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Injury, Int. J. Care Injured 34 (2003) S-B63–S-B76
INJURY
INTERNATIONAL JOURNAL OF THE CARE OF THE INJURED
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Guidelines for the clinical application of the LCP

Emanuel Gautier[1], **Christoph Sommer**[2]

[1] Department of Orthopaedic Surgery, Kantonsspital Fribourg, 1708 Fribourg, Switzerland
[2] Department of Surgery, Kantonsspital Chur, 7000 Chur, Switzerland

Summary[1]

The Locking Compression Plate (LCP), in combination with the LISS and the PHILOS, is part of a new plate generation requiring an adapted surgical technique and new thinking about commonly used concepts of internal fixation using plates. The following guidelines are needed to avoid failures and possible complications in the hands of surgeons not yet confident with the new implant philosophy.

The importance of the reduction technique and minimal-invasive plate insertion and fixation is addressed to keep bone viability undisturbed. Understanding of the mechanical background for choosing the proper implant length and the type and number of screws is essential to obtain a sound fixation with a high plate span ratio and a low plate screw density. A high plate span ratio decreases the load onto the plate. A high working length of the plate in turn reduces the screw loading, thus fewer screws need to be inserted and the plate screw density can be kept low. Knowledge of the working length of the screw is helpful for the proper choice of monocortical or bicortical screws. Selection is done according to the quality of the bone structure and it is important to avoid problems at the screw thread bone interface with potential pullout of screws and secondary displacement. Conclusive rules are given at the end of this chapter.

Keywords: Internal fixator, plate osteosynthesis, locking compression plate, bridging plate, minimal-invasive internal fixation
Injury 2003, Vol. 34, Suppl. 2

Introduction

The recent evolution in reduction and internal fixation of fractures is based on an improved understanding of the biology of bone, of the biomechanics of fracture fixation and fracture healing and on the analysis of previous failures [10, 12, 17, 21, 24, 32, 34]. Improvements in implant designs [15, 37] play an important role in avoiding possible complications and in achieving the primary goals of operative fracture treatment [29, 35], i.e. restoration of the overall function of the extremity involved and recovery of the biological and mechanical integrity of the osseous tissue with return of the prefracture tissue vitality and structure as well as the prefracture stiffness and strength of the injured bone segment [4, 38].

New implants can never be regarded as isolated from the surgical action. New, minimally invasive techniques have had to be developed to optimise the potential of a specific implant able to fulfil the mechanical demands of the fracture and to preserve the biological competence of the involved tissues [1, 2, 5, 6, 8, 9, 14, 18-20, 25, 26, 33, 39, 40]. Such modifications have influenced our thinking about everything that is currently valid [28, 30]. This process requires a careful analysis of each step of a surgical procedure and in many cases previously used operative techniques and strategies judged to be sound cannot be validated anymore and therefore have to be abandoned.

The Locking Compression Plate (LCP) is such a type of new implant that is revolutionising internal fixation using plates. Our task is to give some guidelines to the current state of the art in plating techniques, in the full knowledge that very soon these recommendations will be under criticism and will need to be re-evaluated and re-validated.

In our daily life, guidelines allow the safe application of a device and help avoid potential complications and

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[1] Abstracts in German, French, Italian, Spanish, Japanese and Russian are printed at the end of this supplement.

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doi:10.1016/j.injury.2003.09.026

dangers due to its inappropriate use. The following chapter describes technical details on the use of the internal fixator. The mechanical and biological background information will help provide mechanically and biologically sound constructs to achieve fracture healing.

Even when incorrect from the mechanical point of view, the terms "plate" and "screw" are used as synonyms for the terms "internal fixator" and "bolt".

Concepts of fixation

Generally, there are two basic principles of internal fracture fixation,: interfragmentary compression and splinting. Both are useful and have their places in the repertoire of the orthopaedic trauma surgeon.

Compression is a safe, high rigidity method of fixation suitable for simple fracture patterns in each segment of a bone. Splinting is the more flexible method of fixation that should be used mainly in complex or comminuted fractures of the meta- and diaphyseal segments of a long bone [3, 16, 22, 36].

Due to the specific design of the plate hole, the locked compression plate can be used as a standard plate with standard screws and as an internal fixator using locking screws. The simultaneous use of both concepts is called combination fixation. The mechanical concept of the internal fixator is more or less identical to the concept of the external fixator. The Locking Compression Plate (LCP) allows the following mechanically different internal fixations to be performed (Table 1):

Compression plating.

This can be accomplished either with the tension device or the dynamic compression principle of the plate with eccentric screw insertion. The good indication for this mechanical concept is the simple transverse or oblique fracture in the meta- or diaphyseal segments of a long bone with low soft tissue compromise.

Bridge plating technique or non-gliding splint technique.

Splinting consists of the connection of an implant to the broken bone. The stability of this composite system depends on the stiffness of the splint and the quality of anchorage of the splint to the bone. This technique can be performed with both types of screws for fixation of a comminuted fracture of the metaphysis or diaphysis. The advantage of the use of locked screws is the possible reduction of the screw length to monocortical dimensions and the use of self-drilling screws, which do not

Concept	Technique	Screws Type	Fracture Type	Bone Quality
Compression plating technique	DC-principle	Standard eccentric and standard neutral Standard eccentric and locked	Full or partial contact between main fragments	Normal
	Tension device	Standard alone, Locked alone Standard and locked	Full or partial contact between main fragments	Normal
Bridge plating technique	Distractor, Fracture table	Standard neutral	No contact between main fragments	Normal
	Distractor, Fracture table	Locked	No contact between main fragments	Poor or normal
Combination technique	DC-principle and bridge plate technique	Standard eccentric and locked	Segmental fracture one level simple, one level comminuted fracture pattern	Normal or poor
	Plate lagging screw in meta- or diaphyseal bone segment	Standard and locked	simple oblique fracture	Normal or poor
	Plate lagging screws for articular fragment	Standard and locked	Articular fracture	Normal or poor
Hybrid use of both types of screws	Reduction onto the plate	Locked and standard	Diaphyseal or metaphyseal fracture	Normal or poor
	Malalignment of the plate on bone axis	Locked and standard	Diaphyseal or metaphyseal fracture	Normal or poor

Table 1: Biomechanical concepts of internal fixation using plates

need screw length measurement. For normal bone quality, standard screws or locked screws can be used. In cases of osteoporosis, bicortical locked screws are recommended.

Combination technique

This term refers to a biomechanical mixture of compression and splinting techniques using one plate. There are different reasons for choosing a combination technique:

- In a segmental fracture type with a simple fracture configuration at one level and a comminuted fracture at the other level, interfragmentary compression can be applied to stabilise the simple fracture and the bridging plate technique applied to stabilise the comminuted fracture area.
- Insertion of a plate lagging screw to compress a simple fracture line in the meta- or diaphyseal segment. Depending on the bone quality, osteosynthesis is completed with either standard or locked screws.
- Insertion of a plate lagging screw in the epiphyseal segment for interfragmentary compression of an intra-articular fracture line.

In addition, the combined (hybrid) use of standard and locked screw can be considered in the following situations:

- Reduction onto the plate in case of a residual axial malalignment of a fracture, mostly in the frontal plane.
- Malalignment of the plate with respect to the long bone axis. When the plate is not ideally aligned to the axis of the diaphyseal segment, the screw at the plate end may not meet the bone cortex when a locked screw with its predefined screw direction is used.

Selection of the type of plate

The LCP's cross-section and mechanical properties are identical to those of the Titanium LC-DCP. Therefore, for a specific bone segment and a specific fracture configuration, the same type of implant can be chosen. We recommend the following combinations of implants and fracture areas (Table 2):

Selection of the type of screw

Four diffeent screws can be used with the LCP. The standard cancellous screw, the standard mm cortical screw, the selfdrilling screw and the selftapping screw.

The two standard screws follow the well known principles of plating from the LC-DCP or a DCP. Its use is recommended when the screw needs angulation to avoid penetrating into a joint or when the concept of interfragmentary compression with eccentric screw insertion is considered.

Selfdrilling screws are mainly used as monocortical screws in the diaphyseal segment of bone in cases with excellent bone quality. The cutting tip of the screw

Implant	Indication
4.5 / 5.0 LCP large	Meta-diaphyseal fracture of the femur and humerus Non-union of the tibia
4.5 / 5.0 LCP small	Meta-diaphyseal fracture of the tibia Meta-diaphyseal fracture of the humerus in small women Posterior pelvic ring segment (through anterior or posterior approaches)
4.5 / 5.0 LCP metaphyseal	Meta-diaphyseal fractures of the distal tibia with a short distal fragment or tibial plafond fracture Meta-diaphyseal fractures of the distal humerus
4.5 / 5.0 LCP reconstruction	Symphysis pubis
4.5 / 5.0 LCP T and L-plate	Epi-metaphyseal fractures of the proximal tibia Unicondylar fracture of the distal femur
3.5 LCP	Meta-diaphyseal fractures of the forearm Epi-metaphyseal fractures of the distal or proximal humerus Posterior pelvic ring segment (through anterior or posterior approaches)
3.5 LCP metaphyseal	Epi-metaphyseal fractures of the distal humerus, distal radius, and olecranon
3.5 LCP reconstruction	Epi-metaphyseal fractures of the distal humerus Symphysis pubis, acetabular fractures

Table 2: Selection of the correct type of plate

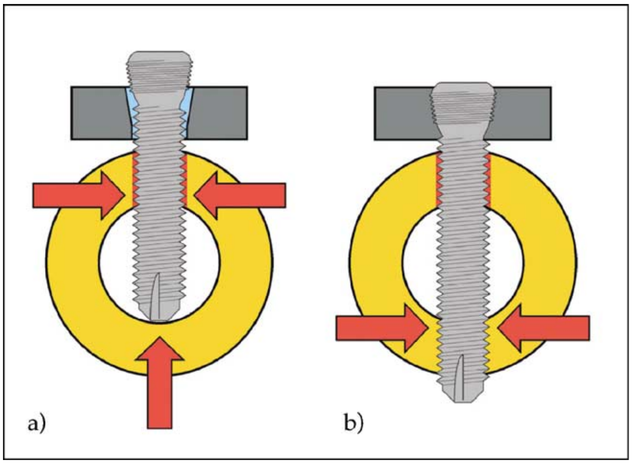


Fig. 1: Danger of insertion of a monocortical selftapping screw. In a low diameter bone the tip of the screw can contacts the opposite bone cortex before the screw head engages in the plate hole thread. This leads to the destruction of the bone thread in the near cortex and complete loss of anchorage of the screw (a). The situation can be solved by inserting a selftapping bicortical screw gaining anchorage in the opposite cortex (b).

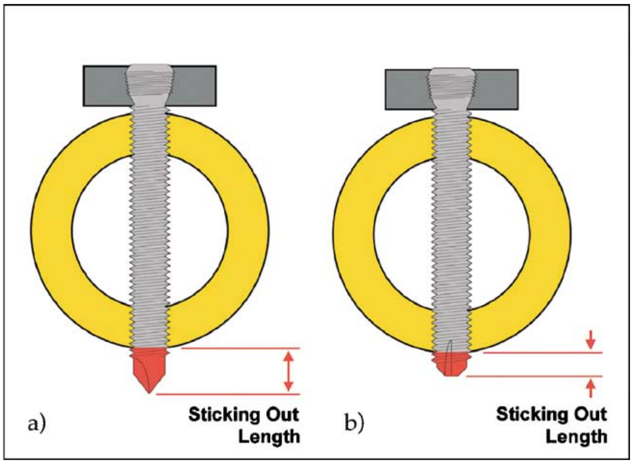


Fig. 2: Different sticking out length of the different screw. The different amount of sticking out length of a bicortical selfdrilling (a) and a bicortical selftapping screw (b) is important to know in case of neurovascular structures being in close vicinity to the opposite bone cortex.

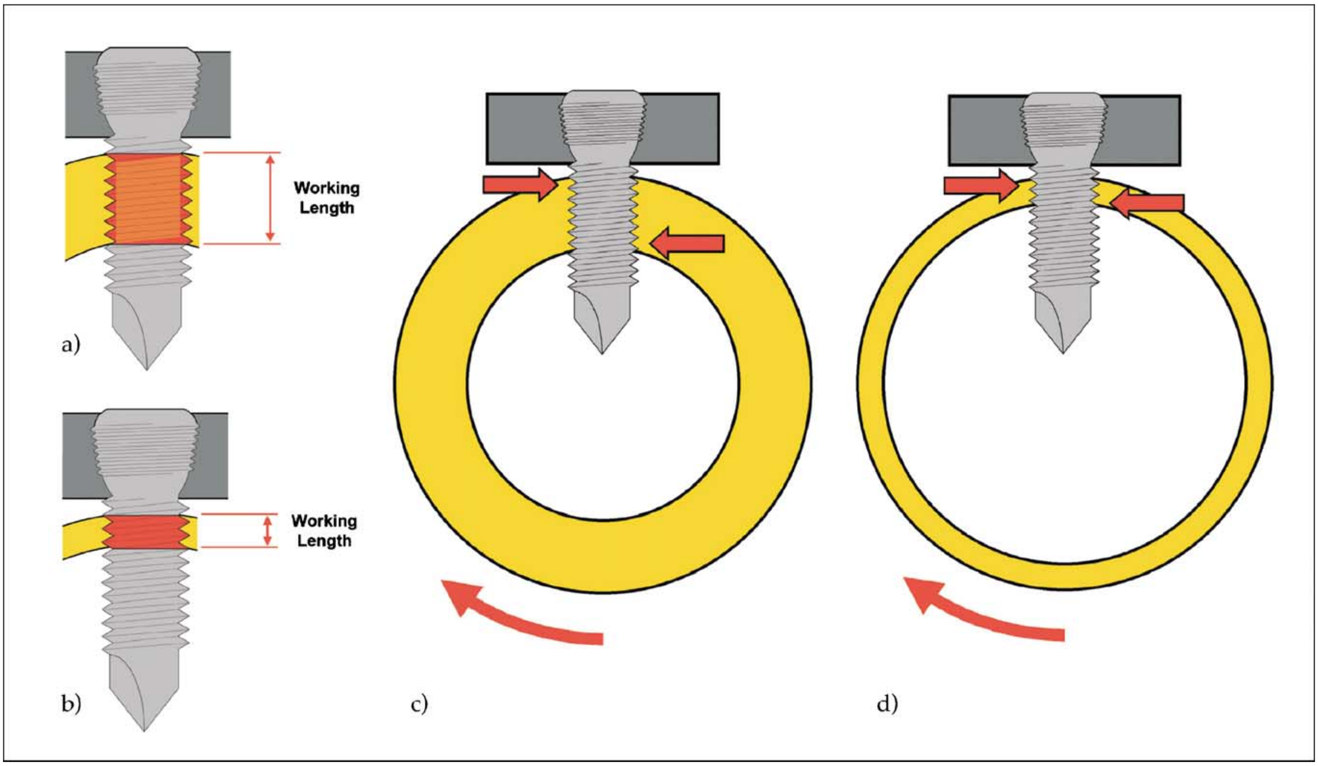


Fig. 3: Importance of cortical thickness on the working length of monocortical screws. The working length of monocortical screws depend on the thickness of the bone cortex. In normal bone this working length is sufficient (a), in osteoporotic bone the cortex regularly is very thin and thus, the working length of a monocortical screw is insufficient (b).

This difference of the working length is important when osteoporotic bones mainly loaded in torque have to be stabilised, such as the humerus. In normal bone the length of anchorage of the screw thread is good enough to withstand rotational displacement (c). In case of osteoporosis this working length is very short due to the thin cortex and under torque the bone thread soon will wear out and secondary displacement and instability will occur (d).

avoids destruction of the bone thread in the near cortex when there is a thin medullary cavity because it is able to penetrate into the opposite cortex. When a monocortical selftapping screw is inserted, even the shortest screw length destroys the bone thread as soon as the screw tip touches the opposite cortex before the screw head is locked inside the plate hole. When this occurs, the screw should be replaced by a bicortical selftapping screw to gain anchorage, at least in the opposite cortex (Fig. 1a, b).

The selftapping screws are used in the epi-, meta and diaphyseal segments of bone when a bicortical screw is planned. The extruding length of the selftapping screw is shorter than that of the selfdrilling screw because it is not equipped with a cutting tip (Fig. 2a, b). For good anchorage of the screw threads in both cortices, even the selftapping screw should slightly stick out of the bone.

In osteoporosis, the bone cortex is usually thin. In such a condition, the working length of a monocortical screw is reduced and thus the anchorage even of a locked screw is poor (Fig. 3a-d). This problem can lead to a complete loss of the holding of the screw and thus, instability of fixation will result. The problem is known for bones loaded mainly in torque (e.g. humerus). For all fractures associated with osteoporosis, the use of bicortical selftapping screws is recommended in all bone segments to enhance the working length and avoid a potential problem at the interface screw thread to bone (Fig. 4).

An additional problem is the complete loss of the surgical feeling of the quality of the bone during screw insertion and tightening because the screw head engages in the conical threaded plate hole. Transcutaneous insertion of short monocortical screws in the diaphyseal area is critical at the far plate end when some malalignment between long bone axis and the plate is present. No anchorage is obtained with the short screw despite the surgical feeling of good tightening (Fig. 5a, b). Technically, the problem can be solved either

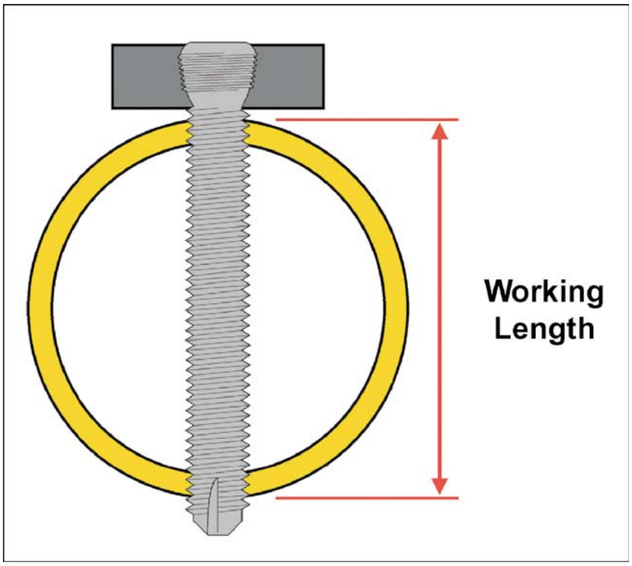


Fig. 4: Improvement of the working length. In osteoporotic bone the standard use of bicortical screws is recommended because of the longer working length leading to a much higher torque resistance.

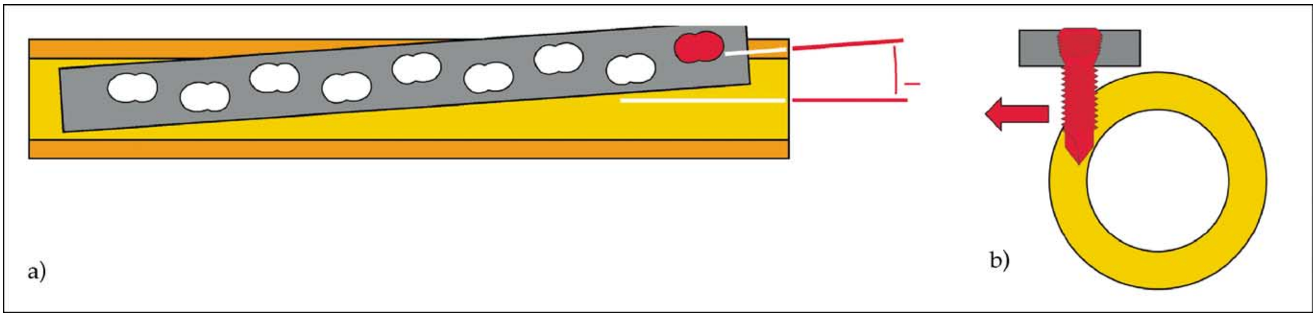


Fig. 5: Malalignment between bone axis and plate. Malalignment between bone axis and plate leads to an eccentric plate position (a). At the fare end of the plate a monocortical screw will not anchor in bone in such circumstances (b).

by inserting a long selftapping screw or using an angulated standard screw (Fig. 6a, b). The problem can be recognised in an earlier stage of the procedure and avoided by using the drill bit to centre the screw and to feel the bone cortex before inserting the monocortical selfdrilling screw.

Position of the implant

The standard positions of the LC-DCP can be adopted for the positioning of the LCP. The function as an internal fixator with locked screws has not yet needed a modification of our standard approaches.

Length of the LCP

The choice of the appropriate length of the LCP is one of the most important steps in internal fixation using plates. It depends on the fracture pattern and the mechanical concept used for fixation.

In intramedullary nailing, the length of the nail to be used is not under debate. The nail length more or less equals the complete length of the fractured bone from one epiphysis to the other. In contrast to intramedullary nailing, the length of the plate remained controversial in plate osteosynthesis for a long time. In the past, a short (or too short) plate was often chosen to avoid a long skin incision and extensive soft tissue dissection. With the newer techniques of indirect reduction, subcutaneous or submuscular implant insertion, the plate length can be increased without additional soft tissue dissection. Thus, no or not much additional damage on the biological side is created and plate length can be chosen according to the pure mechanical demands of the specific fracture that has to be stabilised. From the mechanical point of view, we should keep the plate loading and the screw loading as low as possible to avoid fatigue failure due to cyclic loading.

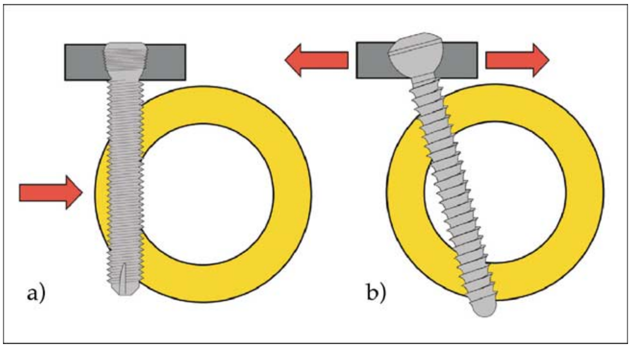


Fig. 6: Screw insertion in eccentric plate position. To overcome the problem of insufficient anchorage of a monocortical selfdrilling screw in case of eccentric plate position either insertion of a long bicortical selftapping screw (a) or of a standard screw allowing angulation in the plate hole (b) is recommended.

Three segments of the plate can be distinguished: the middle segment at the fracture site between the two innermost screws, and the proximal and the distal plate segments anchoring the implant onto the proximal and distal main fragments. The length of the plate and the positioning of the screws influence the loading condition of the plate itself, as well as the screws. In the middle segment, spanning the fracture, is the local mechanical environment responsible for the biological response of fracture healing (indirect healing, direct healing, nonhealing).

The ideal length of the internal fixator can be determined by means of two values: the plate span width and the plate screw density [34]. The plate span width is the quotient of plate length and overall fracture length. Empirically, we found that the plate span width should be higher than 2 to 3 in comminuted fractures and higher than 8 to 10 in simple fractures. The plate screw density is the quotient formed by the number of screws inserted and the number of plate holes. Empirically, we recommend values below 0.5 to 0.4, indicating that less than half of the plate holes are occupied by screws (Fig. 7).

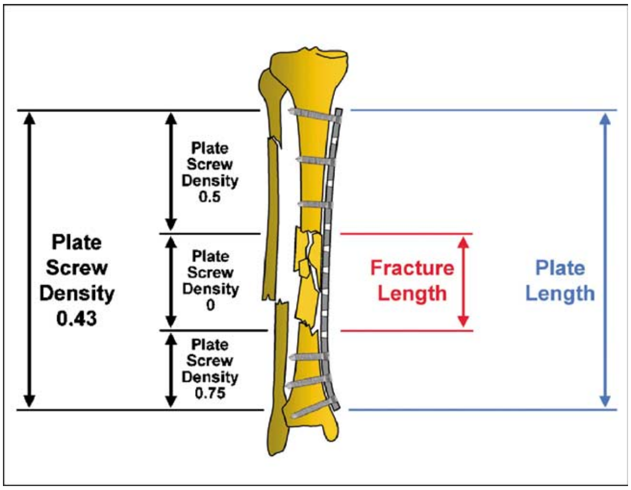
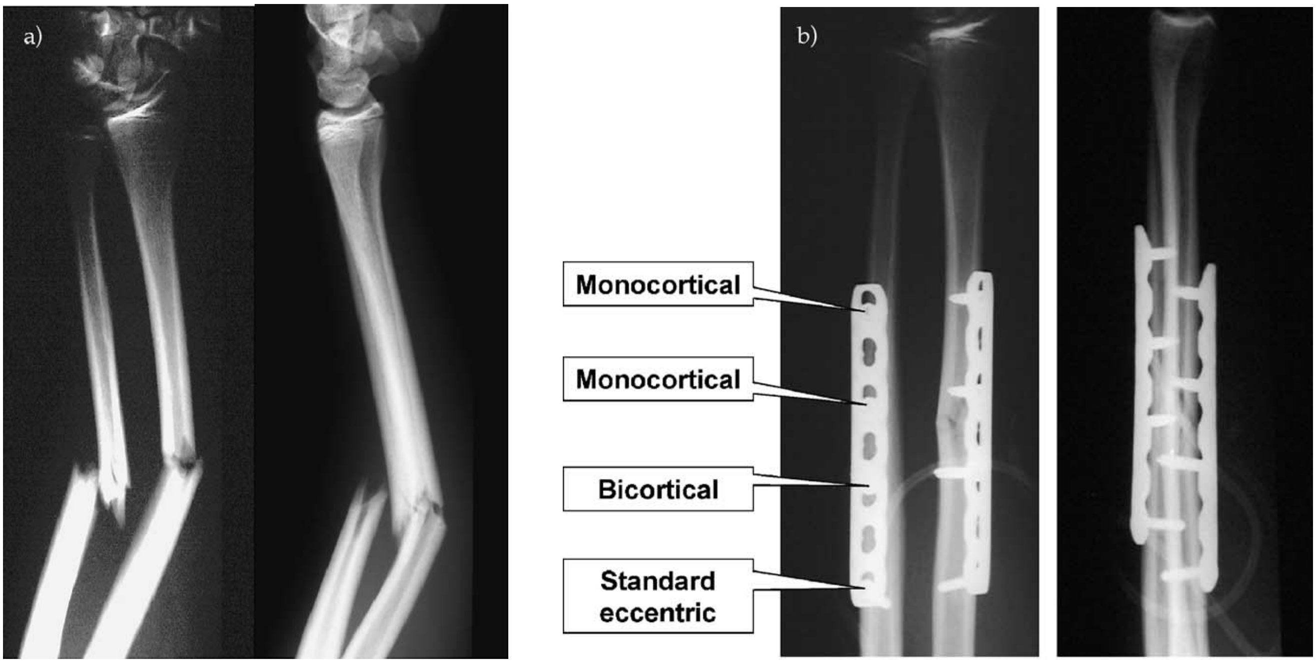


Fig. 7: Importance of the plate span ratio and plate screw density in bridge plate technique. The schematic drawing shows a mechanically sound fixation of a comminuted diaphyseal fracture of the lower leg. The ratio between the fracture length and the plate length is called plate span ratio. In this case this ratio is high enough, i.e. about 3 indicating that the plate is three times longer than the overall fracture area. On the other side the plate screw density is shown for all the three bone segments: the proximal main fragment has a plate screw density of 0.5 (3 hole out of 6 occupied), the segment over the fracture of 0 (0 holes out of 4 occupied), and the distal main fragment of 0.75 (3 holes out of 4). The higher plate screw density in the distal main fragment has to be accepted because for anatomical reasons there is no possibility to decrease it. The overall plate screw density of the construct in this example is 0.43 (6 screws for a 14-hole plate).



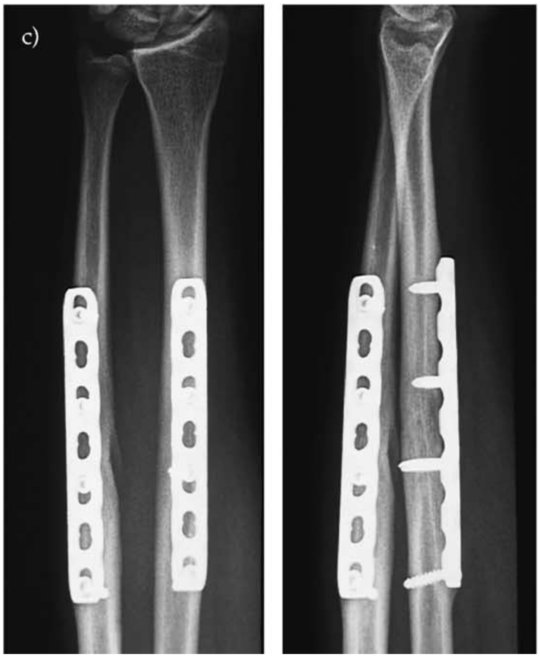


Fig. 8: Minimal requirement for stable fixation. Clinical case of a forearm fracture stabilised with a 3.5 mm LCP in a 17 years old patient. The preoperative (a), postoperative (b) and follow up radiographs at 15 months (c) are shown. With the minimal requirements of stable fixation, i.e. two monocortical screw in the one main fragment fracture healing without implant failure or secondary displacement was achieved. Nevertheless, such a fixation should be used only exceptionally. We recommend the use of more than two screws per main fragment to stay on the safe side of internal fixation of diaphyseal fractures.

Number of screws

The previous AO/ASIF guidelines for a specific number of screws or cortices in each fragment no longer should be used as the only information about anchoring a plate in the main fragments to achieve a good stability of fixation.

As previously stated, it is much more important to insert few screws, but these screws should have a high plate leverage to decrease the screw loading.

From the pure mechanical point of view, two monocortical screws on each main fragment are the minimal requirement to keep the construct stable (Fig. 8a-c). Such a construct will fail when one screw breaks due to overload or when the interface between bone cortex and screw thread shows bone resorption and loosening (pullout of the screw). The use of two bicortical screws on each fragment does not improve the situation with respect to screw fatigue failure, but does improve it with respect to an unstable interface between screw thread and bone. Thus, such a construct can only be used in good bone quality and when the surgeon is sure that all the screws are inserted correctly. For all other cases and for safety reasons, a minimum of three screws is recommended.

When fixing fractures in the epi- and metaphyseal areas neither the length of the plate nor the number of screws can be chosen following only the mechanical demands, because the local anatomy and the length of the epi-metaphyseal fragment will influence plate position and length. In such circumstances, the use of the metaphyseal plate is recommended to achieve a balanced fixation with identical anchorage of the implant on both main fragments of the bone.

Order of screw insertion for the combination technique

When the plate is regularly used for compression plating, the standard screws in their eccentric position should be inserted first in the middle of the plate to achieve fracture compression. As a modification, the plate can be fixed with one or two locked screws on the one main fragment and than compression can be achieved by inserting one eccentric screw on the other fragment or by the use of the tension device. Osteosynthesis is then completed with locked screws.

Mechanical and biological background information

Effect of plate length on screw loading

The length of the plate and the position of the screws modify the loading condition of the screws used. The longer the splint is, the less pullout force is acting in the screws due to an improvement of the working leverage for the screws (Fig. 9a-d). Thus, in plating, very long plates should be used from the mechanical point of view. Using indirect reduction, minimal-invasive insertion and the fixation technique of the LCP, no biological disadvantage of the long implant can be observed. Using the LCP as an internal fixator with locked screws, the screw loading is mainly in bending and not pullout. All the screws are loaded at the same time and failure at the interface screw thread to bone may be less frequent. Nevertheless, the working leverage of an internal fixator should also be kept long and spacious.

Effect of plate length and screw position on plate loading

Bending a plate over a short segment enhances the local strain of the implant. Bending over a longer segment reduces the local strain, resulting in a protective effect against fatigue failure of the implant (Fig. 10a-d). In compression plating with the load sharing condition of plate and bone, the two middle plate screws can be inserted

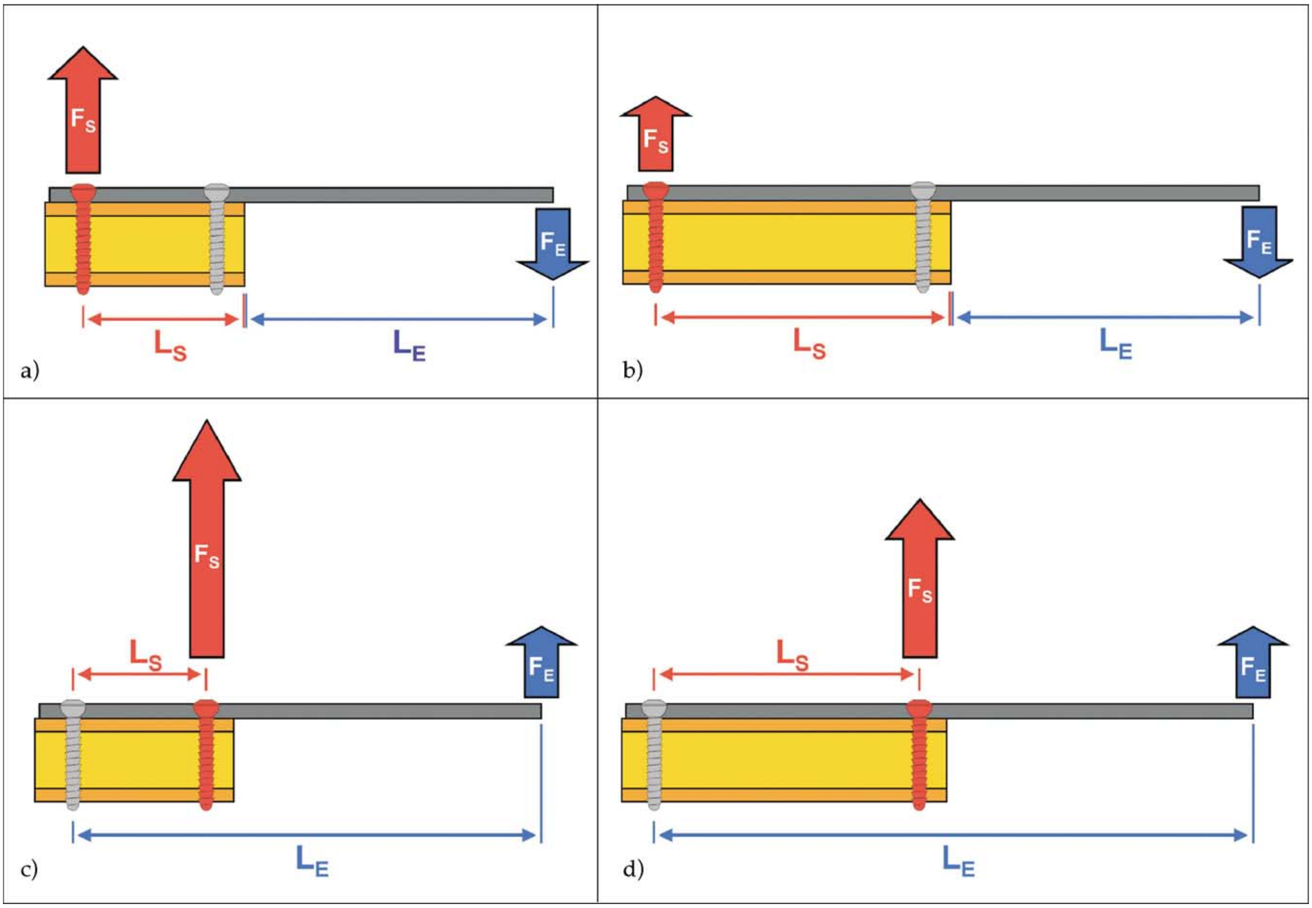


Fig. 9: Pull out force on standard screws and working leverage of the plate.
When a relatively short plate is used the screw loading is relatively high due to a short working leverage of the screws for both directions of a bending moment (a, c). The use of a longer plate increases the working leverage for each screw. Thus, under a given bending moment the pullout force of the screws is decreased (b, d).

FE	External force creating a bending moment on the plate	LE	Lever arm of the external force
FS	Pull out force of the screw	LS	Lever arm of the screw

as close as possible to the fracture, with the peripheral screws inserted at each plate end. For a comminuted diaphyseal fracture spanned with the internal fixator as a non-gliding splint, a longer distance between the two screws adjacent to the fracture is needed to obtain a longer distance and a lower elastic deformation of the plate [7, 11] and also of the interfragmentary tissues.

Effect of plate length on bone healing

Flexible fixation allows the fracture fragments to displace in relation to each other when load is applied. The external load results only in reversible deformation of the splint. After unloading, the fracture fragments move back into their former relative position. When the load results in an irreversible deformation of the splint, the fragments remain permanently displaced. Such a situation with plastic deformation of the implant is called unstable fixation.

It appears likely that some flexibility of fixation is the most important mechanism triggering and inducing callus. A maintained low tissue strain allows the safe differentiation of the granulation tissue into callus [31]. Stability itself seems to be of secondary importance for bone healing. The most critical precondition for sound repair consists of an unimpaired viability of the involved tissues. Avascularity of bone fragments prevents callus bridging of the fracture gaps.

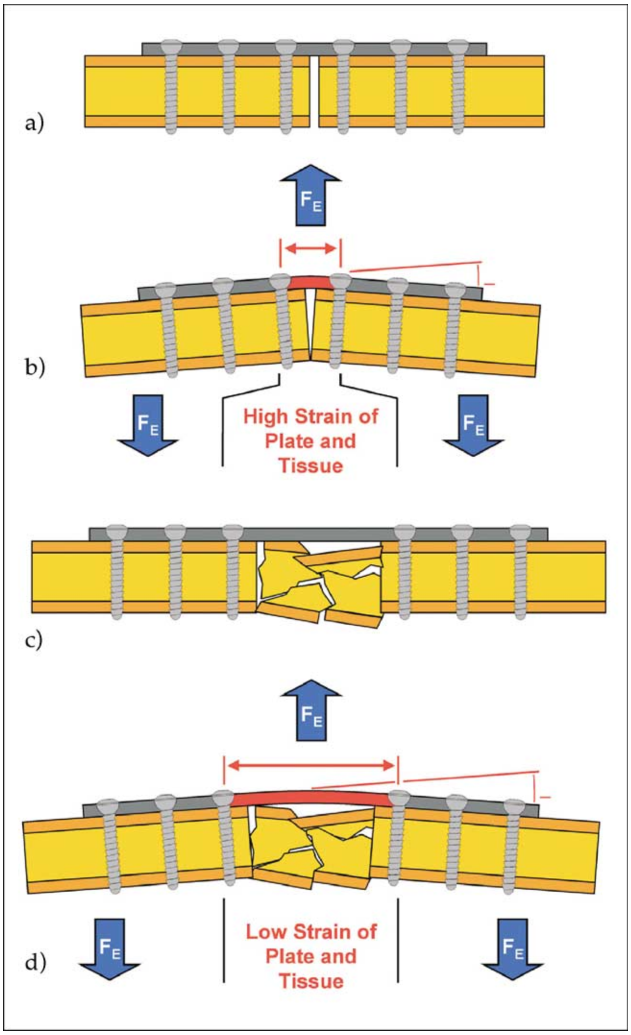


Fig. 10: Plate strain in three point bending. A bending moment leads depending on the amount of the moment to reversible deformation (i.e. reversible angulation) of the implant. When the segment to be bent is short (a, b) the relative deformation (strain) is high and the implant is prone to undergo very soon fatigue failure. When the plate spans a longer comminuted fracture area (c, d) the same three point bending leads to an equal absolute deformation (angulation) of the plate. But, the deformation is distributed over a longer distance leading to low implant strain and higher resistance against fatigue.

Effect of the internal fixator concept on bone healing

The internal fixator leaves a distance underneath the implant; thus, the hole circumference of the bone shows

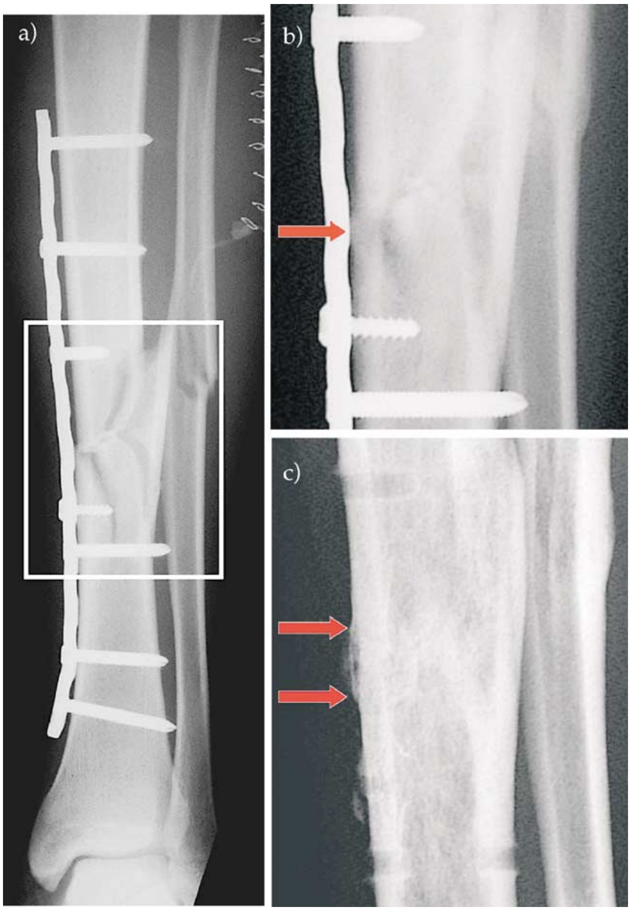


Fig. 11: Callus healing underneath the internal fixator. Clinical case of a lower leg fracture in a 19 years old patient treated with a 4.5/5.0 mm LCP. The postoperative antero-posterior radiograph shows the no contact situation between plate and bone (a). The enlargement of the area at the fracture site shows callus formation underneath the plate at 4 months (b) and after implant removal at 2 years (c) proving vital bone and periosteum underneath the implant.

identical callus formation even directly underneath the implant. Callus formation starts at areas with undisturbed vitality of the bone and the periosteum with direct subperiosteal bone apposition. This is in contrast to the standard plating technique with load transfer by friction where the bone underneath the implant shows a slow healing capacity with a long lasting weakness of the cortex due to the initial implant-induced avascularity. This effect can lead to a stress riser effect with a potential danger for refracture after implant removal [23]. Therefore, for biological reasons, the concept of the locked internal fixator should be preferred whenever it is technically feasible (Fig. 11a-c).

Technique of reduction

With the new implant system the main goal of internal fixation remains unchanged, i.e. anatomical reduction and stable fixation of fractures of the articular surface, and correct restoration of axial alignment, rotational alignment and length of the bone. To achieve these aims, reduction can be performed directly or indirectly. For biological reasons, the indirect approach should be considered whenever it is technically feasible [13, 27].

In the submuscular plating technique of the femur and subcutaneous plating technique of the tibia for meta-diaphyseal fractures, the correction of the length is mainly achieved by traction (manual, fracture table, distractor). The axial alignment needs to be controlled with intraoperative radiographs or an image intensifier in both planes; the rotational alignment is mainly controlled clinically. The advantages of the indirect reduction method include minimal soft tissue compromise and negligible devascularisation of the fracture fragments during surgery. These advantages in turn result in a closer approximation of the natural course of bone healing with rapid integration of the vital fragments into the fracture callus buttressing the fracture area opposite the implant and preventing fatigue failure of the implant.

Indirect reduction and closed fixation techniques are technically much more demanding than an open procedure; thus, accurate preoperative planning is needed to choose the appropriate implant size and length, shaping of the plate and the number, position and order of insertion of the screws (standard or locked) [27].

Shaping of the LCP

Conventional plating calls for the exact adaptation of the implant to the bone to maintain precise reduction. The screws serve to apply a compressive preload at the interface between plate and bone. The bone fragments are pulled towards the implant. Thus, when using the LCP like a conventional LC-DC-Plate, accurate shaping of the implant is needed. Load transfer from one to the other main fragment is by friction. Most of the implant-induced damage to the bone has been traced to the areas of direct contact between the implant and the bone, and attributed primarily to the disruption of the periosteal vascular supply.

Using the LCP as an internal fixator, the exact adaptation of the implant to the bony surface is not mandatory. Load transfer occurs by locking. Once the fracture fragments are properly aligned, tightening of the screws in the conical threaded plate holes does not lead to a secondary displacement and no compression of the soft tissues in the interface plate bone occurs.

The straight and the bent internal fixator

To stabilise a straight segment of a diaphysis a straight internal fixator can be used. In such a situation all screws have the same direction and the screw loading is identical. In very osteoporotic bone, this can be dangerous. To avoid identical screw directions for all the screws, slight bending (multiple waves forth and back) of the internal fixator offers an advantage because it results in divergent and convergent screw direction enhancing the pullout strength of the screws, comparable to the PHILOS plate. This slight shaping can be used in so-called egg shell bone in cases of severe osteoporosis (Fig. 12a, b). Other bone segments, such as the olecranon, need a bent plate from the beginning onwards. The shaping of the plate avoids the screws being parallel to each other.

Reduction onto the plate

The first screw insertion (locked or standard) is in the shorter metaphyseal fragment close to the joint line. Then the screw at the other plate end is inserted and the reduction is checked with the image intensifier or an intraoperative radiograph in both planes. With a flexion or extension malalignment the fragments are reduced with pointed reduction forceps through stab incisions. Where the malalignment is in the frontal plane, introducing the standard screws nearer the fracture can help to reduce the fracture onto the plate. The fixation is completed either with locked or standard screws, depending on the bone quality (Fig. 13a, b). Insertion of locked screws in the middle of the plate maintains the malreduction (Fig. 13c).

Dislocation onto the plate

The inappropriate use of either standard or locked screws can abolish the previous efforts to achieve proper axial alignment. Thus, the remaining axial malalign-

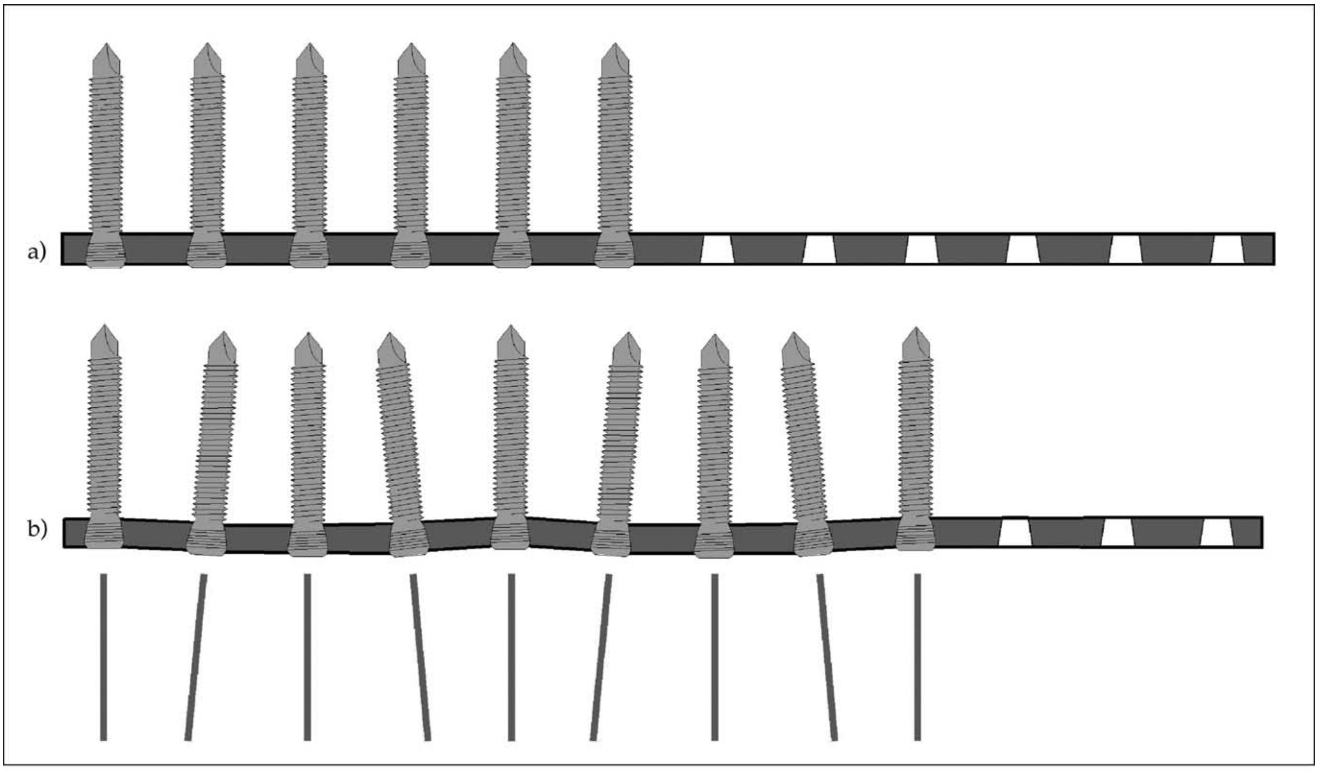


Fig. 12: Bending the internal fixator to avoid parallel screw insertion. In osteoporotic bone parallel insertion of all locked screw may be disadvantageous (a). The pull out resistance of the hole construct can be improved when the plate slightly is bent forth and back resulting in divergent and convergent locked screw directions (b).

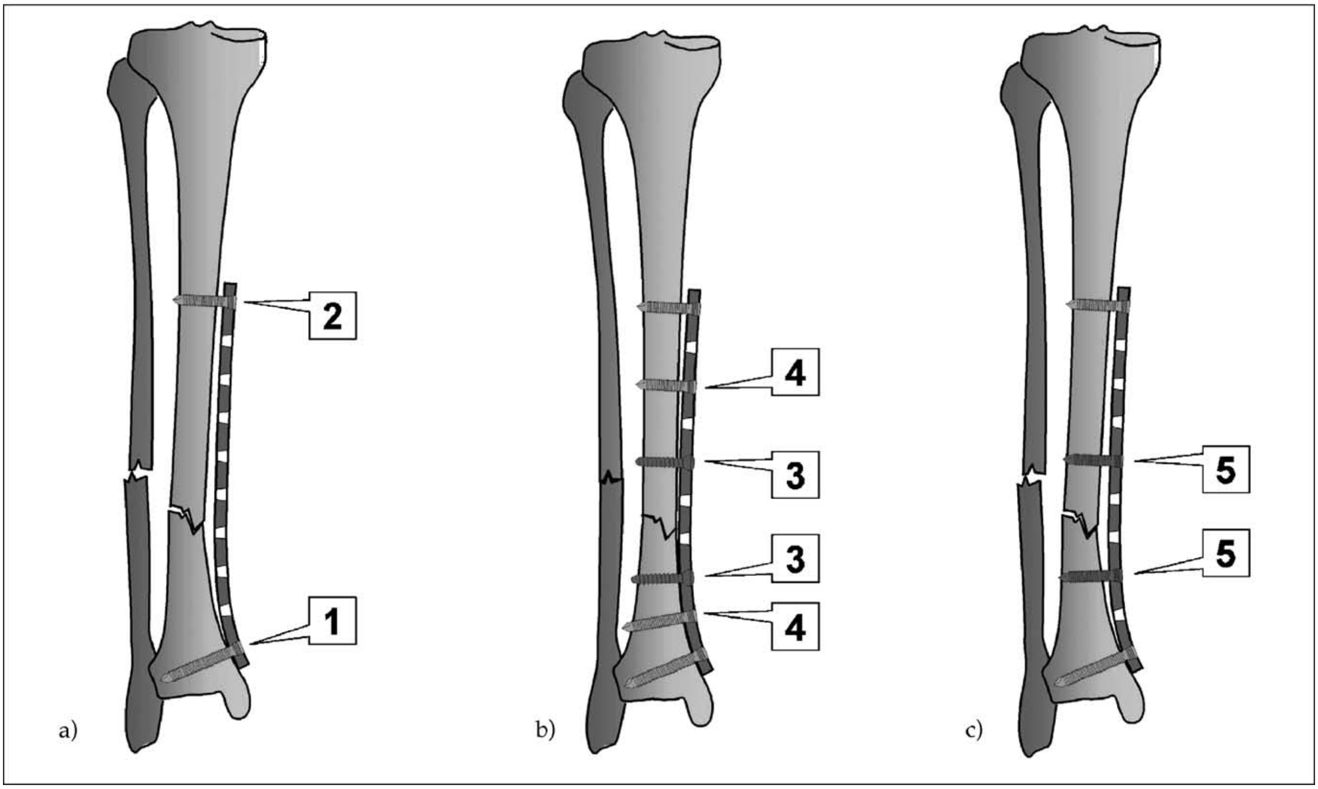


Fig: 13: Reduction onto the plate. After insertion of an internal fixator and single screw fixation (1, 2) in the proximal and distal main fragments a persistent frontal plain malalignment is present (a). Insertion of standard screws (3) in the middle of the plate reduces both fragments onto a properly shaped plate (b). Osteosynthesis is completed with two additional locked screws (4). Unreflected insertion of locked screws in the plate middle (5) will maintain the malreduced position of the fragments (c).

ment on the initial radiological check of reduction will dictate which type of screw has to be inserted at which position of the plate to overcome the problem of dislocation onto the plate (Fig. 14a-c).

Conclusions

Over the past few years new thinking about operative fracture treatment using plates has been prevalent. New implants, such as the Locking Compression Plate, together with an adapted reduction and fixation technique combine the advantages of operative and conservative fracture treatment: proper alignment of the injured bone, sufficient stability of fixation allowing functional aftercare and an undisturbed natural course of bone healing.

Each implant has on the one side a defined mechanical efficiency, on the other side an implant-inherent biological interference, i.e. local devitalisation. The advantage of the particular implant with its efficiency for stabilisation should outweigh the concomitant disadvantage regarding tissue devitalisation.

Internal fixators with locked screws mechanically used as splints are more and more frequently replacing the older conventional plating concepts. Indirect reduction and minimal-invasive plate insertion and fixation minimise the surgical devascularisation and the implant-inherent vascular insult to the bone tissue.

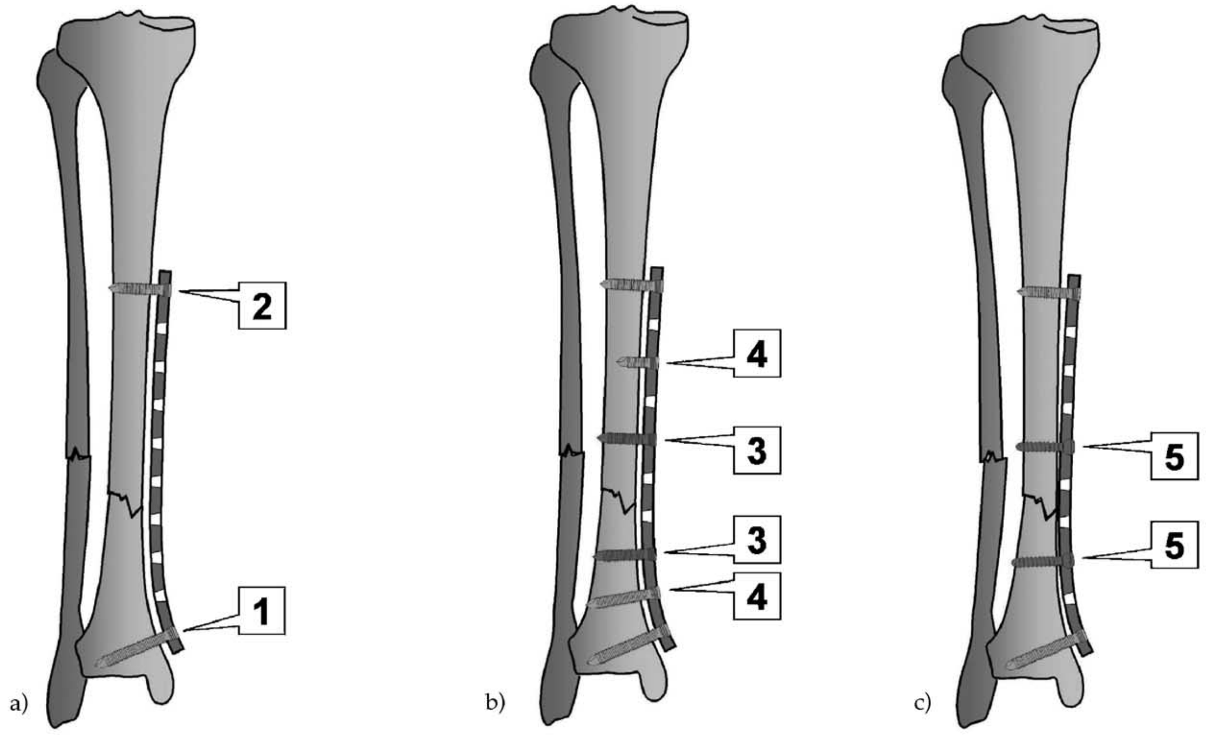


Fig. 14: Dislocation onto the plate. The intraoperative radiographic check shows a proper alignment of the fracture and the correct screw position (1, 2) and shaping of the internal fixator (a). Further insertion of locked screws (3, 4) will maintain the achieved reduction (b), while the wrong insertion of standard screws in the middle of the plate (5) pulls the fragments towards the plate and leads to dislocation onto the plate with residual malalignment (c).

Conclusive rules (valid for 2003)

	Simple fracture	**Comminuted fracture**
Biomechanical concept	Compression technique Rarely bridge plating	Bridge plating technique
Reduction	Mainly direct	Indirect
Implant insertion	Partially open	Minimally invasive
Plate **Shaping**	Conform to bone surface	Not needed
Length (plate span ratio)	> 8 – 10	> 2 – 3
Screws	Standard and locked	Locked
Type of screws	Mainly bicortical	*Diaphysis:* selfdrilling monocortical *Epi- and metaphysis:* selftapping bicortical
Plate screw density	< 0.4 – 0.3	≤ 0.5 – 0.4
Number of screws per main fragment	≥ 2	≥ 2
Number of cortices per main fragment	≥ 3	≥ 4
Screw position	Short middle segment without screws	Long middle segment without screws
Empty plate holes over fracture	0 – 3	≥ 3

Table 3: Rules for plate fixation in simple and comminuted fractures

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Correspondence address:
Gautier Emanuel, MD
Co-Chief Department of Orthopaedic Surgery
Kantonsspital Fribourg, CH-1708 Fribourg
Switzerland
Phone ++41 26 426 71 91 Secretary
++41 26 426 71 96 Office direct
Fax ++41 26 426 72 25
E-mail gautiere@hopcantfr.ch