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# A novel non-bridging external fixator construct versus volar angular stable plating for the fixation of intra-articular fractures of the distal radius—A biomechanical study

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SUMMARY

Non-bridging external fixation has recently been introduced as an alternative to volar angular stable plating for the fixation of unstable intra-articular distal radial fractures. The purpose of this study was to biomechanically compare a new non-bridging external fixator construct to volar angular stable plate fixation in a dorsally comminuted intra-articular fracture model of the distal radius.

*Materials and methods:* Five pairs of fresh frozen human cadaveric radii were randomly supplied with either a non-bridging external fixator or a stainless steel volar locking plate. A three-fragmental AO 23–C2.1 fracture was created by removing a 15° dorsal wedge with remaining volar cortical contact and by an intra-articular osteotomy lateral to the lister-tubercle. Physiological load transfer via the wrist was simulated by means of a custom-made seesaw. For biomechanical testing, the bones were loaded in cyclic axial compression. Starting at 100 N, the load was monotonically increased at 0.025°N per cycle until failure of the construct. Motion of the lunate and scaphoid fragments with respect to the radial diaphysis was acquired by optical three-dimensional (3D) motion tracking. Plastic wedge deformation was determined after 2000, 4000 and 6000 cycles.

*Results:* The amplitude of wedge motion at the beginning of the test as a measure for construct stiffness was significantly lower for the fixator group ($P = 0.003$, power = 0.99). Plastic wedge deformation after 2000, 4000 and 6000 cycles was found significantly lower for the external fixator (repeated measures analysis of variance (ANOVA), $P = 0.009$, power = 0.86). Displacement of the intra-articular gap was found below 0.6 mm (mean) for both groups ($P > 0.05$).

*Conclusion:* The study revealed superior biomechanical properties of the proposed non-bridging external fixation compared to volar locked plating in an unstable intra-articular fracture model with volar cortical support. However, both fixation techniques seem to apply sufficient stabilisation to restore and retain anatomy after fracture of the most distal part of the radius and should be individually chosen according to distinct criteria.



Distal radial fractures are among the most common injuries, with an estimated overall crude incidence of 36.6/10,000 person-years in women and 8.9/10,000 person-years in men.[30] Assuming a continuous rise in the incidence of distal radial fractures with age, and based on the fact that older population continues to grow, incidence of distal radial fractures can be expected to increase.[4,12,39] To allow for good functional outcome following unstable distal radial fractures, restoration of both the radiocarpal and the radioulnar relationship is essential, therefore surgical treatment should facilitate for anatomic reduction and maintenance of the reduction.

Volar angular stable plate fixation is one treatment of choice for unstable distal radial fractures.[1,4] Numerous biomechanical studies have shown that volar locked plating provides adequate stability in dorsally comminuted intra- and extra-articular fracture models.[3,17,20,21,23,28,33,41] Clinical studies display mostly good and excellent results[14,27,29,31,32]; however, secondary loss of volar inclination and other complications such as irritations of flexor tendons by the plate itself, irritation of extensor tendons from screw prominence and ischaemic contracture of the pronator quadratus muscle are yet to challenge.[1,2,5,6,14,19,36]

One continuing dilemma in the treatment of distal radial fractures is to restore radial length. Joint-bridging external fixation

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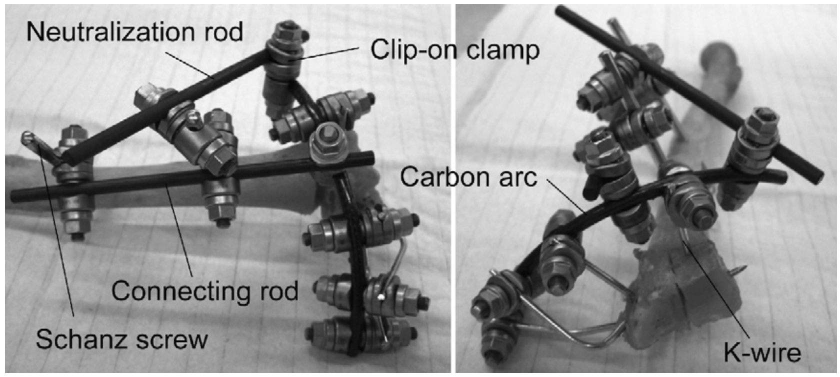


**Fig. 1.** Non-bridging external fixator configuration. A curved fibre rod is mounted distally on the connecting rod to allow for multiplanar insertion of four K-wires in the subchondral region of the distal radius.

serves as an alternative procedure using Schanz screws inserted minimally invasive into the distal radius and metacarpus. However, individual fracture fragments may still heal in a displaced or angulated position[26,34] and prolonged immobilisation or over-distraction can lead to persistent motion restriction of the wrist.[15,25]

Non-bridging external fixation for distal radial fractures was introduced as a versatile tool to combine closed reduction and functional after-treatment.[7,8,18,24,26,34] Direct manipulation of fragments enables fracture reduction, but most authors have recommended this technique only for extra-articular fractures ensuring sufficient size of the distal fragment for anchorage of at least two Schanz screws.[15,18] Recently, a non-bridging external fixator using multiplanar Kirschner wires (K-wires) was introduced to extend the indication of non-bridging external fixation to both intra-articular fractures and fractures with a small distal fragment due to broad dorsal comminution with promising clinical results.[10] Yet, little is known about its biomechanical performance in dorsally comminuted intra-articular fractures of the distal radius.

The purpose of the present study was to analyse whether non-bridging external fixation using multiplanar K-wires provides sufficient stability under cyclic loading, when compared to volar angular stable plate fixation.

## Materials and methods

### *Specimens and study groups*

Five pairs of fresh frozen (−20 °C) human cadaveric radii were used in this study. Bone mineral densities (BMDs) were measured in the distal radial epiphysis by peripheral quantitative computed tomography using an Xtreme-CT (Scanco Medical AG, Bassersdorf, Switzerland). The pairs were randomly assigned to two study groups: (1) plate group (two right and three left bones) and (2) ExFix group (three right and two left bones). All specimens were thawed at room temperature and stripped of soft tissue.

### *Instrumentations and fracture model*

The external fixator instrumentation comprised two Schanz screws (diameter 4.0 mm) placed at the dorsal aspect of the radial diaphysis at 40 and 80 mm proximal to the articular surface. The Schanz screws were inserted through both cortices after pre-drilling with a 2.8-mm drill bit. A carbon fibre connecting rod (diameter 4.0 mm, length 100 mm) was attached using self-holding titanium clip-on clamps at 30-mm elevation from the bone. A carbon fibre arc (diameter 4.0 mm) was attached to the rod with a clip-on clamp parallel to the later osteotomy line. Four K-wires (diameter 2.0 mm, threaded tip) were inserted into the distal radius in a semi-circular manner from the dorsal radioulnar corner to the styloid. All K-wires showed bicortical anchorage. Two K-wires were placed in dorsovolar direction into the lunate fossa and the scaphoid fossa. One was inserted parallel to the articular surface from the styloid in lateromedial direction and one from the styloid in caudocranial direction to the lateral aspect of the radial diaphysis. If necessary, the K-wires were bent with a bending forceps before connecting to the fixator frame with clip-on clamps. Finally, the frame was stabilised with a carbon fibre neutralisation rod (diameter 4.0 mm, length 100 mm) connecting the proximal Schanz screw to the lateral end of the carbon arc (Fig. 1).

For the plate group, stainless steel volar LCP distal radius plates (2.4 mm, three proximal shaft holes and five distal metaphyseal holes; Synthes Inc., Bettlach, Switzerland) were used. Instrumentation was performed according to the operation manual. A bicortical 2.4-mm cortex screw was placed into the compression shaft hole. A unicortical 2.4-mm locking screw was inserted into the most proximal hole. Distally, the plate was precontoured to the shape of the bone before occupying four of the distal holes with subchondrally placed locking screws, leaving the middle hole empty. The screw length was individually determined for each hole, ensuring unicortical screw placement. Predrilling was performed for all screws using a 1.8-mm drill bit and corresponding drill guide.

All operations were performed by a single experienced surgeon (G.G.). All implants used in this study were manufactured by Synthes Inc., Bettlach, Switzerland.

After instrumentation, a three-fragmental AO 23–C2.1 fracture was created for all specimens. By means of an oscillating saw, a 15° dorsal wedge was removed 10 mm proximal to the articular

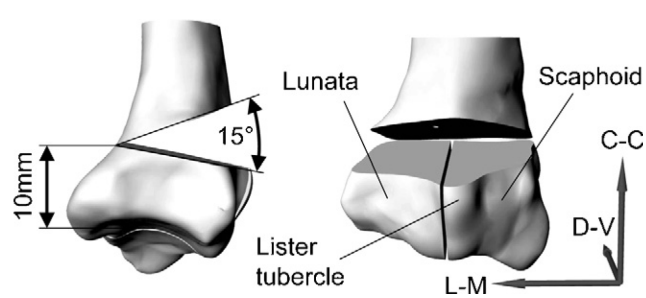


**Fig. 2.** Illustration of the used 23–C2.1 fracture-model, with 15° dorsal wedge being removed 10 mm proximal to the articular surface simulating a dorsal comminuted zone with volar cortical support. An additional intra-articular cut was created lateral to the lister-tubercle. (L–M) lateral–medial; (D–V) dorsal-ventral; (C–C) cranial–caudal.