Infection after internal fixation

Part 1: Biomechanics

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When a surgeon faces a postoperative infection the next step of treatment is critical in respect to avoidance of a chronic infection and to reach safely and promptly healing and function. We discuss here first biomechanical elements that need to be considered because they play an important role.

Sample case

Fig. 1 shows a locked plate that bridges a closed distal spiral tibia fracture providing a balanced fixation. The situation 6 weeks later Fig. 2 shows acute infection. Fig. 3 visualizes the situation of the stably anchored implant after releasing pus, removing all necrotic tissue and cleaning with antiseptic solution and applying specific antibiotic suppression.

The first decision is whether to remove the stable implant or replace it *(1).*

- Aspects of **stability of fixation** in infection:
  - Stable fixation improves infection resistance *(2)*.
  - A maintained fixation is precondition of anatomically correct healing *(3).*
  - The implant protects the healing fracture as it keeps position and shares load *(3).*

- **Loosening** of implants is a common observation in infection. The tissue reaction to micromotion *(4) (5)* is intensified by infection and loosening occurs in a situation that without infection would have a chance to avoid gross loosening *(2).*

- **Preloading** the interface between screws and bone avoids micromotion and enables maintained stability. The best tool to prevent screw loosening is radial compression *(6)* as demonstrated keeping in mind that the cortical bone does tolerate only 2% deformation *(7)*. The difference between pilot hole and a standard Schanz screw is less than 0.1mm. If a larger difference is applied the cortical bone is severely damage and anchorage is compromised. Such precision is made possible using self-drilling and self-tapping screws avoiding uncontrolled “shaking” that is typical for hand operated tapping. In this respect drill operated tapping is second best. Fig. 4 and Fig. 5.

- **Adhesion of soft tissues** prevents formation of dead space between the implant and non-adhering tissue. Mechanical irritation between non-adhering tissue and implant plays a role in respect to formation of the dense capsule. Tissues adhering to the plate keeps bacteria from expanding and keeps them assailable. The following conditions for tissue adherence to metal stand out:
  - Optimal **bio tolerance** of the implant material like cp. titanium.
  - The **surface structure** of the implant needs to promote the adhesion.
  - **Early** tissue adherence. Displacement of **soft** tissue produces small shearing forces and therefore enables adherence. Once a **dense capsule** is formed adherence needs to overcome large shearing forces, which exceed the potential of early adherence.
  - **Suction** removes dead space and promotes contact as does special pressure dressing.

- **Design of the implant:** Under certain conditions the design of the implants plays an important role. This has been demonstrated comparing slotted hollow nails and solid nails where the dead space inside the nail allows spreading of bacteria without defense Fig. 6.

- **Application of implant:** The surgical approach *(8)* and reaming *(9)* have been demonstrated to modify infection resistance.

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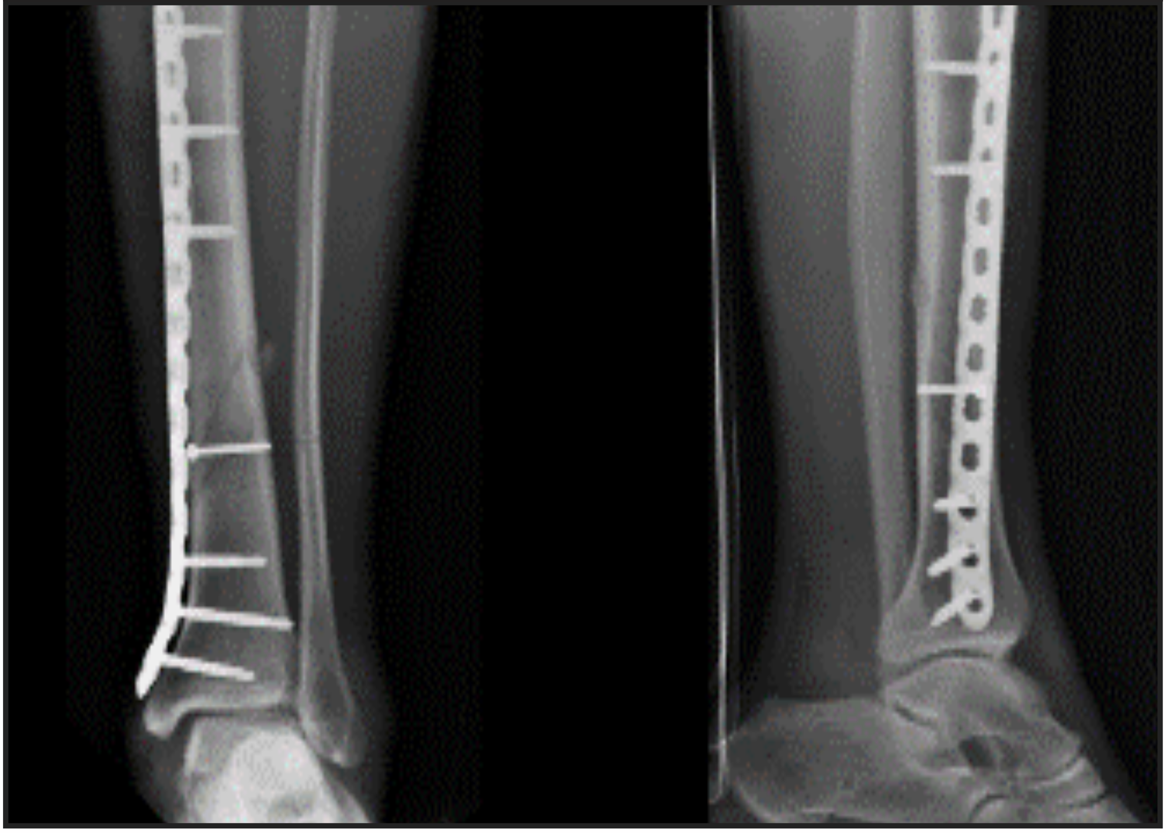

Fig. 1: **The locked plate** bridges a closed distal spiral tibia fracture providing a balanced fixation.

Fig. 2: Clinical aspect: Six weeks after initial treatment acute infection.

Fig. 3: **Plate anchorage.** The titanium plate is still solidly anchored in cortical bone .

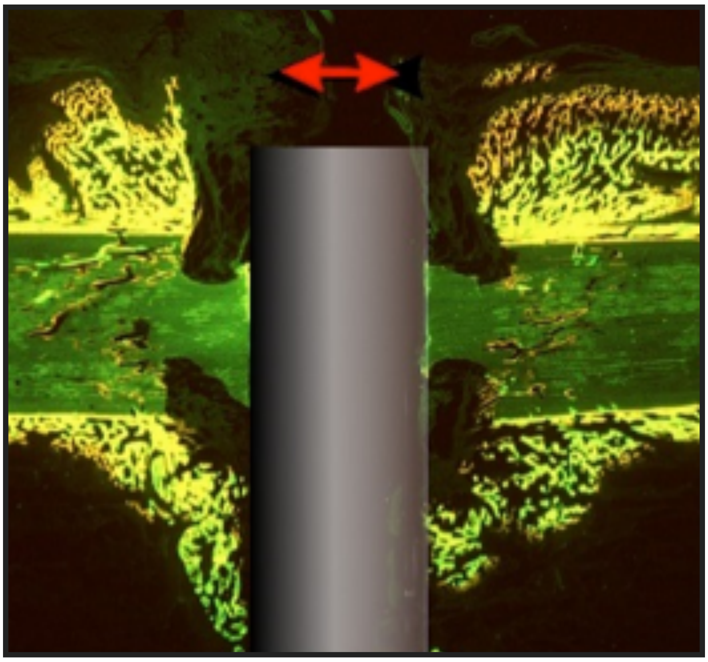

Fig. 4: **Example of loosening:** The pilot hole for an experimental Fixateur fits exactly the size of the pin which is moved back and forth a few micrometers. Massive callus formant and bone resorption around pin.

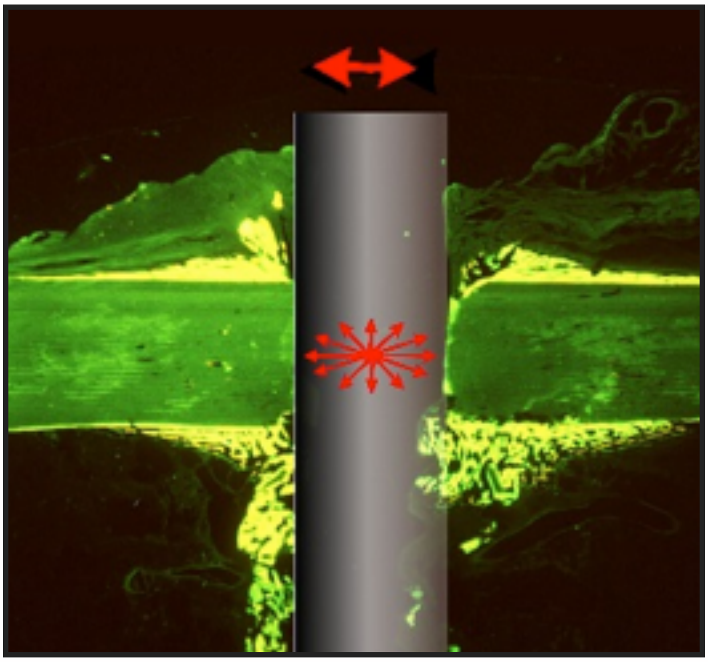

Fig. 5: **Example of stably anchored pin:** Radial expansion for stabilization: The pilot hole is 0.1mm smaller than the pin, the result is radial expansion stabilizing the interface, no bone resorption. Stability is maintained.

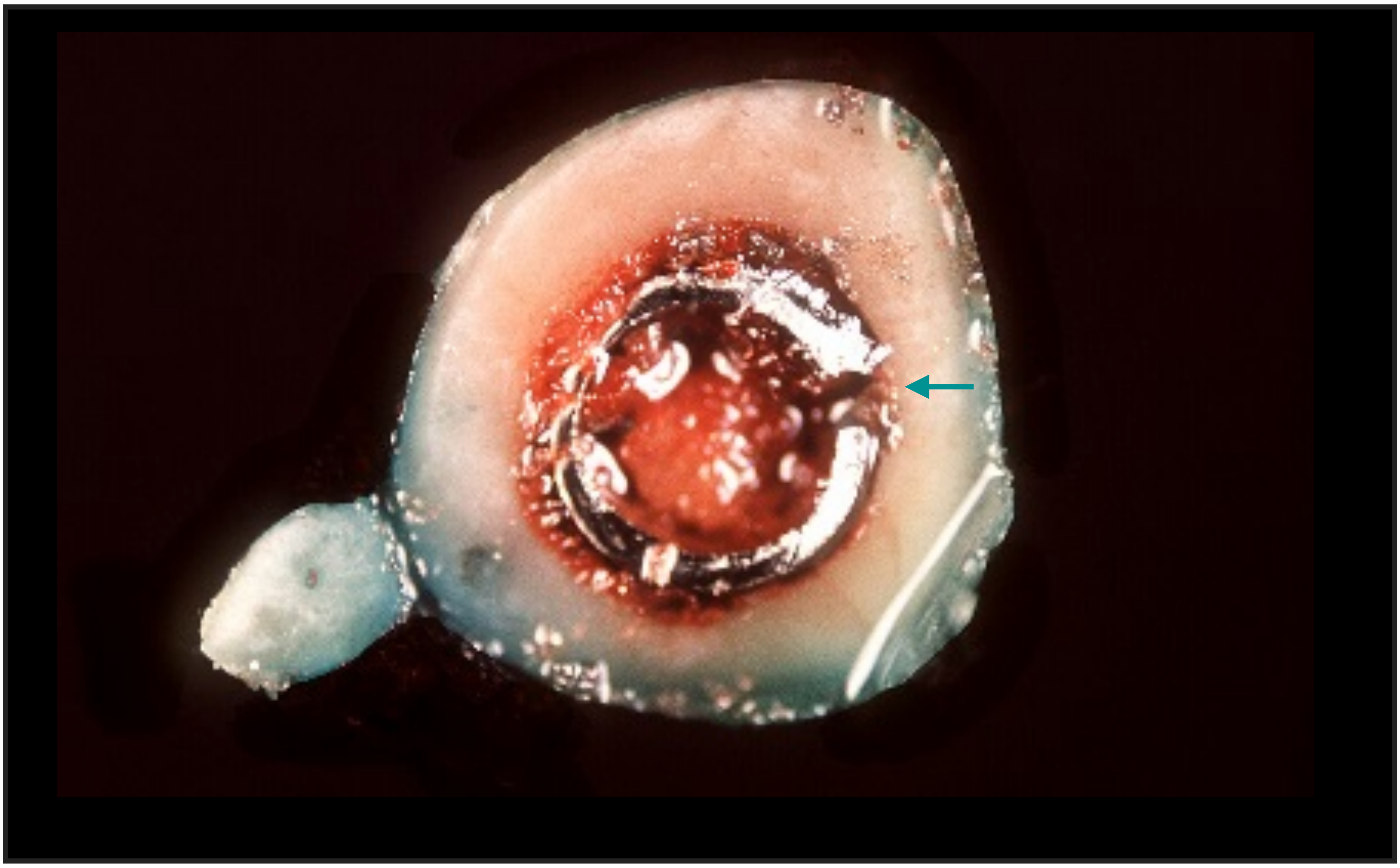

Fig. 6: Cross–section through medullar nail in place. The inside of the nail represents a dead space which allows bacterial growth with limit access of the body defense through the small slot (arrow).

Effect of design, application and material on infection. Different experimental data is summarized. The number of experiments in each comparison is > 40.

- **Solid nail:** 27% infected vs. **Slotted nail:** 59% infected**, P<0.05.** *(9)*
- **Unreamed nail** 50% infected vs. **Reamed nail** 64% infected, **P<0.05.** *(9)*
- **Titanium solid nail** 58% infected vs. **Steel solid nail** 77% infected, **P<0.05.** *(9)*
- **Plate DCP titanium** 35% infected vs. **Plate DCP steel** 75% infected, **P<0.05.** *(4)*
- **PC Fix** 26% infected vs. **DCP** 63% infected, **P<0.05.** *(10)*

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