The issue of mixing principles[1] in internal fixation.

- Pros and cons -

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Preamble: The expression "mixing principles" suggests a procedure that is in dispute. The issue concerns the two basic but different functions of implants. On the one hand we use implants that produce and depend upon absolute stability such as lag screws. On the other hand we take advantage of implants which do allow a degree of instability, like splinting plates. At first glance combining the two different functions is incompatible. Nevertheless, for instance, protecting a lag screw with a splinting plate is a standard procedure. Whether mixing is advantageous or not depends entirely upon which kind of implant-functions are combined, and how and why they are combined, the sequence of steps at application may play a role.

Different **types of fixation,** depending on the function of the implants, are defined as:

- Absolute stability: no fracture mobility so promoting primary healing
- Relative stability: some fracture mobility to induce callus formation
- Loose-lock stability[2] : an important issue when considering combining implant functions.

The **mechanical principles** of functions of an implant[3] are compression and/or splinting. For example:

- A plate alone bridging a fracture gap provides stiffness, which reduces but does not abolish fracture mobility.
- A plate may compress the fracture zone, and thus abolish fracture mobility[4] while at the same time the plate acts as a splint.
- A lag screw may compress the fracture, but may not be strong enough to withstand functional load.
- The same holds true for a tightly tensioned cerclage.
- A loose cerclage does allow a limited amount of displacement, which remains too much to protect a lag screw.

1 The term "principles" addresses a basic mechanical action like compressing or splinting, while the term "function of an implant" addresses the clinical effect of compression, protection, support, tension band etc.
2 Loose-lock stability: this is a special type of relative stability that occurs when an implant couples to bone only after a certain amount of displacement e.g. a loose cerclage wire allows non-resisted relative movement of fragments until the fragment contacts the wire and further displacement is strongly resisted. It is a two phase process with sharp transition.
3 Implants are currently named according to their clinical function, like compression plate, tension band plate, protection plate etc. Different functions can be offered by the same design of plate like the LCP and single or combined principles of action.
4 A straight plate alone produces compression near the plate. To compress also the remote cortex and thus offer better resistance to torque the plate may be "prebent" and/or combined with a lag screw.

Different **implant behavior:** Under limited load a plate or a nail may deform elastically. That is, when the load is removed the implant springs back to its shape before loading [5]. The lag screw acts differently. The bony thread of a screw tolerates very small axial deformation [6] before it strips and the lag screw loses its function permanently. Furthermore, standard x-rays may fail to detect such stripping. A cerclage applied to allow elastic spring-back [7] provides 'loose-lock' stability. Before a loose cerclage provides stability, it allows some mechanical motion. Similarly, a conventionally locked nail allows motion between the locking screw and the corresponding hole in the nail. Loose-lock stability may offer an important combination between small mobility (low strain) that induces callus and limited larger mobility (high strain) that still allows solid union.
Different **application** of the same implant: A plate applied in a conventional way, pressed onto the bone surface, provides tight friction-coupling; when applied as a locked elevated plate it provides splinting with elastic coupling without friction. In both applications, the plate provides load-sharing. A lag screw provides compression but limited strength. One may therefore take advantage of combining the efficient compression of the lag screw with the protection of the plate.
Mixing with shortcomings: An excessively flexible bridging implant may not protect the lag screw which when overloaded permanently loses its function. This construct thereafter functions like a bridging implant (e.g. plate) alone.
Mixing without shortcoming: If flexible fixation was intended using a bridge plate, the addition of a lag screw would result in a protected absolute stability, which does not achieve the intended goal.
Mixing with positive effect: Protecting a lag screw from stripping by adding the function of a protecting [8] plate appears at first glance to be mixing "principles". But it is simply protected compression.
Degree of protection by plate: This depends entirely on the stiffness provided, and is dependent on stiffness inherent in the plate design, the stiffness derived from the application (free span of bridging), and to a lesser degree on material stiffness.

Conclusions: Combining different implant functions is harmless with rare exceptions. The combination to avoid comprises the combination of a very flexible bridging implant that allows a degree of fracture mobility under which e.g. a lag screw fails because it is not tolerant to displacement. To protect a lag screw the bridging [9] plate construct needs to be stiff enough.

5 Under excessive load these implants may deform plastically, that is after unloading the deformation remains and the intended function is lost or the implant may break.
6 Actually a fraction of the pitch of the thread.
7 See chapter "cerclage mechanics, special aspects" in ICUC newsletter October 2015 and here.
8 Neutralization means cancelling by adding an opposed force. This is not the case when adding a bridging plate to a lag screw fixation. Such a plate shares load and protects the lag screw from excessive load that may strip the thread. The term protection correctly and understandably expresses the function of such a protection plate.
9 The term bridging applies to the type of application. The function of a bridging plate may be either reducing fracture mobility or protection of a lag screw through load sharing

The cases shown in Figures 2 to 6 are extracted from the ICUC® database of continuous, complete, unchanged and audited recordings and can be easily found in the ICUC app with their case IDs: 12-SI-779, 12-SI-668, 12-SI-436, 12-SI-111 and 12-SI-610.

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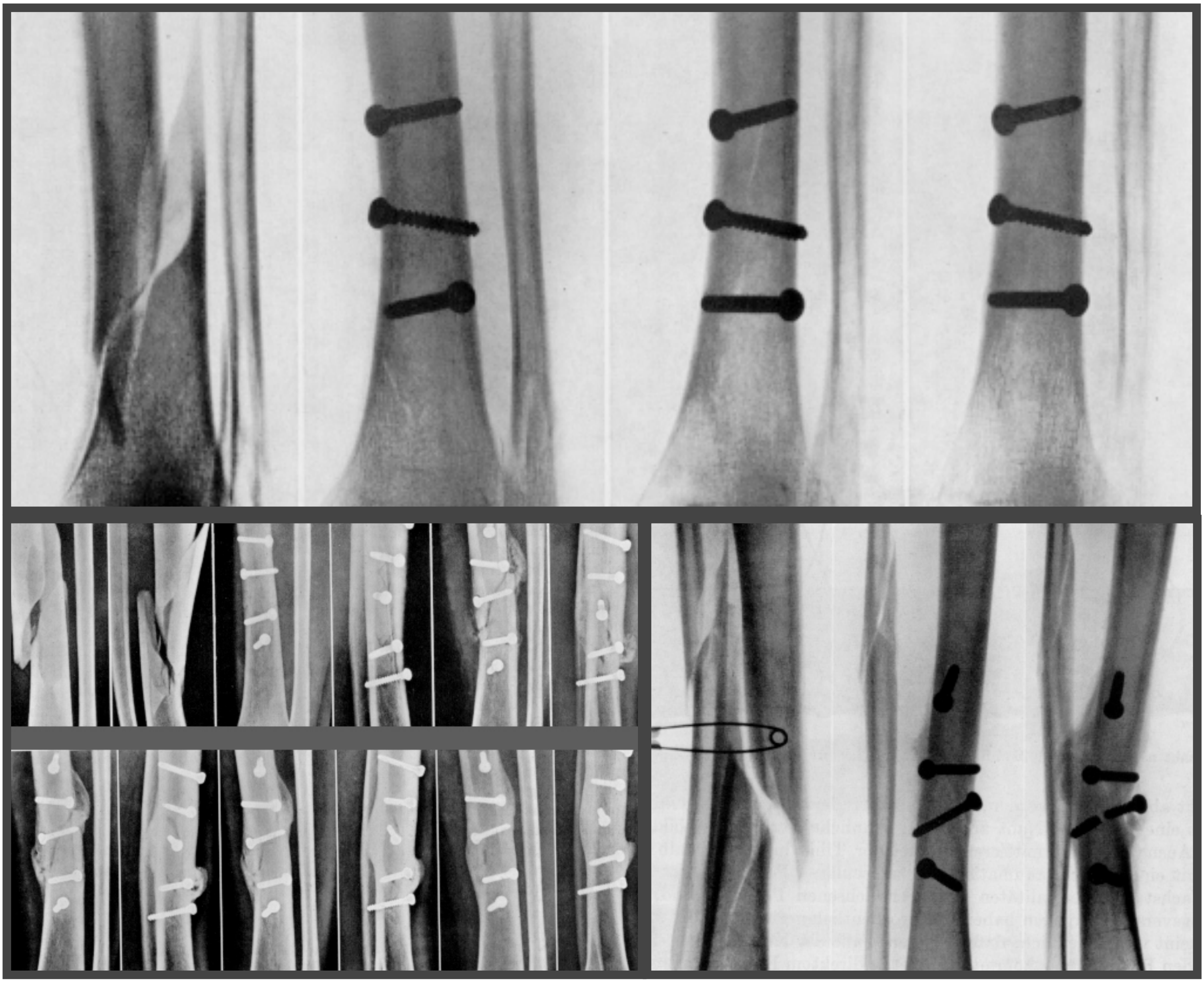

Fig. 1 ***Pure lag screw fixations*** *from the early days of AO.* ***Above*** *the classical, though rare, case of successful pure lag screw fixation. The screws follow the rotation of the fracture spiral and are well spaced. Such internal fixation does not allow early weight bearing but moving without relevant loading.* ***Below left****: Loss of stability but with unloading callus healing in maintained acceptable reduction.* ***Below right****: complete mechanical failure, "debriccollage".*

Fig. 2 ***Pure splinting a fracture gap*** *results here in healing via periosteal callus. This is a situation where callus may bridge on a long periosteal pathway while in the small gap strain is initially too high for direct interfragmental callus connection. Once the periosteal bridge reduces mobility the gap may also form a solid callus bridge. The next step then is reduction of the now useless periosteal callus.*
ICUC App case ID: 12-SI-779

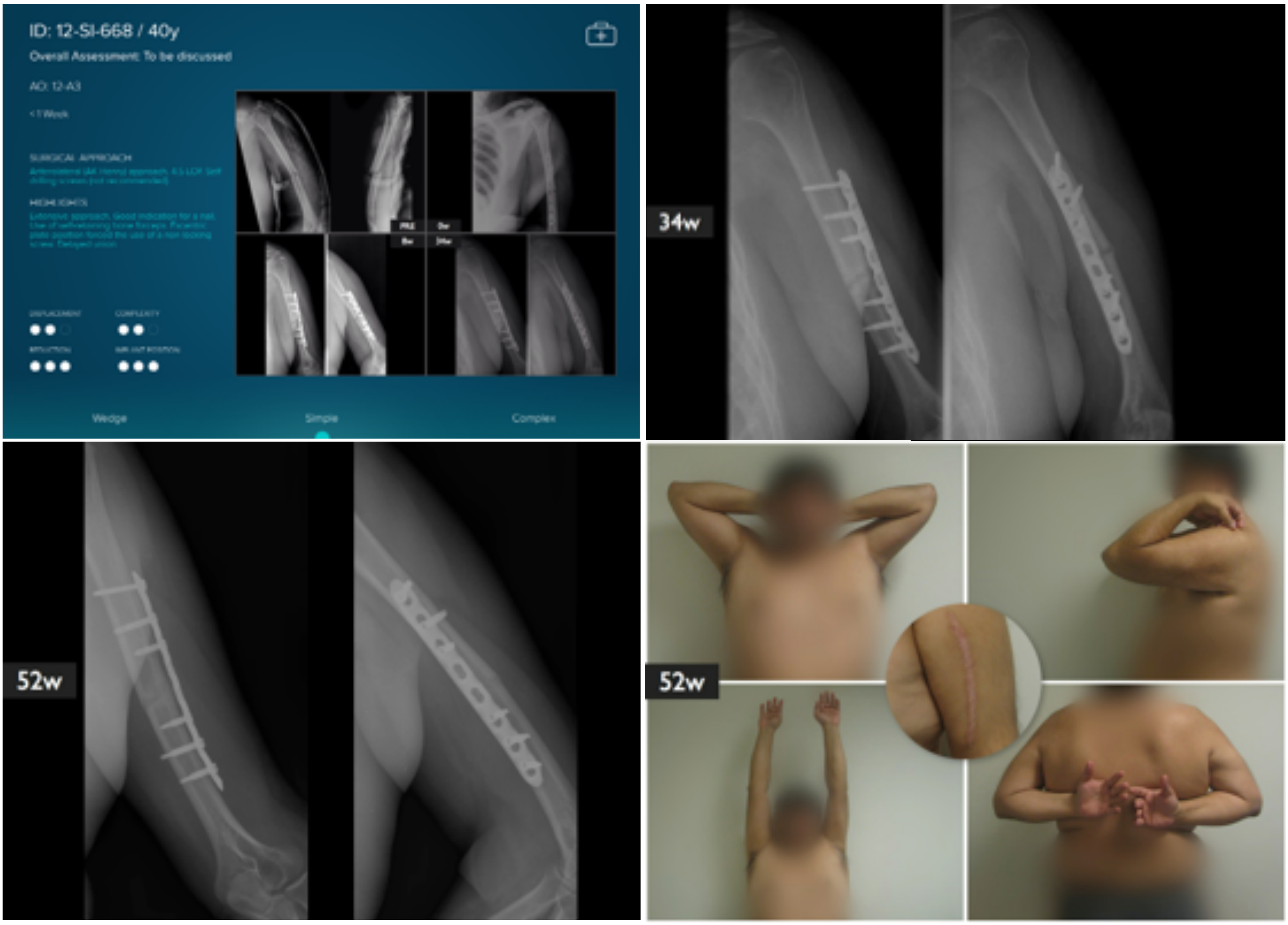

Fig. 3 Fracture treated with pure splinting by locked plate. *The fracture gap fills internally without periosteal callus. Here the bridging plate together with the existing functional load allowed direct callus connection within the fracture gap. Explaining the absence of periosteal callus as "foregoing the need" for such callus would presumes intelligent reaction. Long path periosteal strain for inducing extra-osseous callus may be too low and nonexistent intelligence of bone not required. The tissue reacts to conditions in a way that to our understanding seems to make sense but it may simply be a reaction with optimal outcome. The function checked after 1 year is excellent.* ICUC App case ID: 12-SI-668

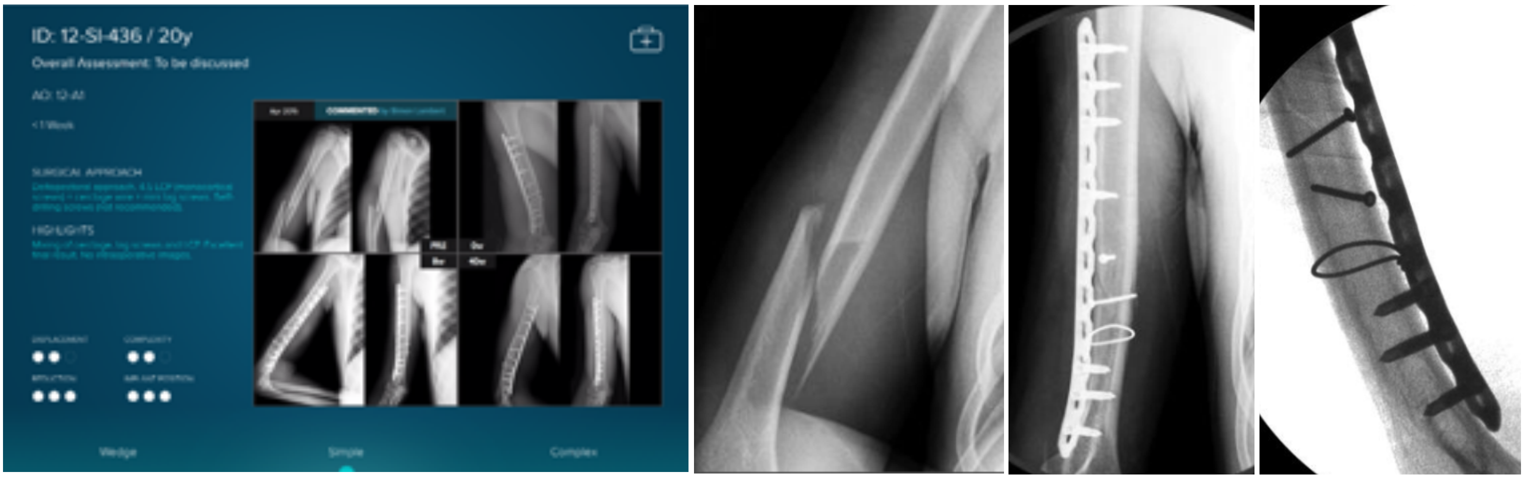

Fig. 4 ***Combination of two lag screws with cerclage and protecting plate.*** *The cerclage provided initial reduction and with it optimal application and function of the lag screws. When the orientation of the fracture surface would require applying the lag screw with insertion remote from the plate the resulting stripping damage requires careful balancing mechanical advantage against biological shortcoming. Whenever the orientation of the fracture surface allows application of the lag screws inserted nearby the plate , as in this case, additional tissue damage is not an issue.* ICUC App case ID: 12-SI-436

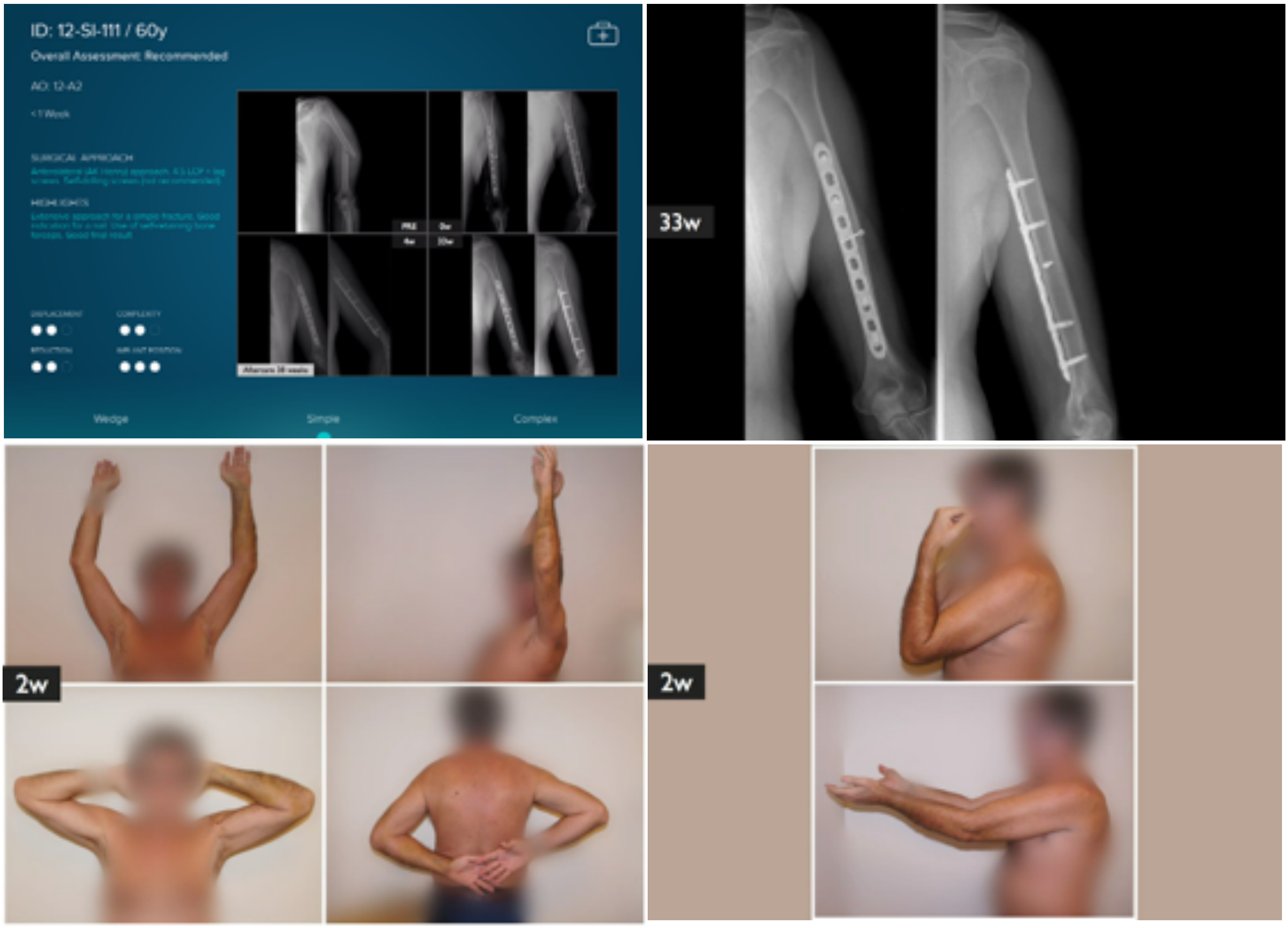

Fig. 5 Combining lag screw and plate *with perfect reduction, callus free healing and excellent function at two weeks. Still a long span bridging a lag screw fixation is demanding and success and failure may be close-by.* ICUC App case ID: 12-SI-111

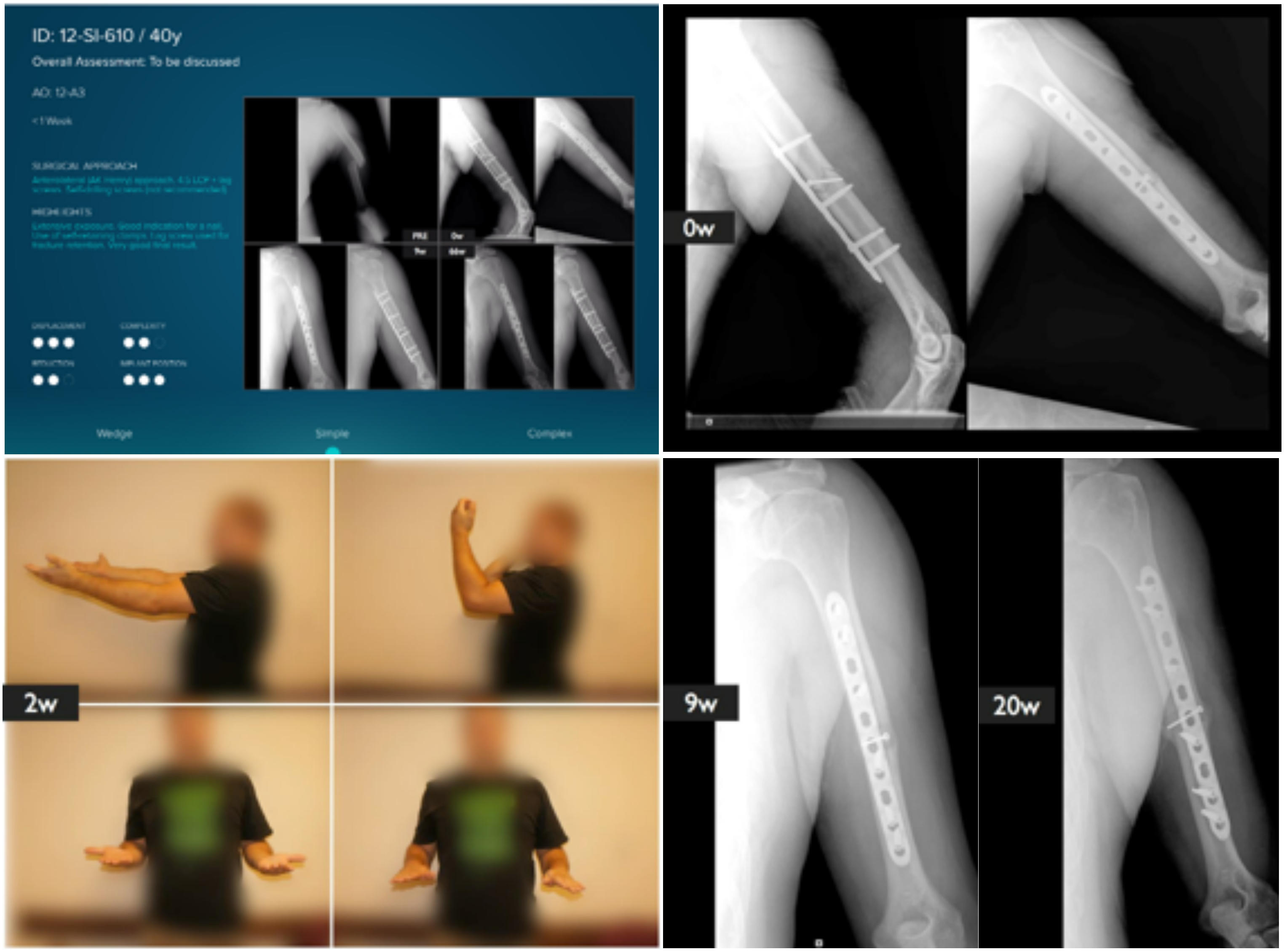

Fig. 6 Mixing a lag screw with a splinting protection plate. Excellent early function. The increased callus formation between the 9th and 20th week suggests that stripping of the lag screw has occurred meanwhile. ICUC App case ID: 12-SI-610