting was performed, and secondary grafting had to be carried out in six cases because of delayed union or nonunion; in all of these cases there was an open fracture with bone lost or severe vascular damage. Four infections occurred in three patients with severe open fractures and in one polytraumatized patient with a closed fracture.

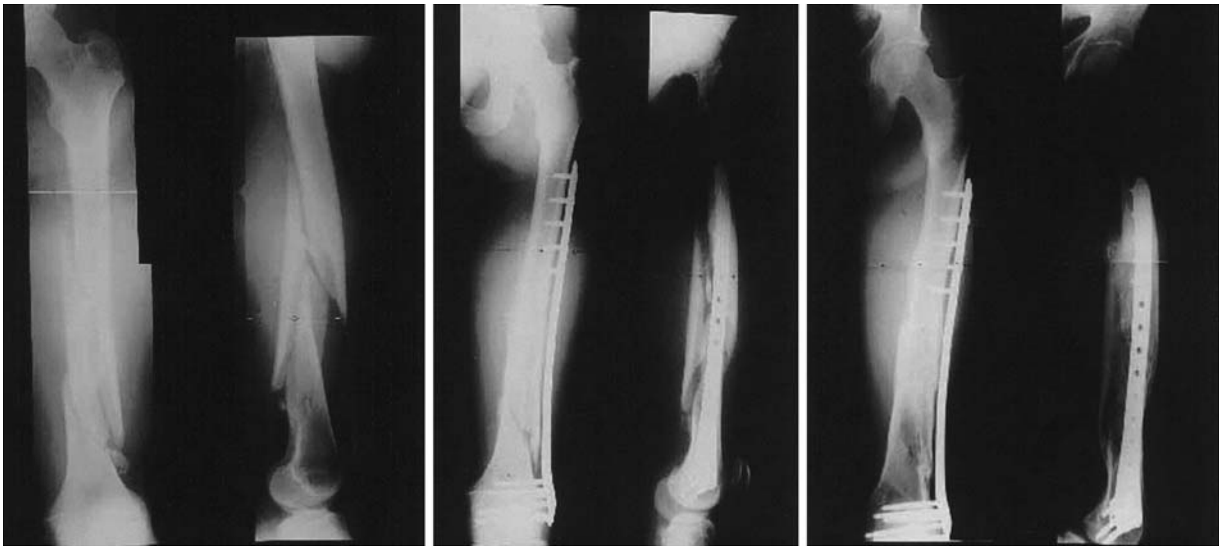
As a result of our study it was clearly shown that the LISS-DF can be used to treat all fractures of the distal femur in an excellent manner using a minimally invasive approach. In addition, osteoporotic fractures in a,b  c

Fig. 6. Internal fixation treatment of a distal femoral shaft fracture using the internal fixator (LISS-DF). This 32-year-old man had polytrauma, with a fracture classification of 32-C1.2. **a** Preoperative radiograph. **b** At 6 weeks. **c** At 6 months. The distance between implant and bone are clearly visible on the anteroposterior (AP) radiograph

a,b  c

Fig. 7. Osteosynthetic treatment of a proximal tibial (PT) fracture using the internal fixator (LISS-PT). This 24-year-old man had polytrauma, with a fracture classification of 41-C3. **a** Preoperatively. **b** Follow-up control after 4 months. **c** Clinical aspect after 4 months and the skin grafts required

the elderly, including periprosthetic fractures, were stabilized safely until fracture consolidation.

Locking compression plate

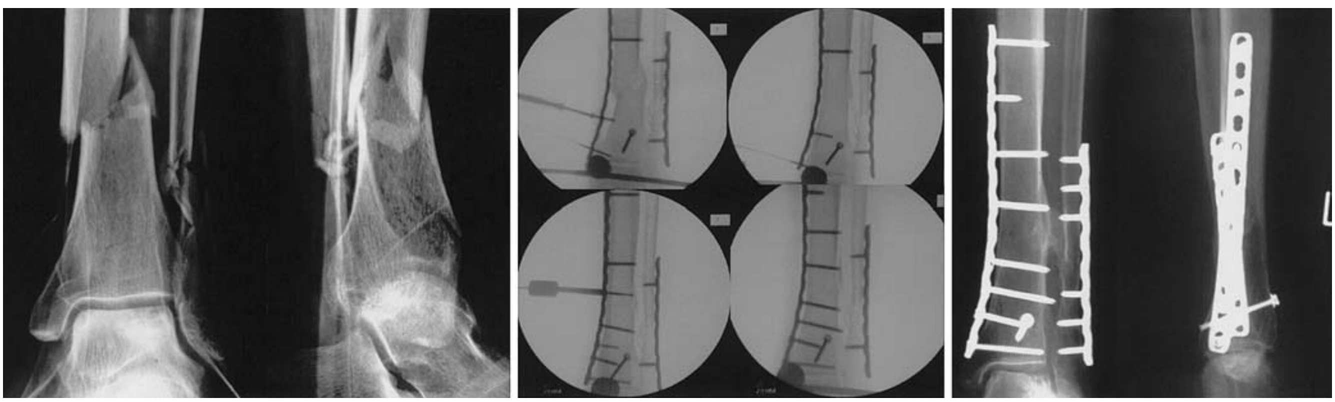
The new screw-hole geometry of the combination hole is the latest development in plate osteosynthesis.[17] This plate hole can be filled with a conventional cortex screw or an angular-stable screw (locking head screw) (Fig. 8).

Up to now nearly all plate shapes have been equipped with the new locked compression plate (LCP) hole that allows use of either conventional cortex screws or angular-stable screws (Fig. 9). Previous experience of our own cases showed that the cortex screw is used only

Fig. 8. Combination hole of the new locked compression plate (LCP) provides the possibility of treating fractures with conventional standard screws, angular-stable locking head screws, or both

a b

Fig. 9. Treatment of a distal radius fracture (23.C2) using a volar 3.5 LCP T-plate. **a** Preoperative radiograph. **b** Six-month postoperative follow-up control radiograph. Angular-stable screws support the radial articular surface and allow early functional mobilization



a,b c

Fig. 10. A 72-year-old woman suffered a distal lower leg fracture (43.A3) caused by a traffic accident. First, the length of the fibula was reconstructed by means of an angular-stable 3.5-mm LCP (**a**). The tibia was then stabilized by prebending a 4.5 LCP and inserting it percutaneously (**b**). The articular block was reduced using a cortex screw and stabilized with angular-stable locking head screws. **c** Consolidation image after 12 months

as a reduction screw (Fig. 10), whereas the locking head screws (LHSs) are used as implant set screws. At least three monocortical LHSs should be securely anchored in each main fragment. In highly osteoporotic bone the use of bicortical screws is recommended. The LHS is implanted preferably after predrilling with a 2.8-mm drill bit (3.5 system) or 4.3-mm drill bit (4.5 system) over a drill guide, which locks in the angular-stable hole.

The new angular-stable systems are particularly indicated for metaphyseal fractures of the proximal and distal humerus, the distal radius, and the distal tibia. In the meantime, new anatomy-related implants are already being tested for these zones. These implants are especially suitable for stabilizing such fractures.

Conclusions

The biological disadvantages of conventional plate osteosynthesis led to the development of the first internal fixator systems. Today, after almost 10 years of clinical experience, this new stabilization principle proves not only to spare the periosteal blood circulation but offers other advantages over conventional plate osteosynthesis. In addition to improving the fixation properties in poor metaphyseal or osteoporotic bone structures, it also facilitates minimally invasive, percutaneous osteotechniques. Completely new surgical techniques and implant concepts for juxtaarticular fractures have been developed based on this new principle. After years of diminishing indications for conventional plate osteosyntheses, this development has resulted in a revolution in new stabilization methods similar to plates.

References

1. Blatter G, Weber BG. Wave plate osteosynthesis as a salvage procedure. Arch Orthop Trauma Surg 1990;109:330–3.
2. Gautier E, Perren SM, Ganz R. Principles of internal fixation. Curr Orthop 1992;6:220–32.
3. Gautier E, Ganz R. [The biological plate osteosynthesis] Zentralbl Chir 1994;119:564–72.
4. Haas NP, Schütz M, Hoffmann R, et al. LISS — Less Invasive Stabilization System: ein neuer Fixateur interne für distale Femurfrakturen. OP J 1997;13:340–4.
5. Hansmann C. Eine neue Methode der Fixierung der Fragmente bei complicierten Frakturen. Verh Dtsch Ges Chir 1886;158.
6. Jörger K. Akute intrakortikale Durchblutungsstörung unter Osteosyntheseplatten mit unterschiedlichen Auflageflächen. Zentrubl Chir 1987;1:75.
7. Luthi U, Rahn BA, Perren SM. [Area of contact between osteosynthesis plate and bone in internal fixation.] Akt Traumatol 1980;10:131–6.
8. Mast JW, Jakob RP, Ganz R. Planning and reduction technique in fracture surgery. Berlin: Springer; 1989.
9. Müller ME, Allgöwer M, Schneider R, et al. Manual der Osteosynthese. Berlin: Springer; 1992.
10. Perren SM. The concept of biological plating using the limited contact-dynamic compression plate (LC-DCP): scientific background, design and application. Injury 1991;22(suppl 1):1–41.
11. Ramotowski W, Granowski R. Zespol: an original method of stable osteosynthesis. Clin Orthop 1991;272:67–75.
12. Schandelmaier P, Krettek C, Ungerland A, et al. [Pre-bending and tension adjustment of narrow 4.5 mm AO titanium LC-DCP (limited contact dynamic compression plate).] Langenbecks Arch Chir 1997;382:325–31.
13. Schavan R, Frigg R, Angst M. LISS – ein neuartiges minimal invasives extramedulläres Fixationssystem für Metaphysäre Frakturen der unteren Extremität. Hefte Unfallchirurg 1997;702–6.
14. Schutz M, Müller M, Krettek C, et al. Minimally invasive fracture stabilization of distal femoral fractures with the LISS: a prospective multicenter study; results of a clinical study with special emphasis on difficult cases. Injury 2001;32:48–54.
15. Tepic S, Perren SM. The biomechanics of the PC-Fix internal fixator. Injury 1995;26:5–10.
16. Vattolo M. Der Einfluss von Rillen in Osteosyntheseplatten auf den Umbau der Korticalis. Zentralbl Chir 1986;1:89.
17. Wagner M, Frigg R. Locking compression plate (LCP): ein neuer AO Standard. OP J 2000;3:238–43.