ICUC One-Page Paper

Mixing a lag screw with a splinting protection plate

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The 20th century has seen three essential improvements of surgical fracture fixation:

1) Shifting attention from mere fracture healing to quickly recovering function minimized dystrophic complications.
2) Shifting attention from pure mechanics of fixation to minimally invasive surgery optimized biology.
3) Shifting attention from mobility to tissue deformation that allowed improved handling of flexibly locked fixation.

Now the combined use of splinting and compressive technology requires reappraisal of biomechanical aspects avoiding possible incompatibilities of different implant functions.

Surgical implants, which stabilize a fracture, may function according to two fundamentally different principles: splinting and compression. When combining the different implant functions synergy or conflict is possible. Conflicting functions may result from the combined use of long span, flexible splinting by plate together with non-flexible lag screws. The following analysis shall allow better understanding for improved clinical applications of such combinations.

Splinting: Stabilizing a fracture with a plate or a nail is an obvious example of splinting. The fracture fragments are bridged with implants fixed to the main fragments of the fracture. The stiffness of the bridging implant reduces the mobility of the fracture but does not abolish it.

Compression: When two fracture surfaces are (com-)pressed against each other the contact between the fragments is maintained within a bandwidth of functional load (Fig. 2A, 2B). The surfaces only separate and fracture mobility occurs when functional traction exceeds the compressive preload (Fig. 1) or when functional shear exceeds the friction installed by the compression and/or the interdigitation between rough surfaces held together by compression.

Special aspects of the lag screw as a potentially non-forgiving implant:

The proper location and inclination of a lag screw in respect to the fracture surfaces is challenging but not discussed here. Furthermore, the additional surgical damage produced when a lag screw needs to be inserted from a plane outside the main surgical approach is not considered here. The examples used concern diaphyseal cortical bone but the principles apply similarly to metaphyseal or pure cancellous bone.

Aspect of tolerance to deformation: A plate (or a nail or an external fixator) that functions as a splint, reduces but still allows, movement of the fracture fragments. The splint allows a degree of deforming load and reversibly returns, when unloaded, to its original shape and function is a **tolerant behavior** of the implant. The screw does tolerate only minimal displacement at the bone thread interface before it irreversibly gives way and permanently loses its function, an **intolerant behavior.** It is obvious that combining a forgiving implant, which allows displacement with a non-forgiving implant that irreversibly loses its function under the allowed displacement is potentially incompatible and requires special attention. This applies to lag screws used for reduction only. In a compressed fracture, displacement occurs merely when traction exceeds preload and stripping is less probable.

The lag screw used in compression technology: In fracture fixation, which installs so called absolute stability, the lag screw optimally contributes to stability and displacement only occurs after excessive loading when the functional traction exceeds the compressive preload. The lag screw may produce large amounts of ideally aligned compression from within the fracture plane, while for instance a plate applies eccentric compression. As a self-standing implant the lag screw does not usually provide enough axial strength to resist bending of a short oblique fracture with typically inefficient leverage that results in large axial traction. Furthermore, the compression produced by lag screw tapers off quickly with distance from the screw axis and with it the leverage against torque around the long axis of the screw is small. If the fracture plane allows application of a second well-spaced lag screw, leverage is improved but the usual application needs protection from peak load e.g. by a load sharing protection plate.

No callus is observed with maintained motionless fixation, this in turn may be used as an indicator of maintained lag screw function (Fig. 2A, 2B).

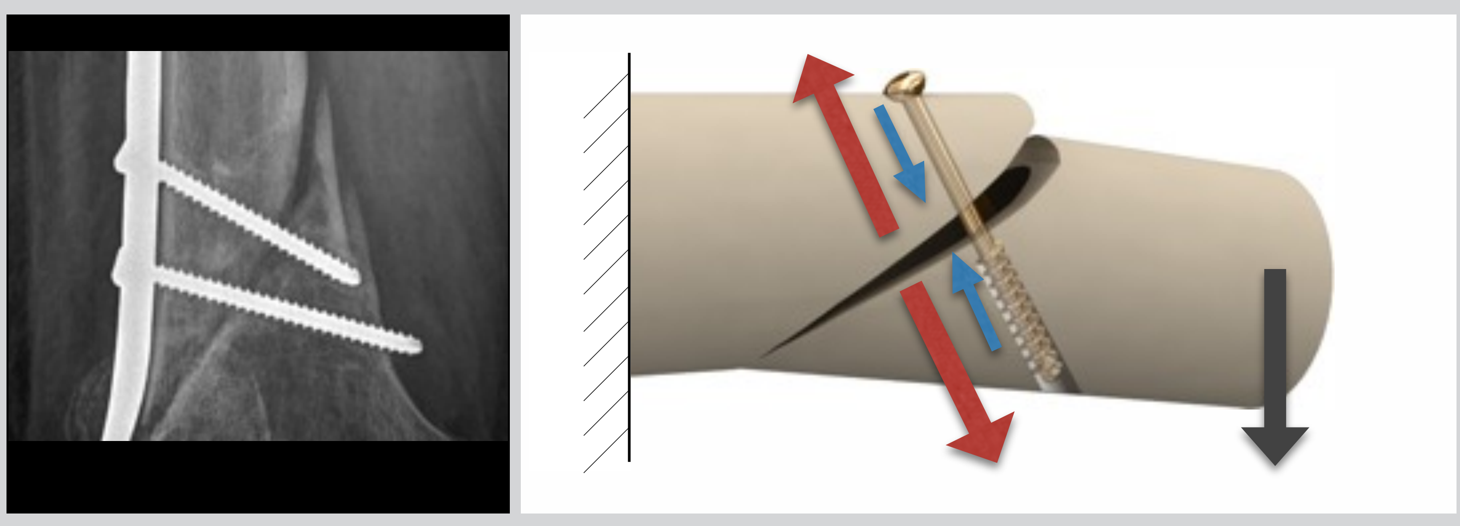

Fig. 1 Stripping of the lag screw. *LEFT: Anecdotal case. Not in the ICUC App. Stripping lag screws diagnosed by bone resorption. RIGHT: the traction produced by functional bending exceeds compression by lag screw. The thread of the lag screw strips and function of the lag screw is lost.*

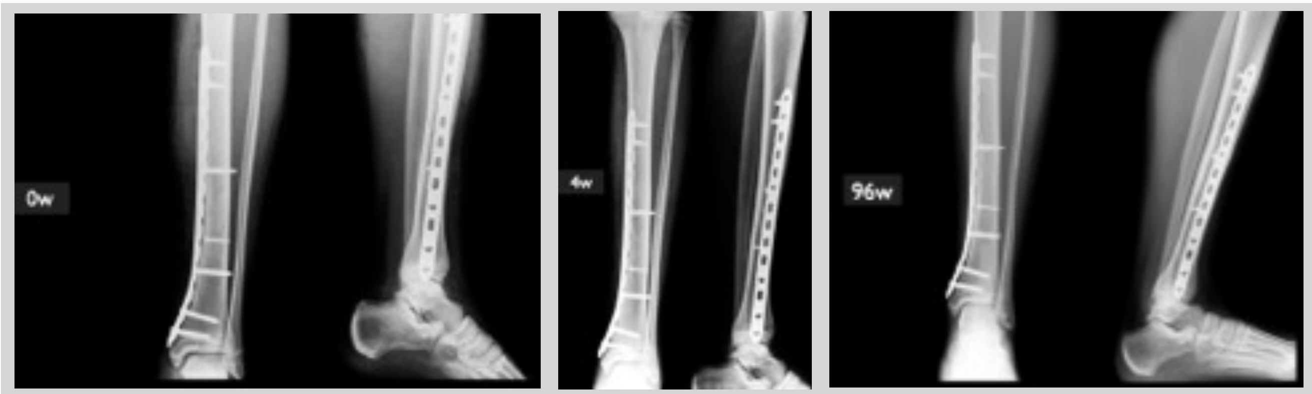

Fig. 2A Good lag screw construct with protecting plate. *Lag screw, balance of forces. No callus. 20 year-old patient.*
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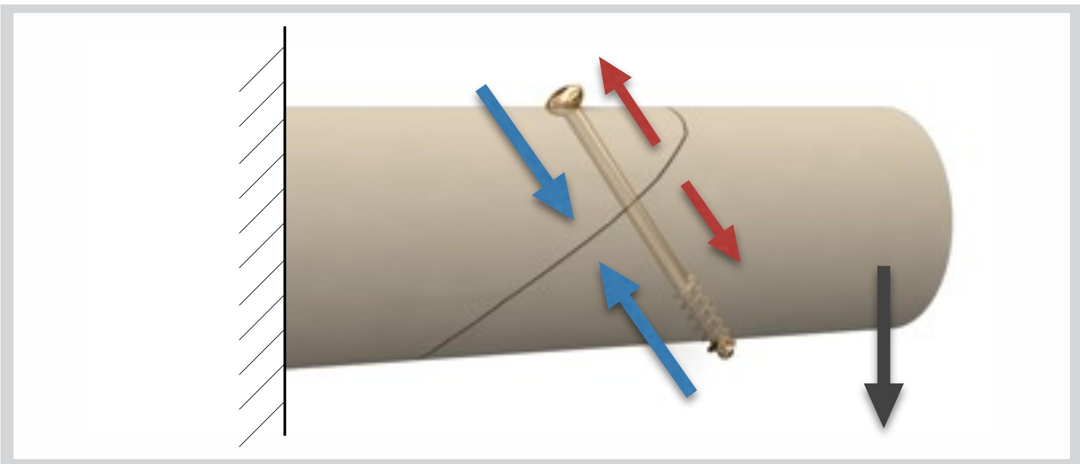

Fig. 2B Lag screw, balance of forces. *The oblique fracture is stabilized with a lag screw.*
The compression exerted by the lag screw (blue) exceeds the traction (red) produced by bending.
The fracture remains in close contact.

The lag screw used in flexible splinting technology: Fractures are often treated using flexible locked splinting technology to improve biomechanical induction of fracture repair. When in this context lag screws are used for reduction achieving proper location and inclination of the screw, especially when applied through stab incision is demanding and suboptimal lag screw function is frequent. As it is difficult to judge clinically whether the function of the lag screw is maintained one needs to rely on the appearance of callus indicating fracture mobility. When callus appears this may indicate loss of lag screw fixation (Fig. 3).

Diagnosis of lag screw stripping: When the lag screw strips and the head is pushed back, stripping is obvious but rare. When the lag screw strips, the onset of mobility at the interface between implant and bone thread induces resorption of bone. Such resorption is usually limited to the depth of the thread and it is difficult to observe.

When stripping of a lag screw occurs secondarily, after a callus free first period, late callus appearance indicates mobility of the fracture and that the lag screw has stripped (Fig. 4).

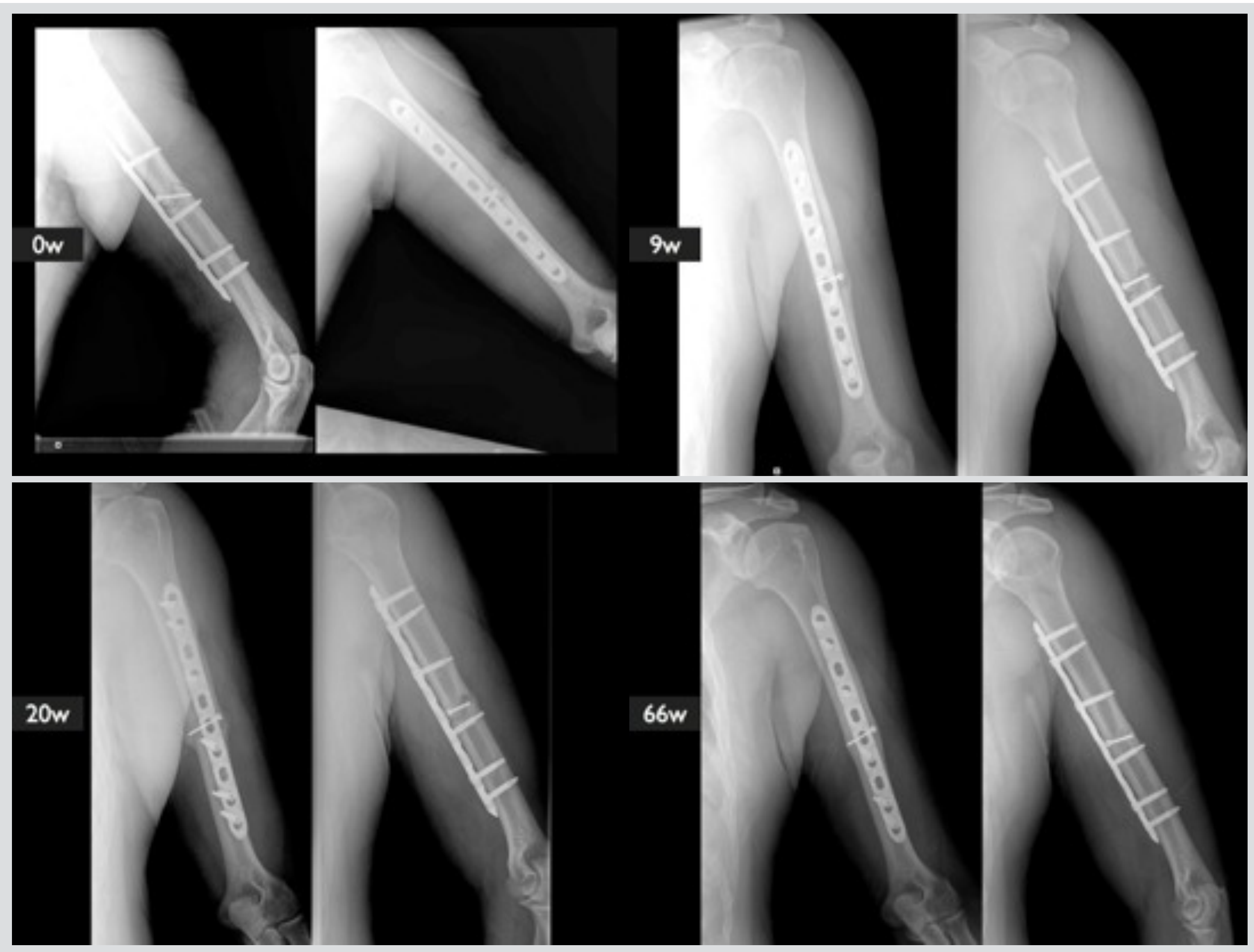

Fig. 3 Indirect signs of a lag screw construct failure. (Bone resorption at the fracture site + periosteal callus). 40 year-old patient.
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Fig. 4A *Long span, flexible, plate splinting a lag screw fixation. 40 year-old patient. At 12 weeks no sign of lag screw stripping, at 21 weeks irritation callus indicating loss of lag screw function with some fracture mobility, at 34 weeks solid callus bridging and saving the situation. The fact that the lag screw was inserted through a comparably small spike seems to have contributed to the outcome.*
ICUC App ID: 32-SI-608

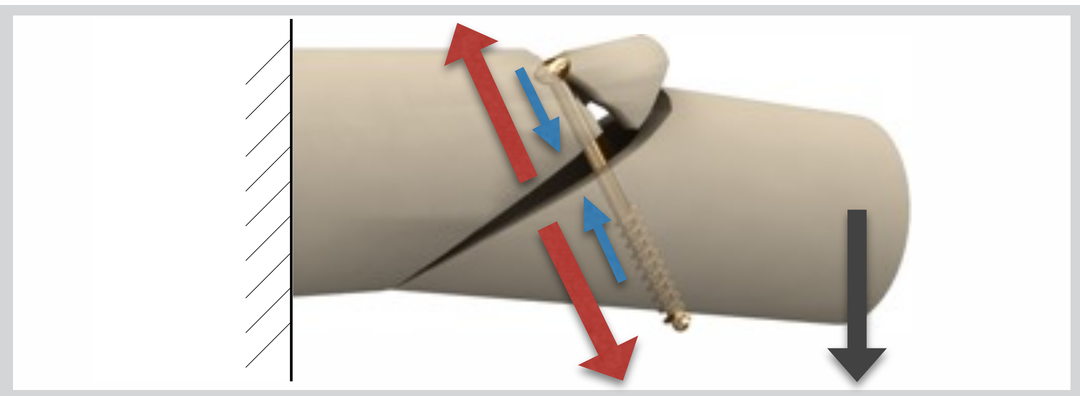

Fig. 4B *Lag screw positioned near thin end of bone fragment. The bone spike does not resist and breaks, the fracture opens. The function of the lag screw is lost.*

For further information:

Harnroongroj, Thossart: Die biomechanische Bedeutung der interfragmentären Zugschraube bei der Plattenosteosynthese der Tibiaschaftschrägfraktur. Univ., Diss.--Saarbrücken, 1985. [Mikrofiche-Ausg.].

Lambotte A (1913): Chirurgie opératoire des fractures. Paris: Masson.

Mardian, S.; Schaser, K. D.; Duda, G. N.; Heyland, M. (2015): Working length of locking plates determines interfragmentary movement in distal femur fractures under physiological loading. In: Clinical biomechanics (Bristol, Avon) 30 (4), S. 391–396. DOI: 10.1016/j.clinbiomech.2015.02.006.

Misaghi, A.; Doan, J.; Bastrom, T.; Pennock, A. T. (2015): Biomechanical Evaluation of Plate Versus Lag Screw Only Fixation of Distal Fibula Fractures. In: The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons 54 (5), S. 896–899. DOI: 10.1053/j.jfas.2015.03.011.

Müller, Maurice E. (1979): Manual of internal fixation. Techniques recommended by the AO group. Unter Mitarbeit von Allgöwer M, Willenegger H und Schneider R. 2. ed., expanded and rev. Berlin u.a.: Springer.