

# **The Basic Biomechanical Principles of External Fixation**

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Vreden Orthopaedic Research  
Center



<http://rniito.org>

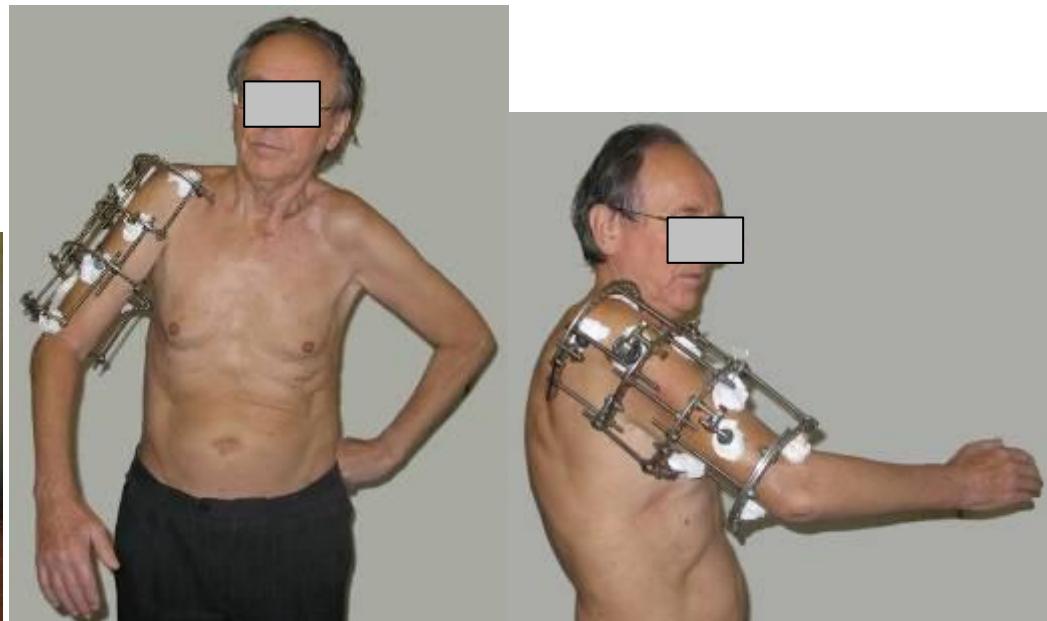
St.Petersburg, 2022

# Objectives

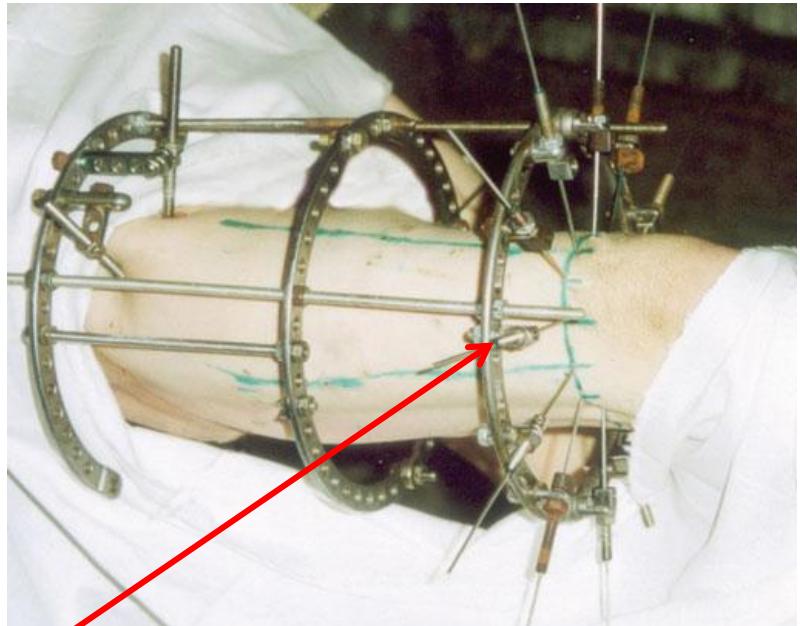
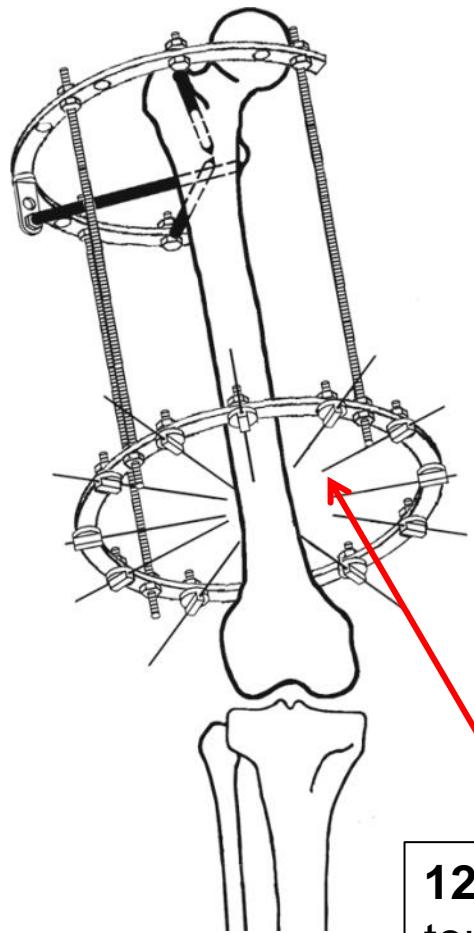
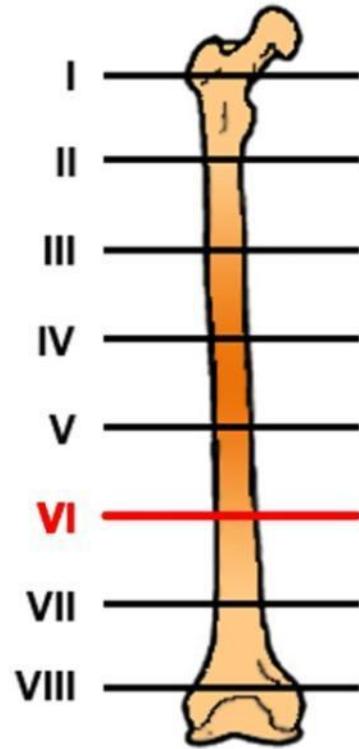


1. The relationships between the transosseous elements (wires, half-pins) and the surrounding tissues
2. Bone fragments reduction control
3. Bone fragments fixation control

# Transfixion pin-induced joint stiffness

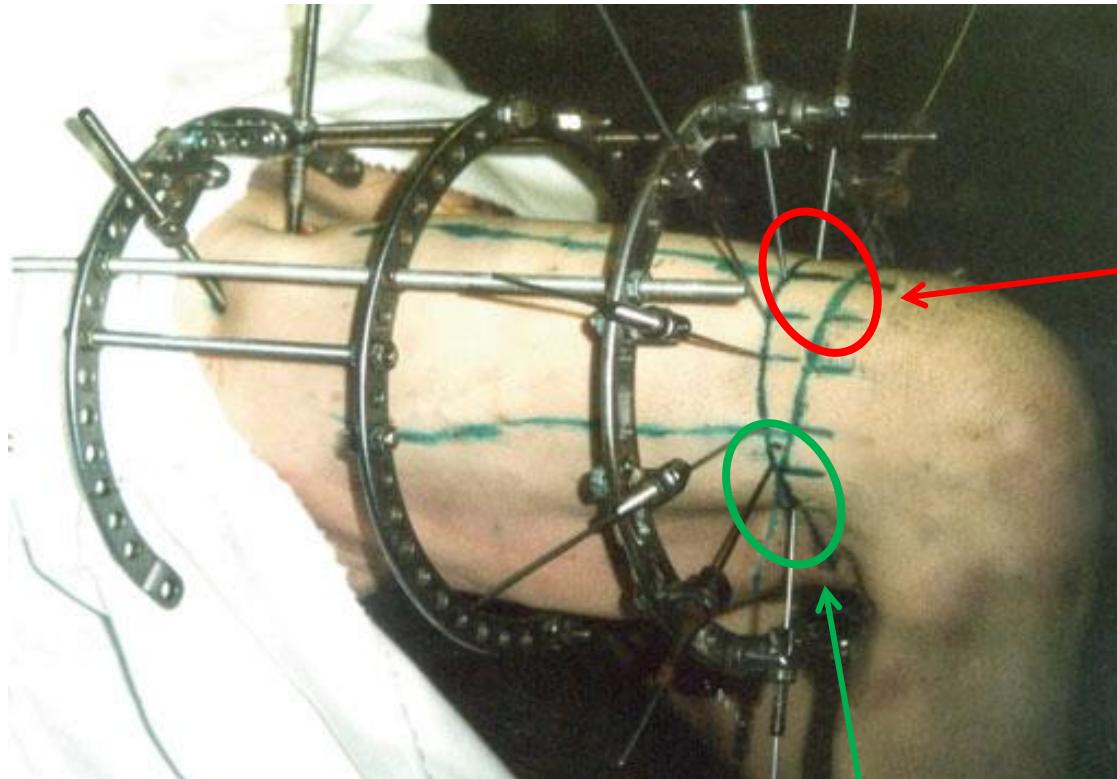


# Cadaver lab step-by-step RP identification



12 markers  
touch the skin  
only

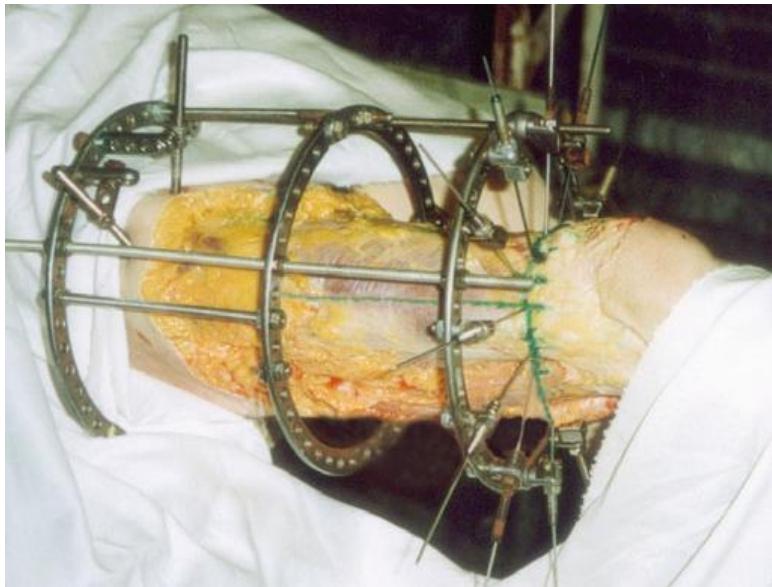
# Skin displacement



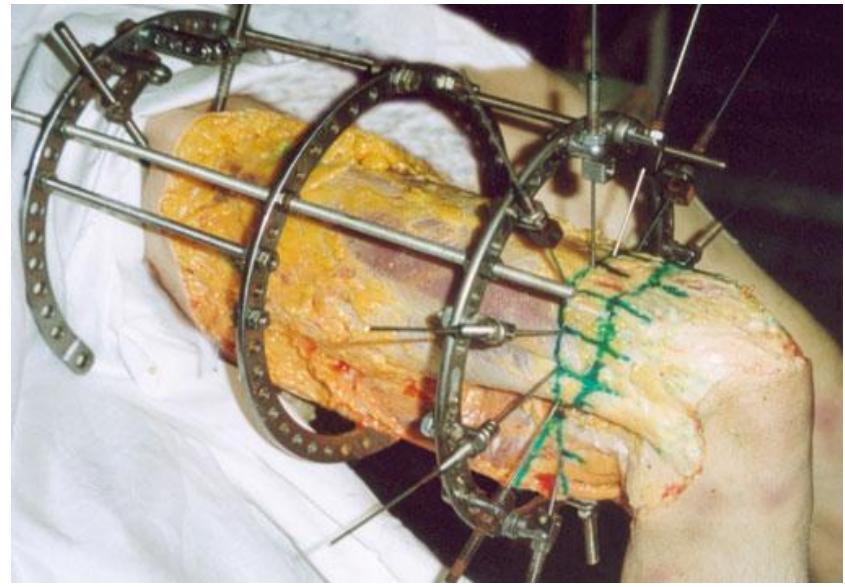
maximum  
displacement

zero displacement

# Fascia displacement

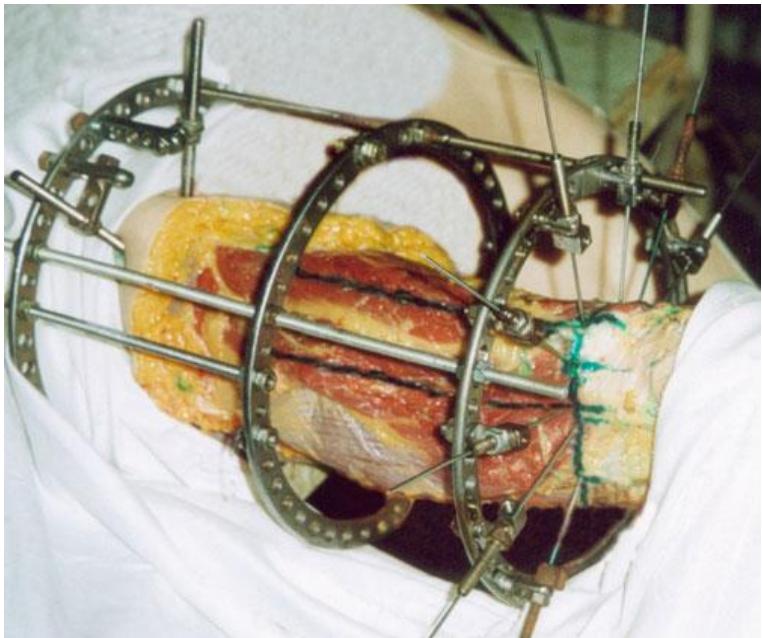


knee extension

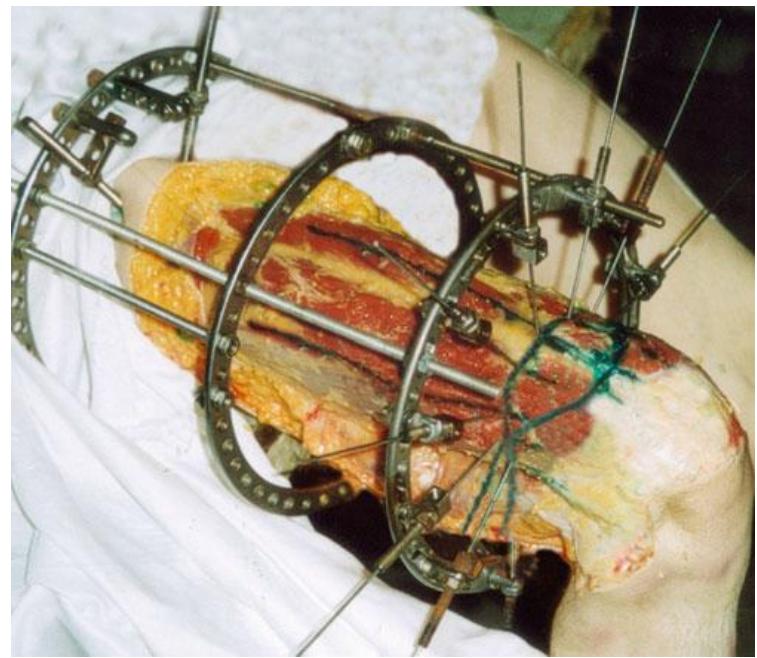


knee flexion

# Muscles displacement



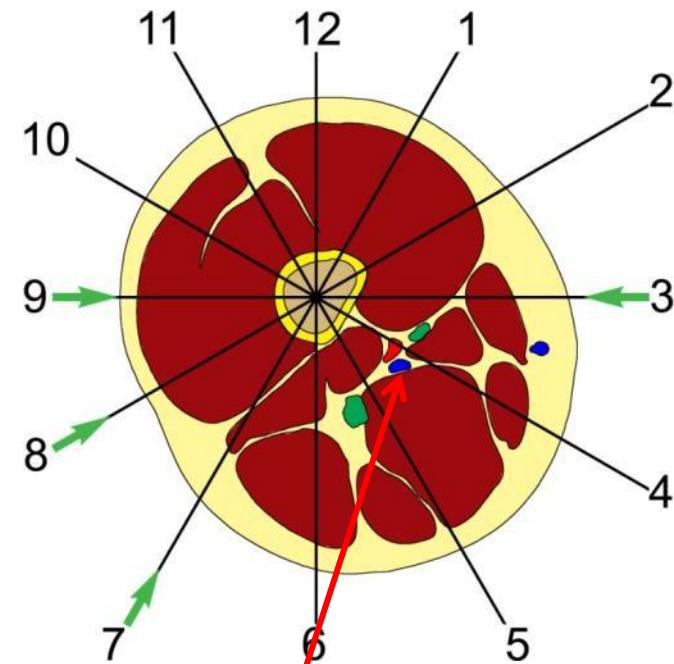
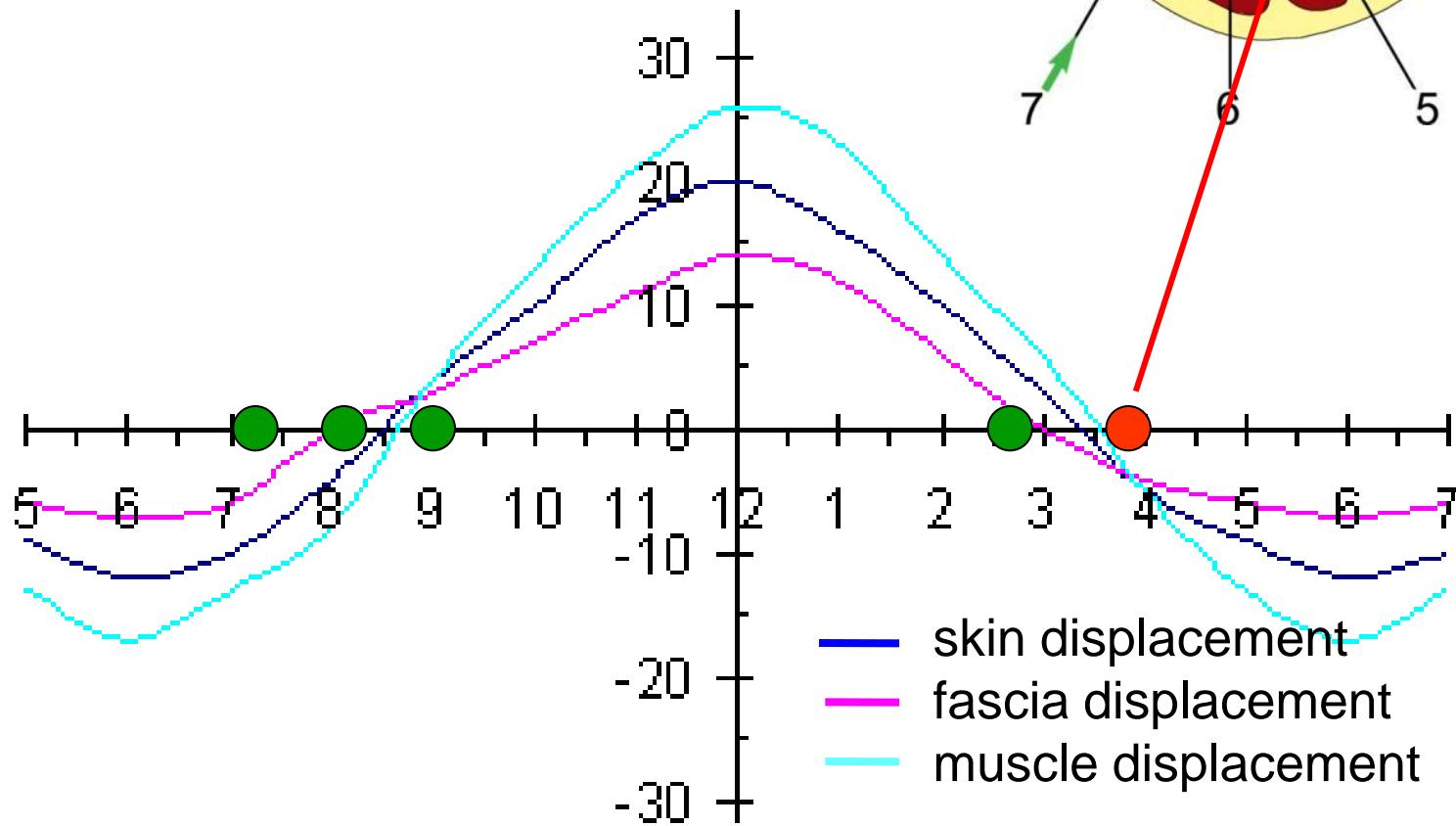
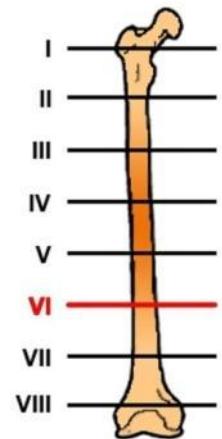
knee extension

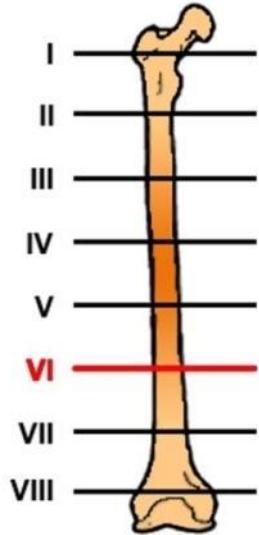


knee flexion

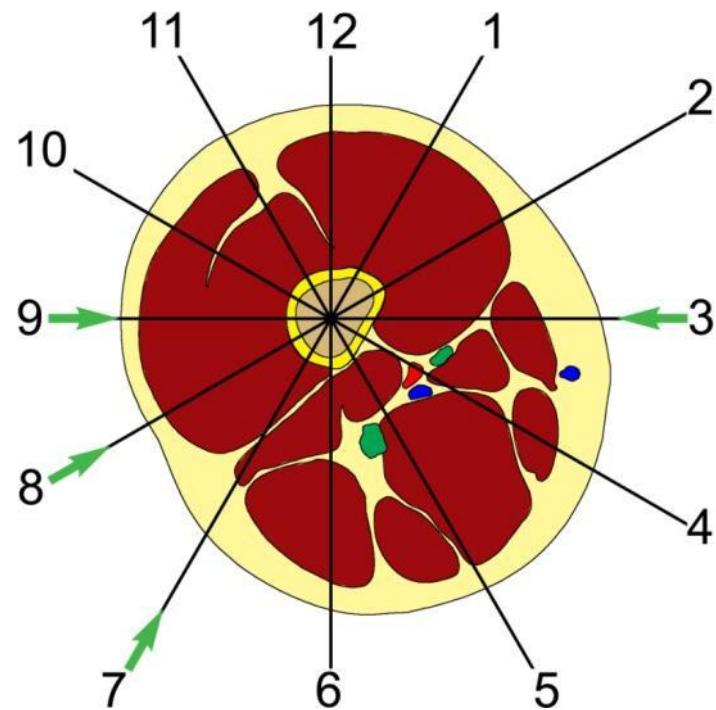
# Diagrams of the soft-tissue displacement

in knee joint flexion  
at Level VI



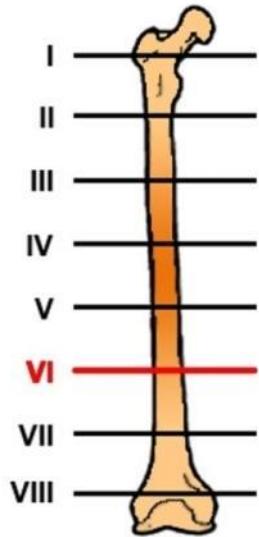


Forbidden Positions: 4,5,6  
Safe Positions: 1,2,3,7,8,9,10,11,12  
Reference Positions (RP): 3,7,8, 9

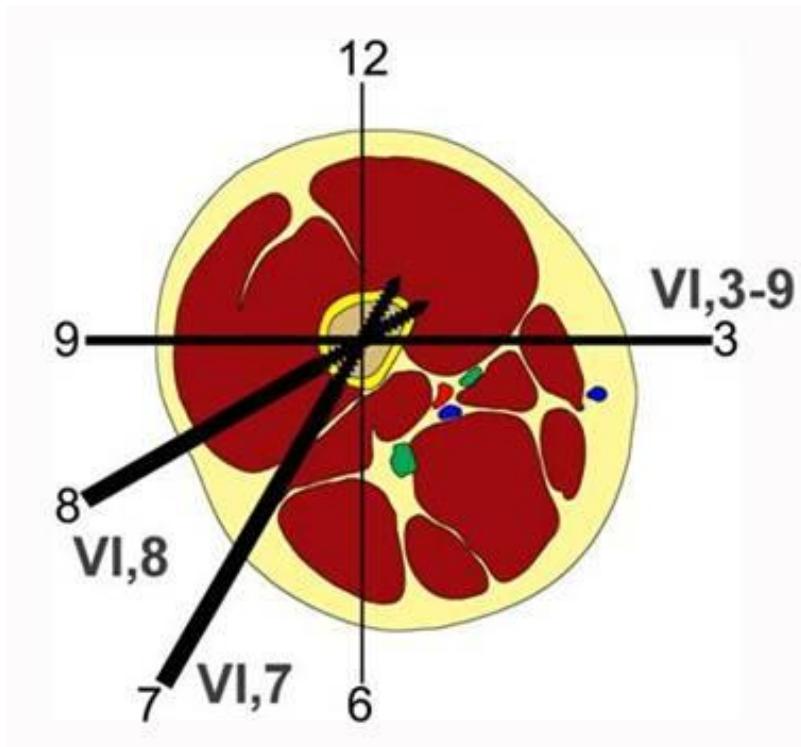
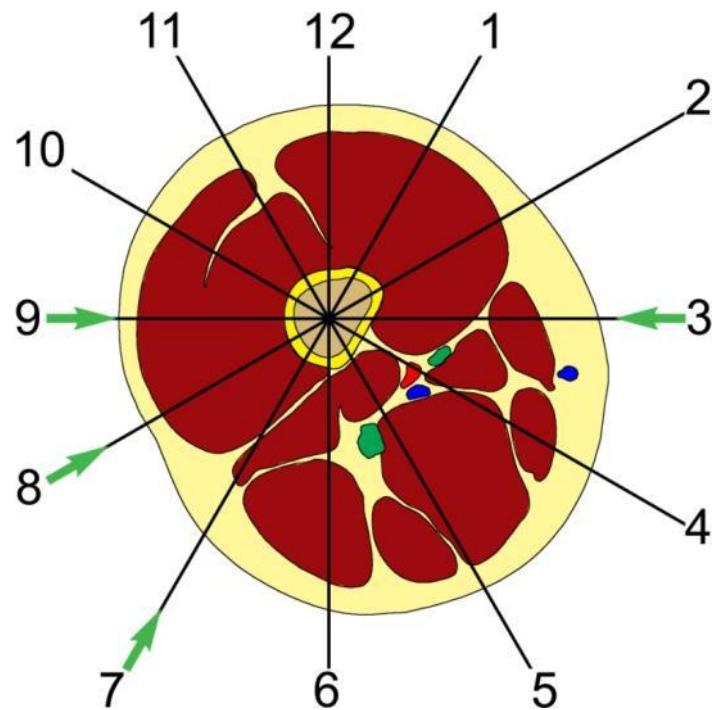


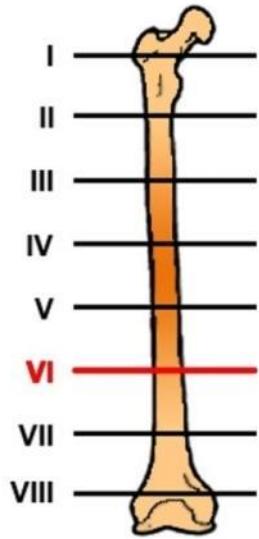
Wire or Pin?

3, 7, 8, 9



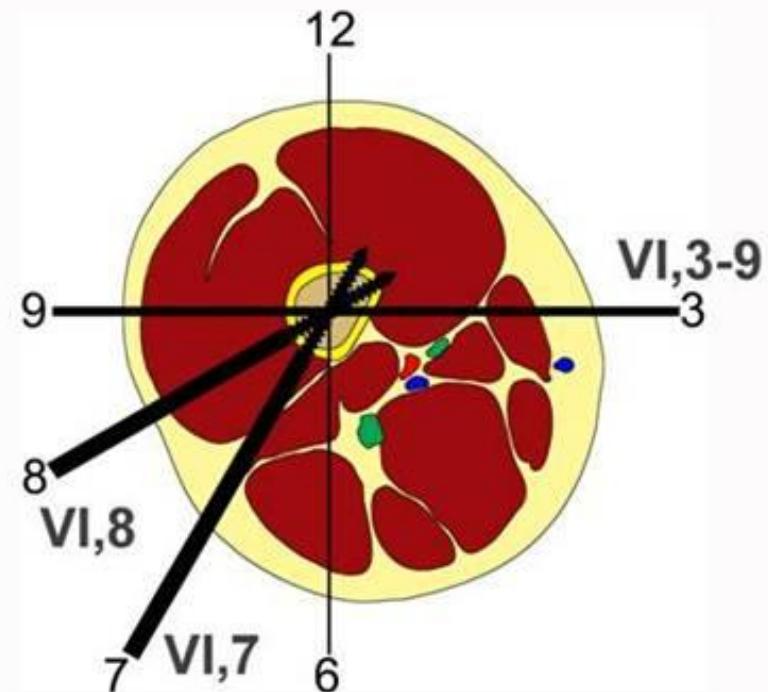
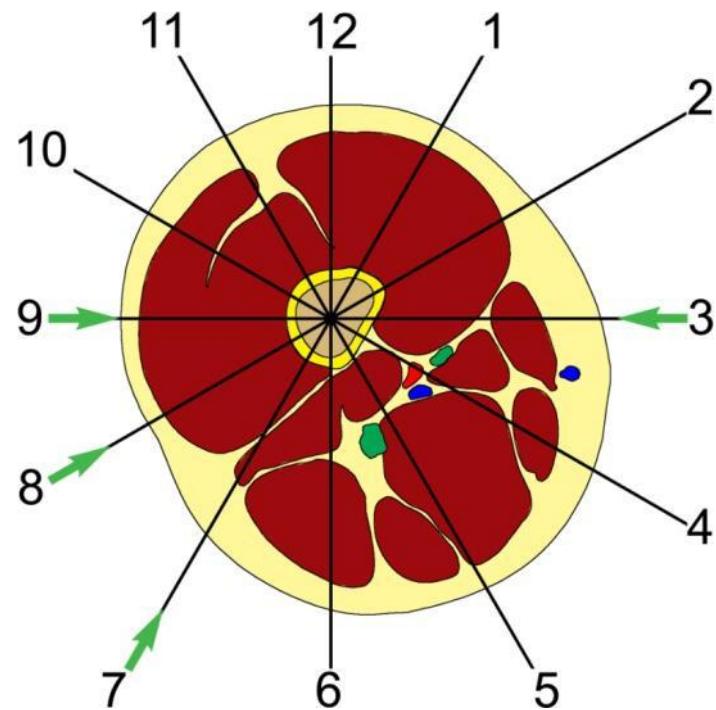
Forbidden Positions: 4,5,6  
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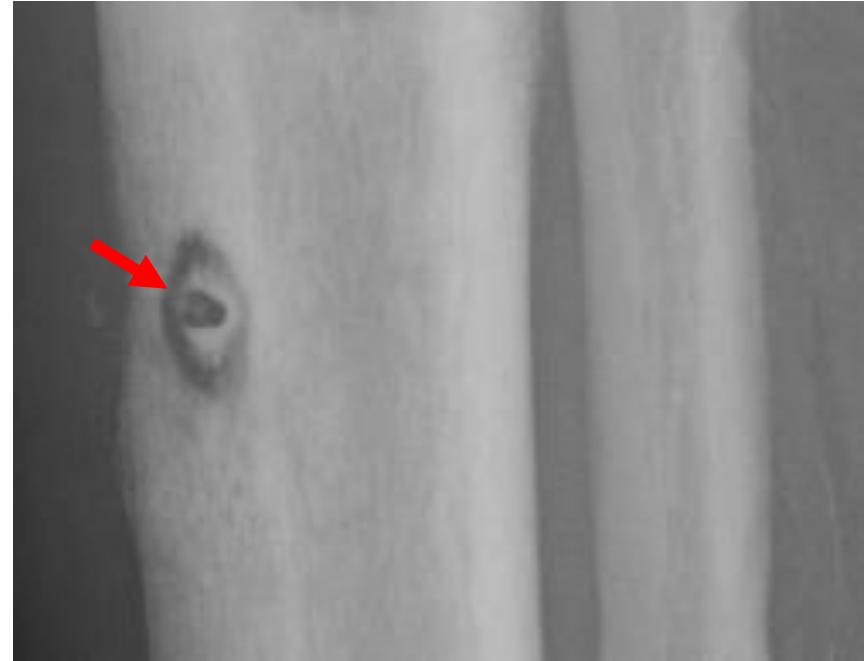
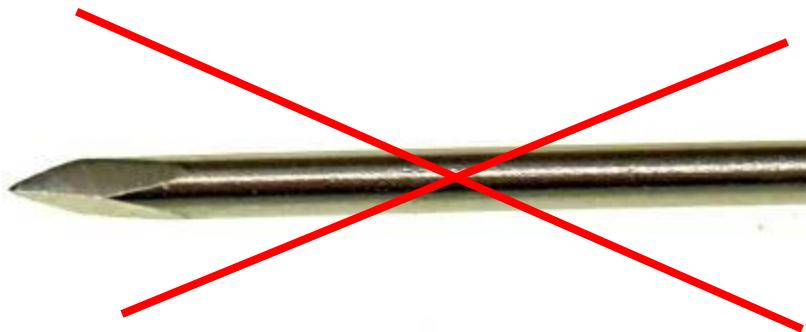


Forbidden Positions: 4,5,6  
Safe Positions: 1,2,3,7,8,9,10,11,12  
Reference Positions (RP): 3,7,8, 9

Reference transosseous elements:  
VI,3-9; VI,3; VI,7; VI,8; VI,9



# Variants of wires cutting ends



# Half-pin types



diaphyseal and metaphyseal

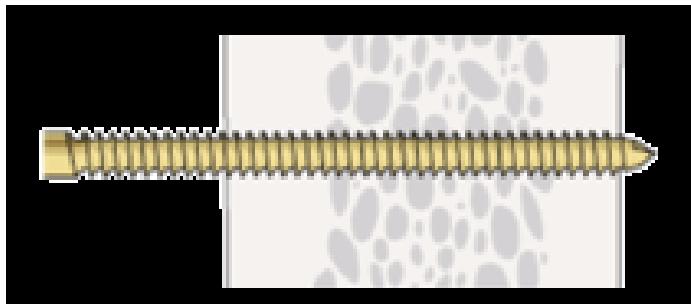


hydroxyapatite-coated

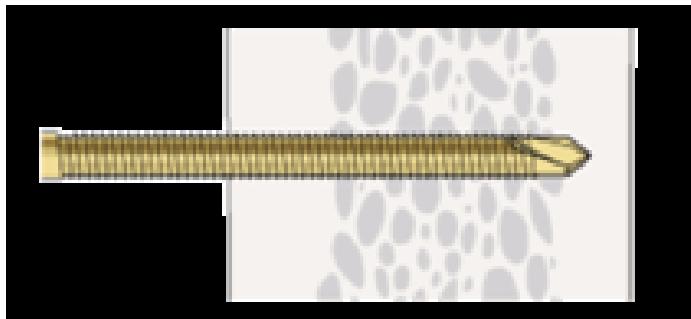
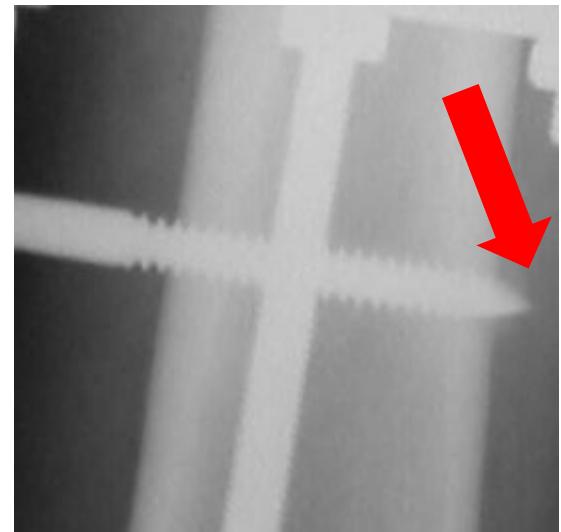


self-drilling

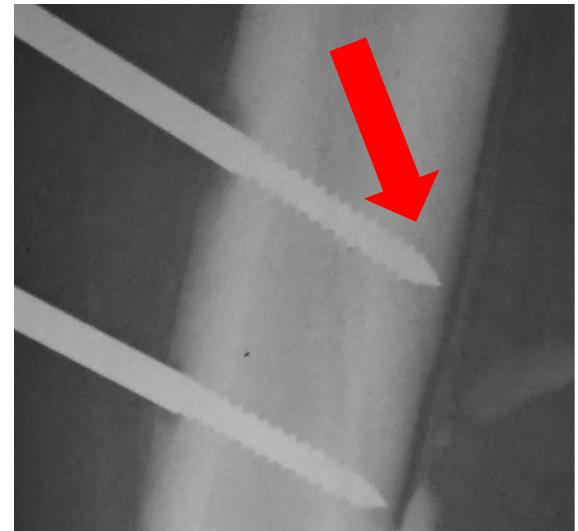
# Pin placement



conventional  
self tapping



self drilling



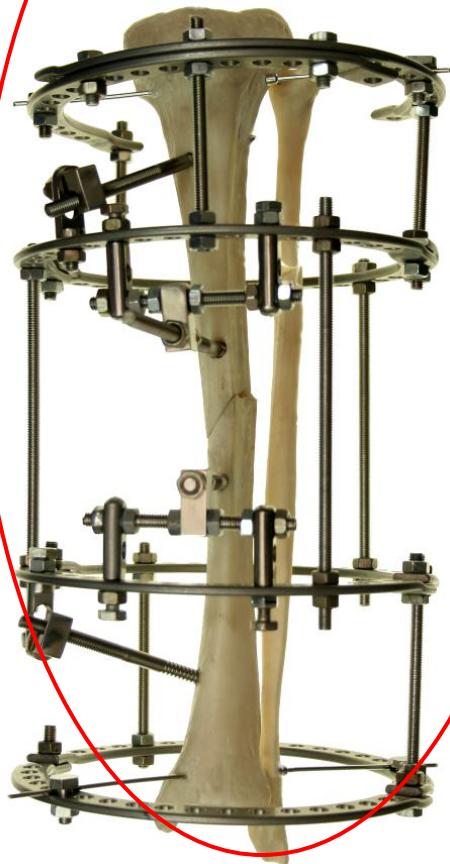
*(AO Foundation, Switzerland)*

# Biomechanics of external fixation:

1. The relationships between the transosseous elements (wires, half-pins) and the surrounding tissues
2. Bone fragments reduction control
3. Bone fragments fixation control

# Principal types of frame assembling

for fracture  
healing



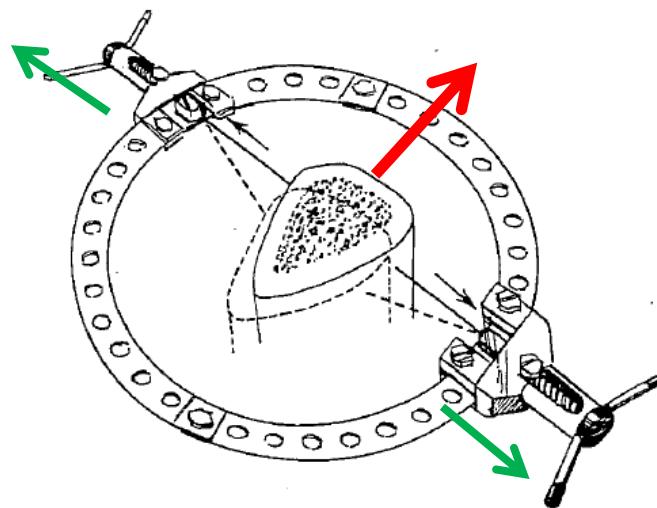
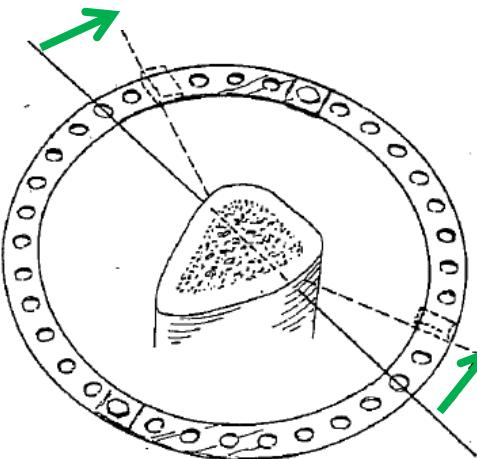
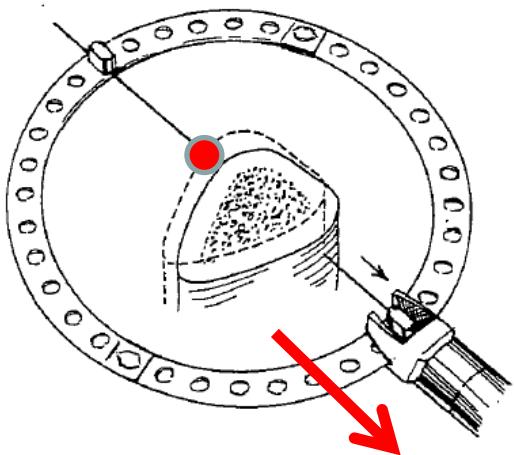
for deformity  
correction



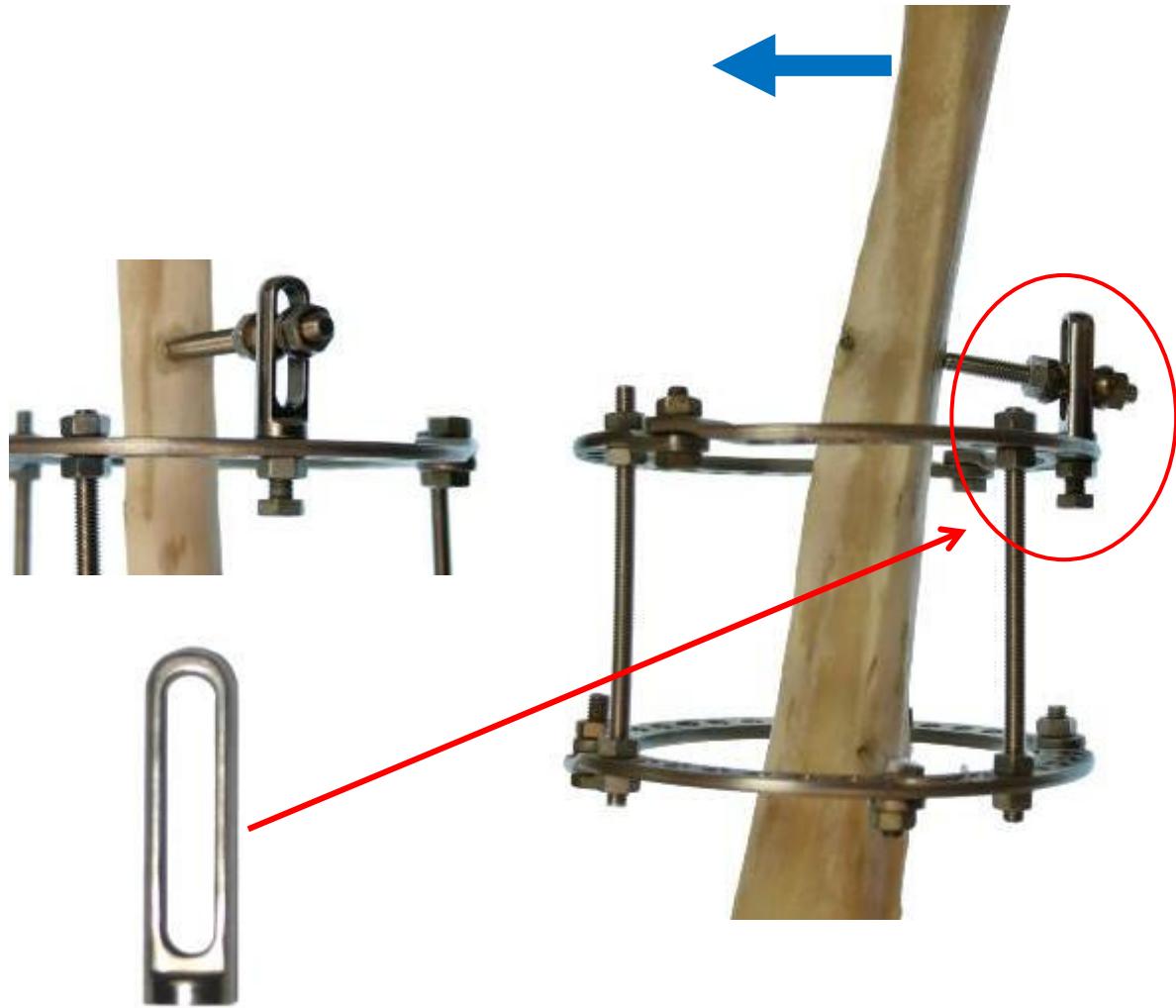
for bone  
transport



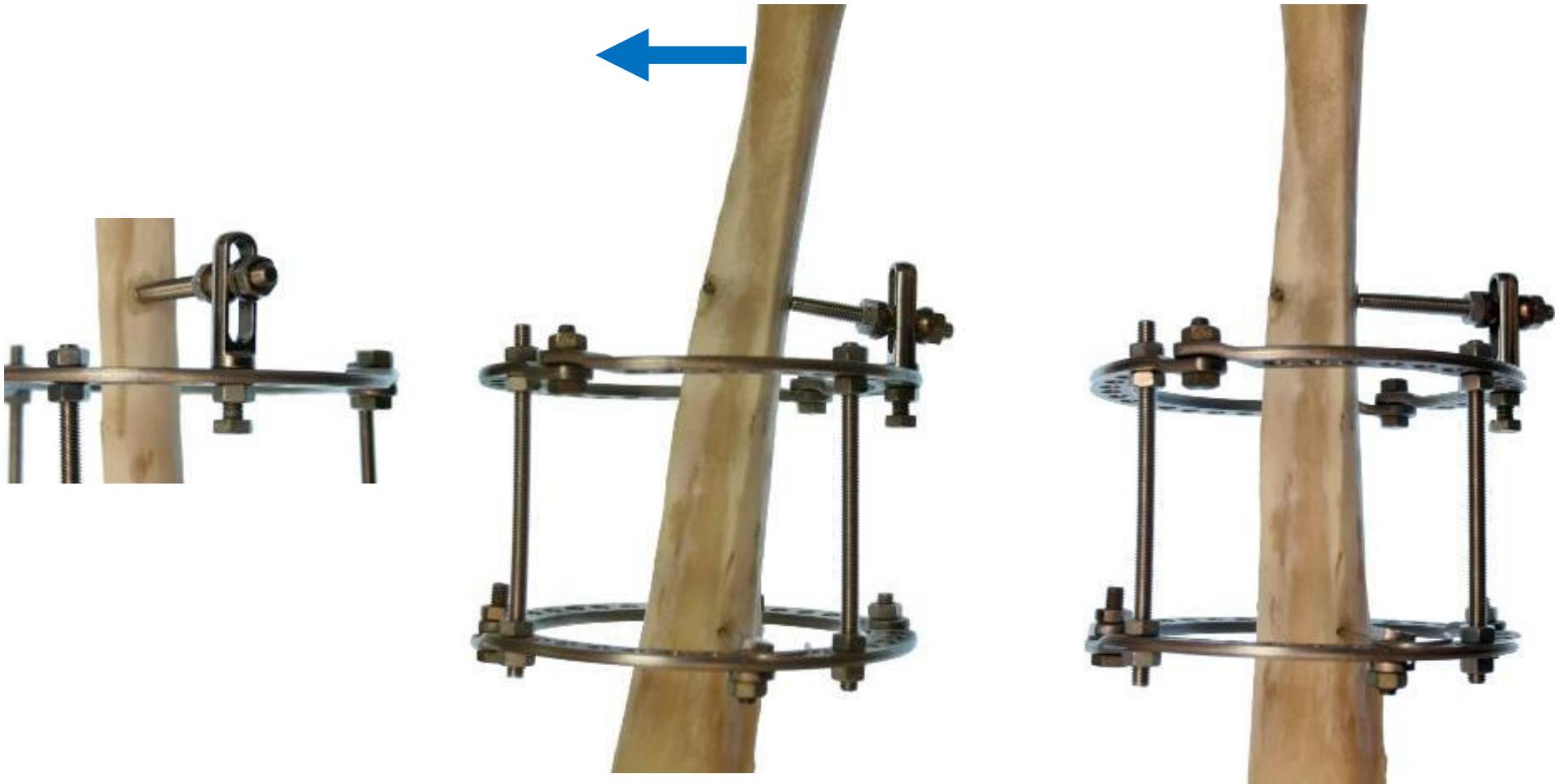
# Reduction using olive-wire



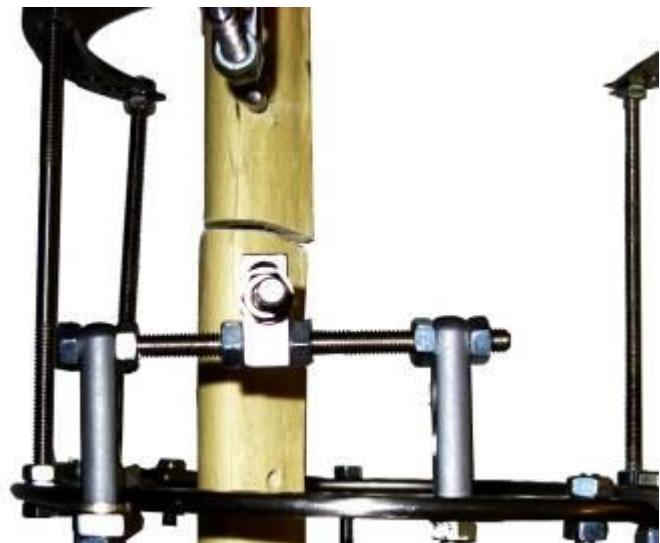
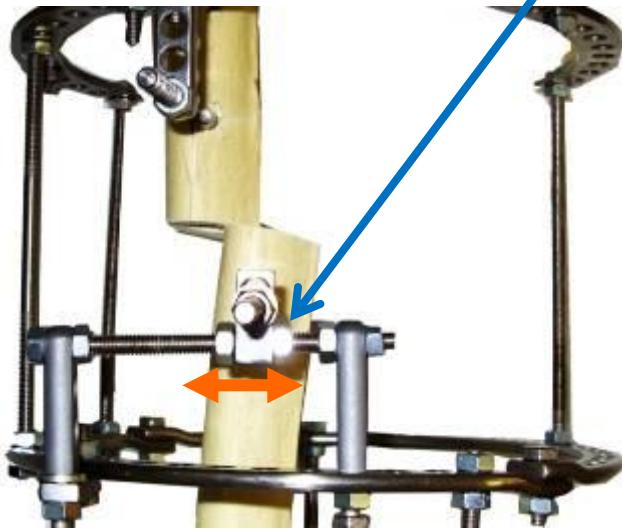
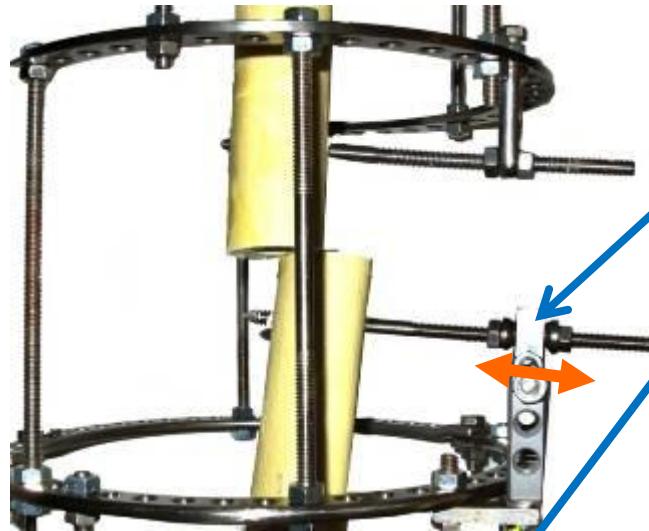
# Reduction using half-pin



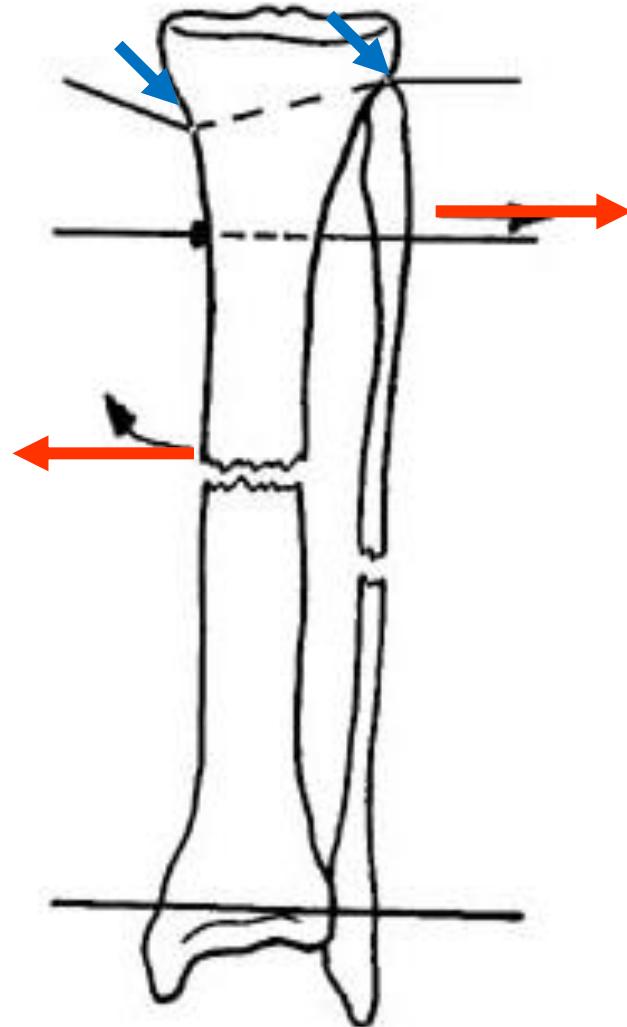
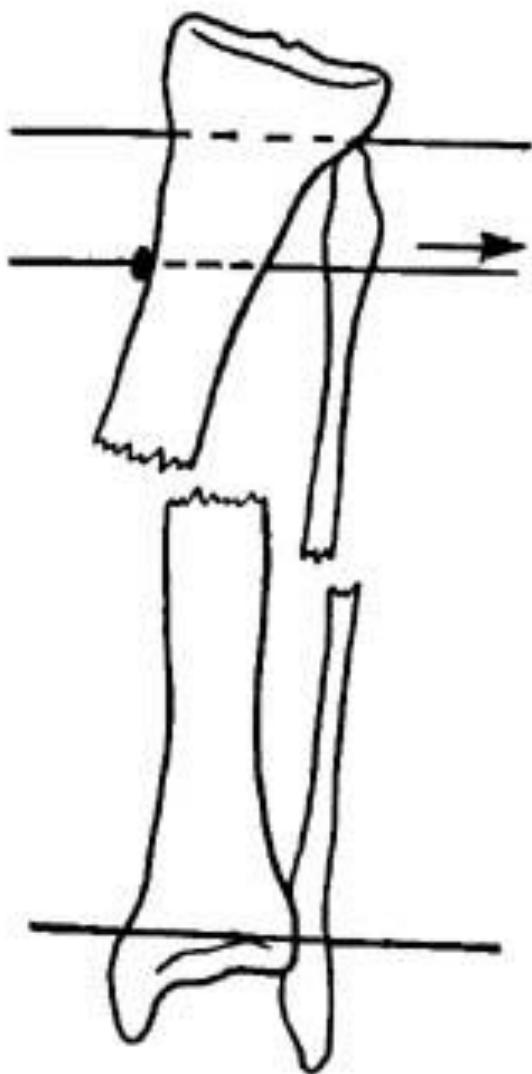
# Reduction using half-pin



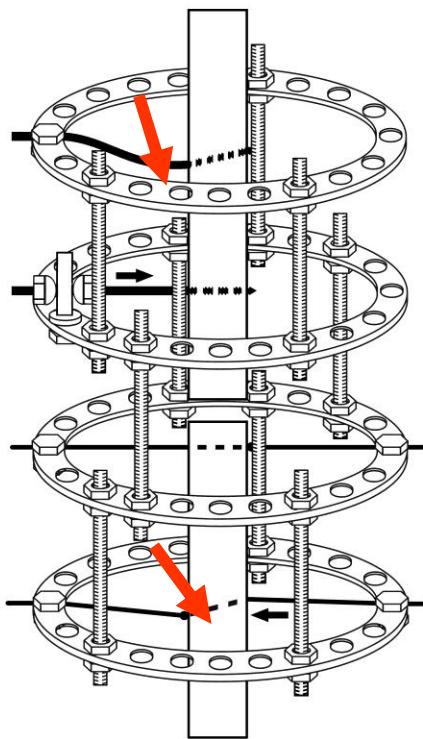
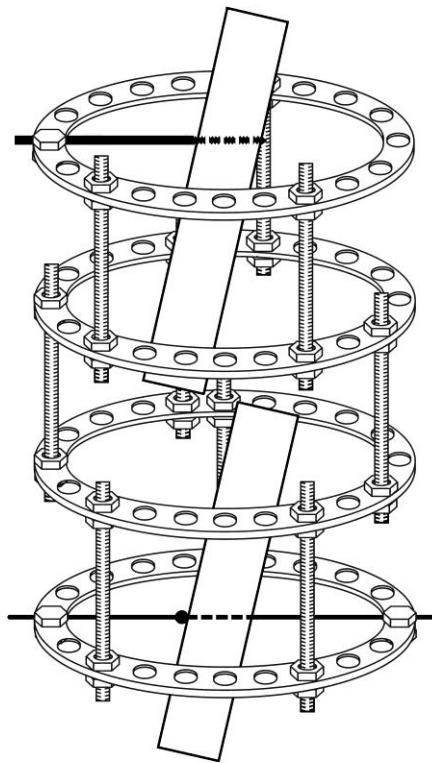
# Two-plane bone fragment reduction



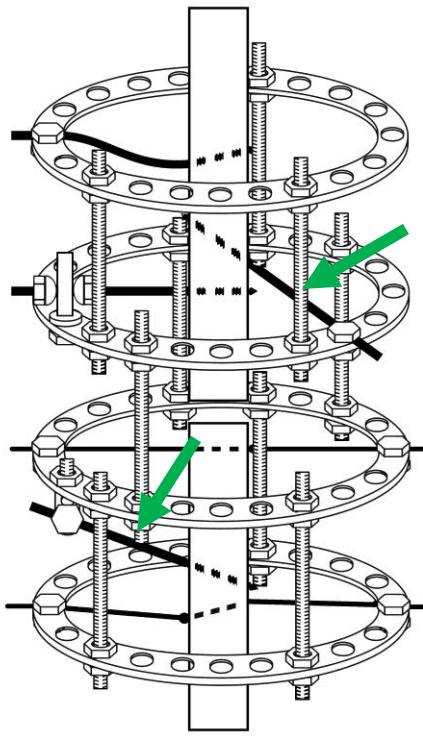
# Occurrence of displacing forces



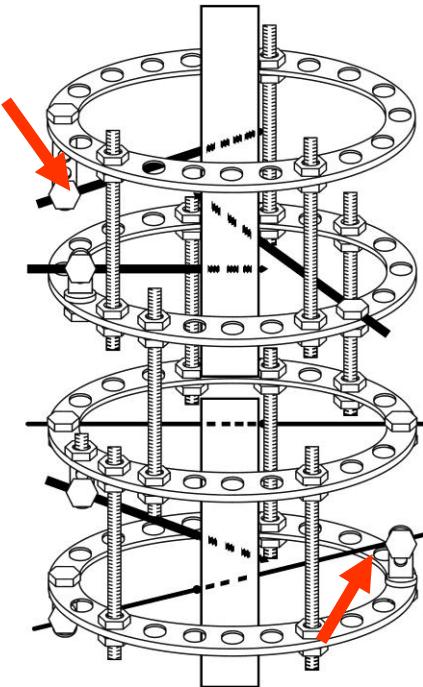
# The scheme of partial frame reassembling in deformation of basic wires and pins



base wires and pins  
deformity



insertion of  
stabilizing pins



re-fixation of base  
wires and pins

# Principal types of frame assembling

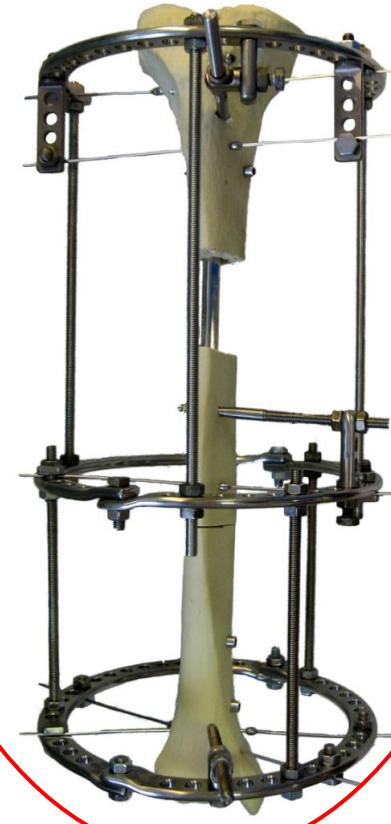
for fracture  
healing



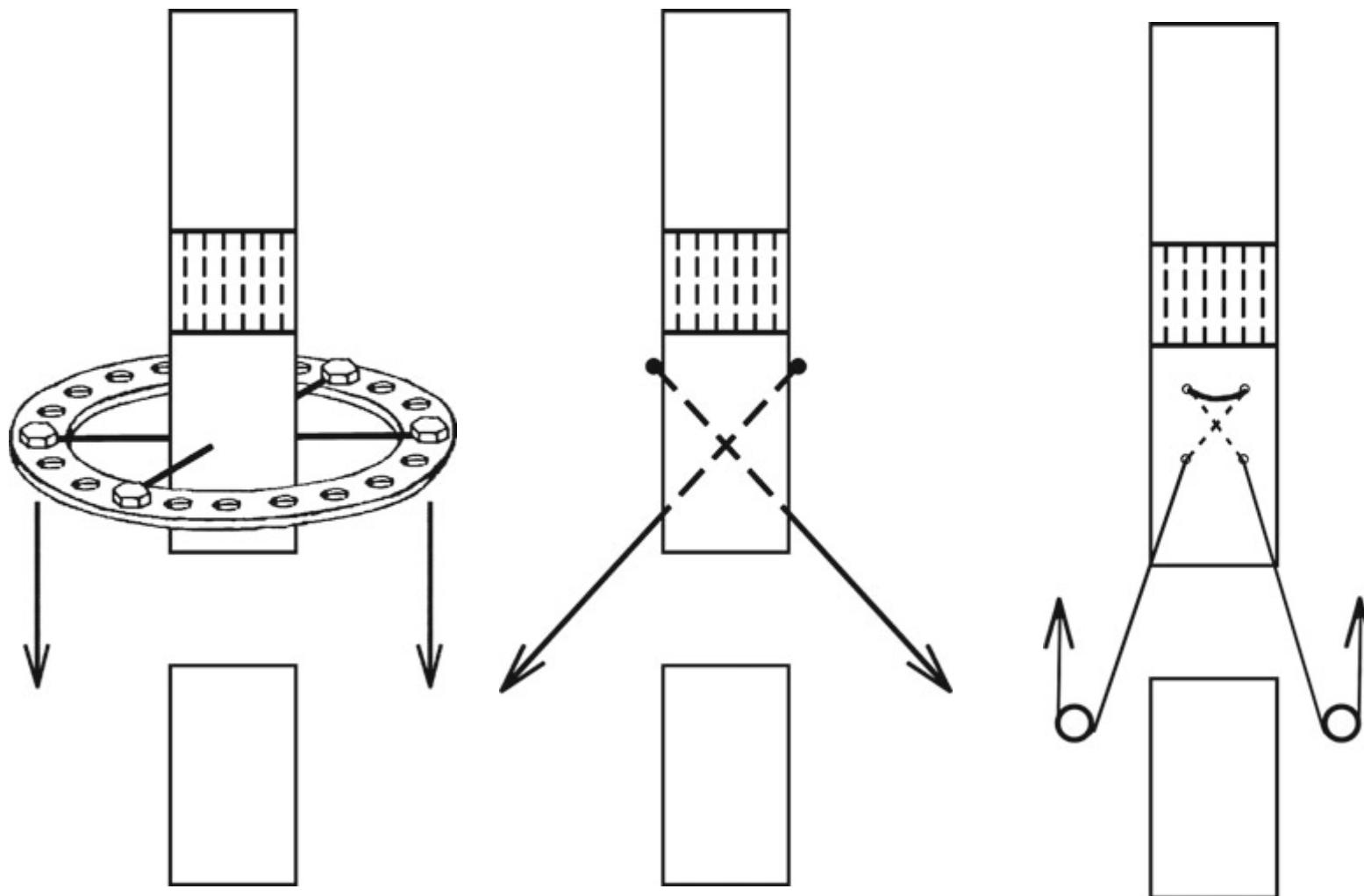
for deformity  
correction



for bone  
transport



# Bone fragment movement: transport



# Principal types of frame assembling

for fracture  
healing



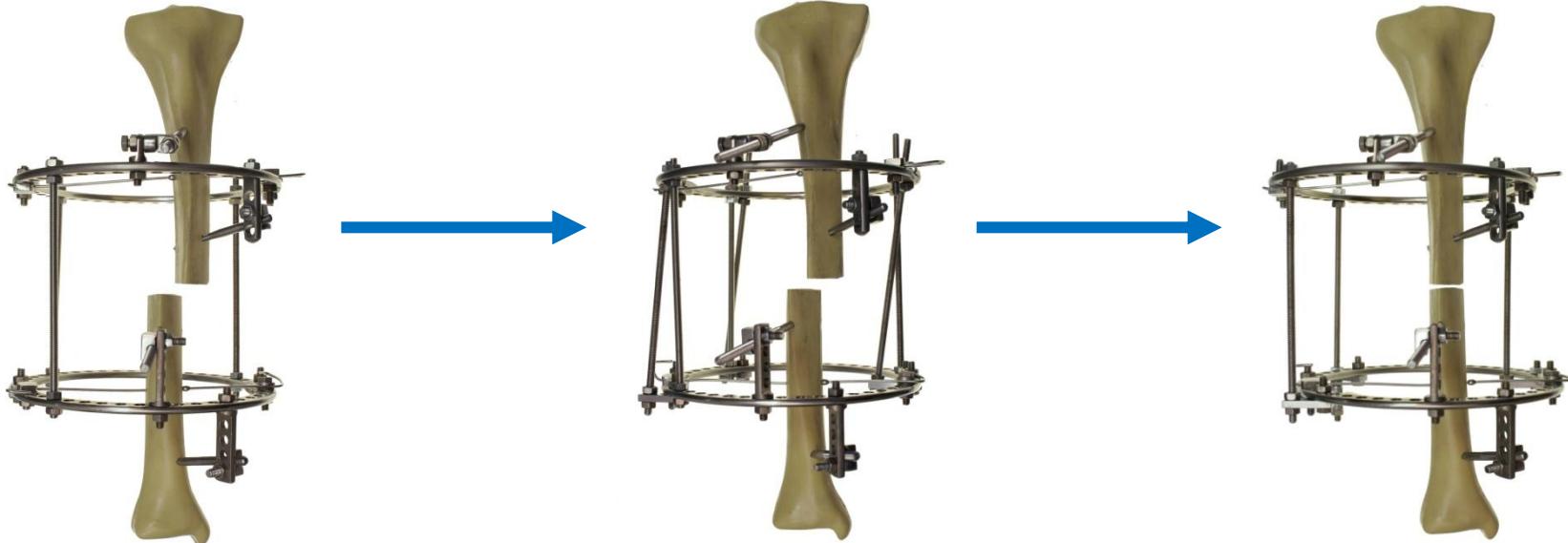
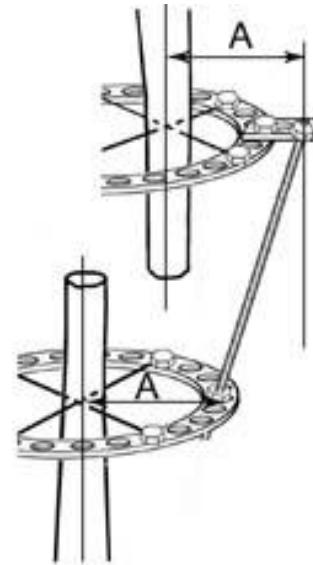
for deformity  
correction



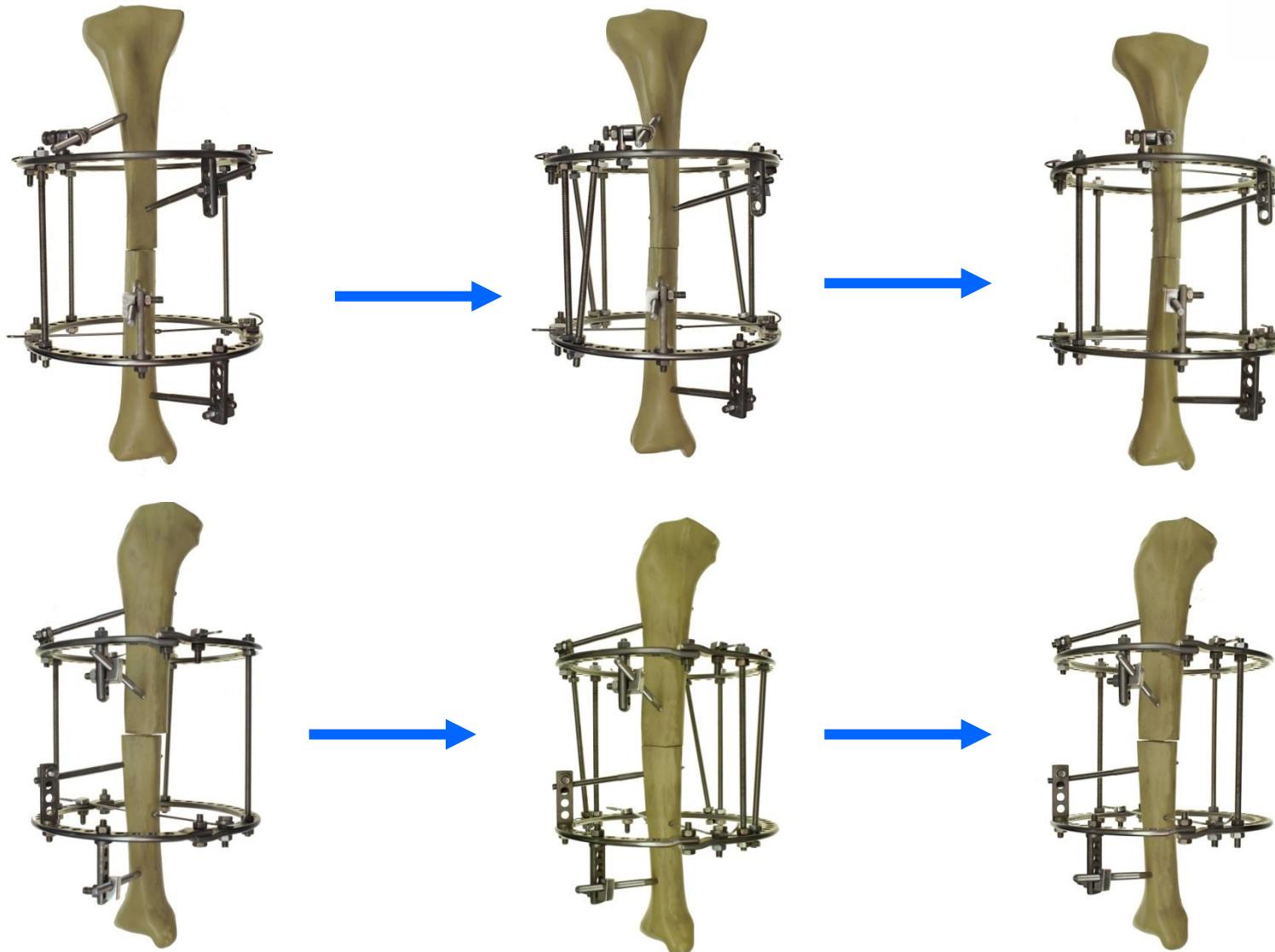
for bone  
transport



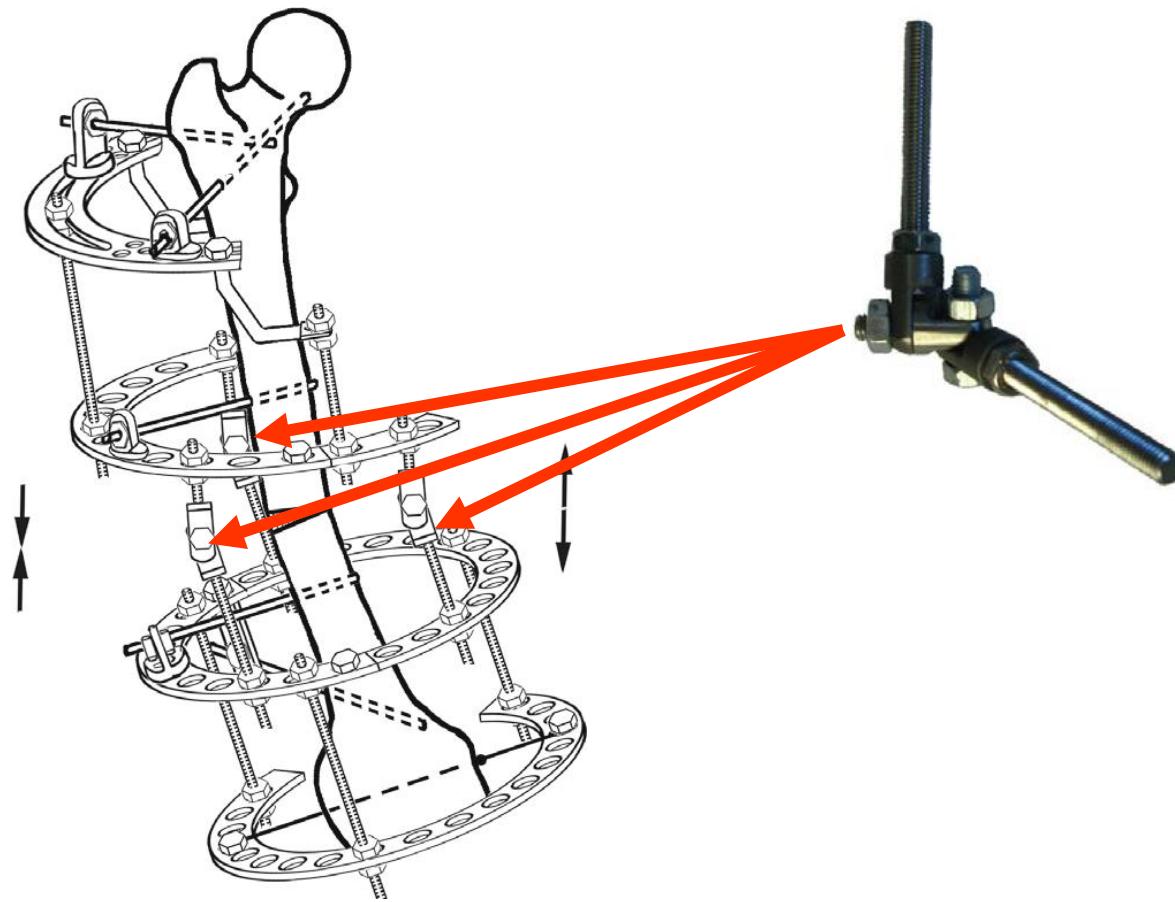
# Acute translation unit



# Acute torsion unit



# (Acute) angular correction unit: “virtual hinge”

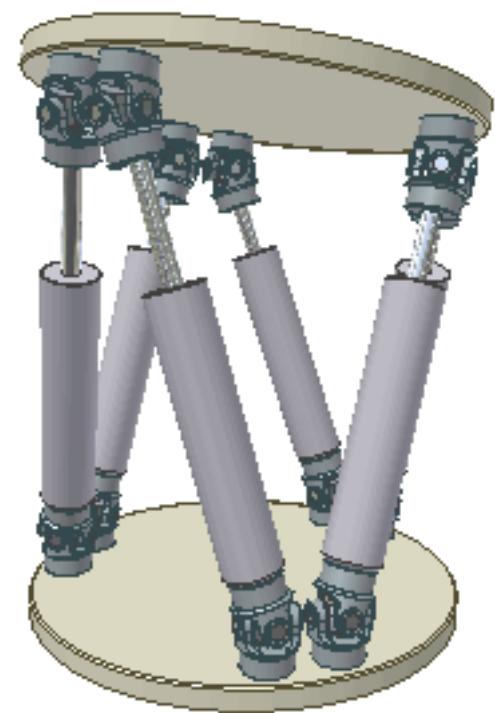


# Basic ways of modules moving

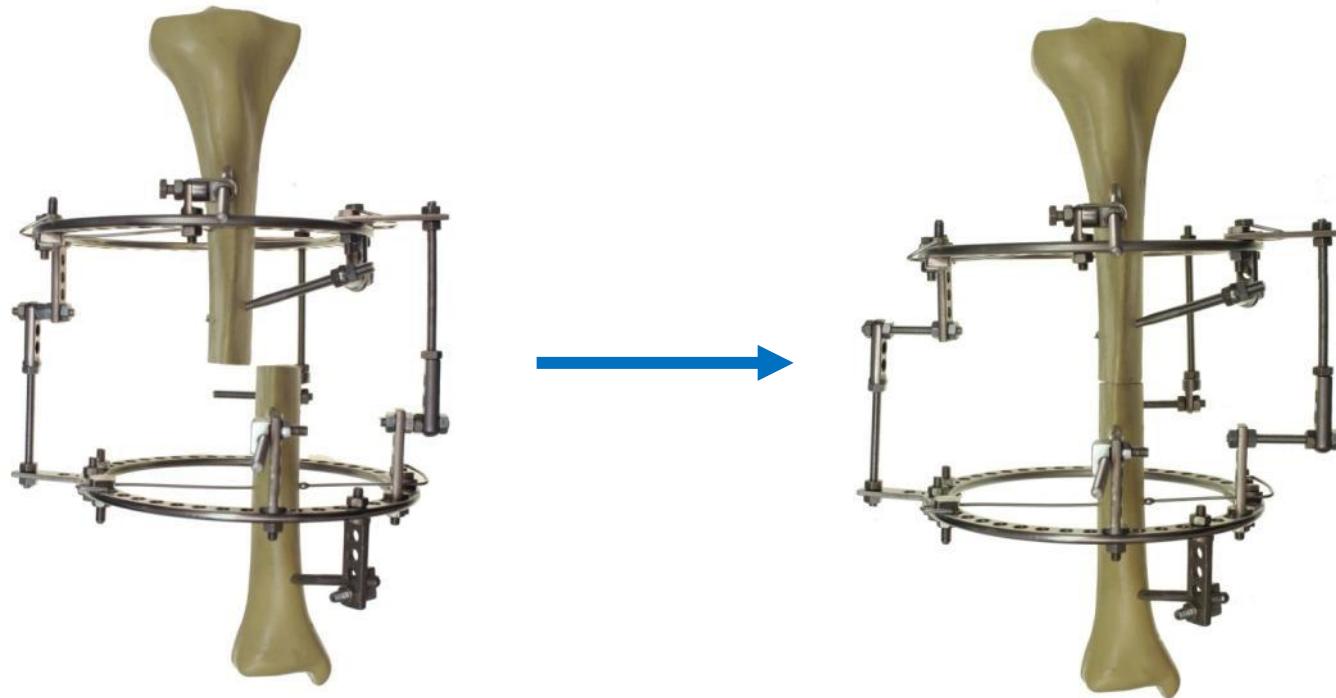
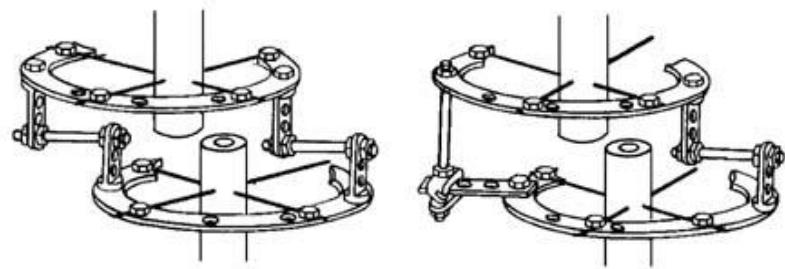
using **unified “Ilizarov hinges”**



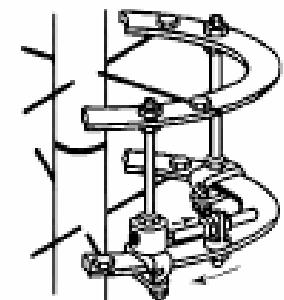
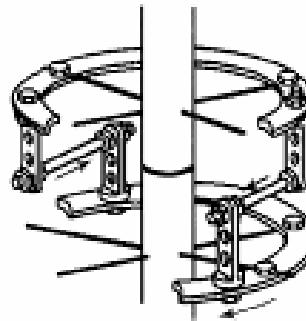
using **universal units**  
(hexapod)



# Gradual translation unit



# Gradual torsion unit

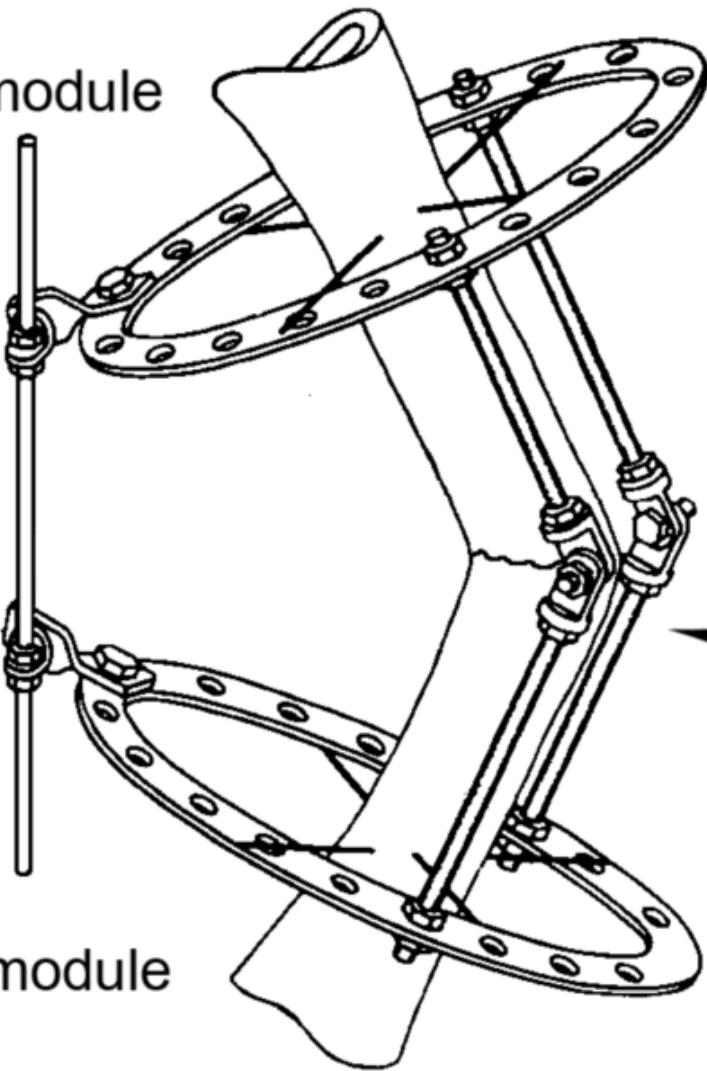


# Unit for correction of angular deformity

Proximal  
transosseous module

Swivel hinge

Distal  
transosseous module

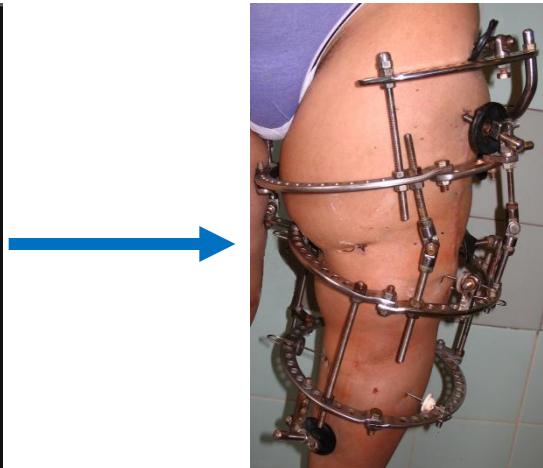


at bisector  
of deformity  
(CORA) level

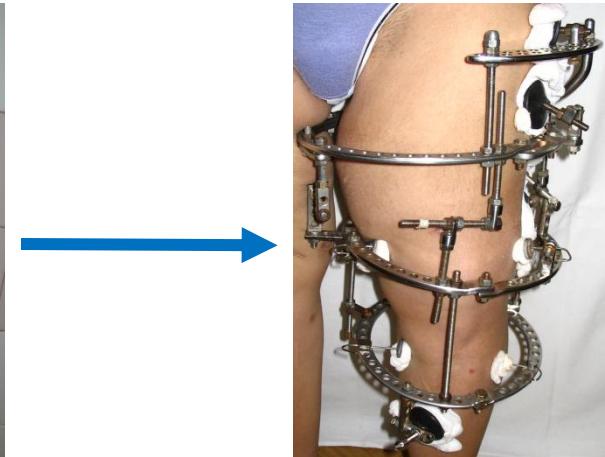
# Ilizarov step-by-step method of gradual deformity correction



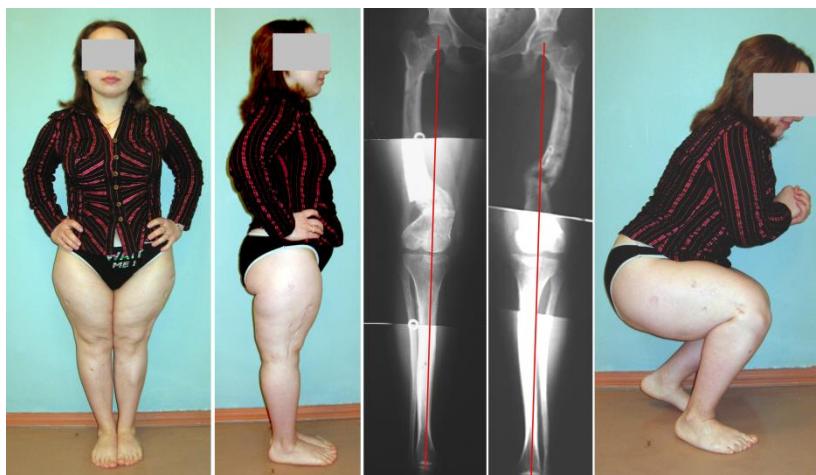
Before  
treatment



Step 1 – lengthening and  
angular deformity correction



Step 2 – torsion correction



Result



Step 4 - fixation



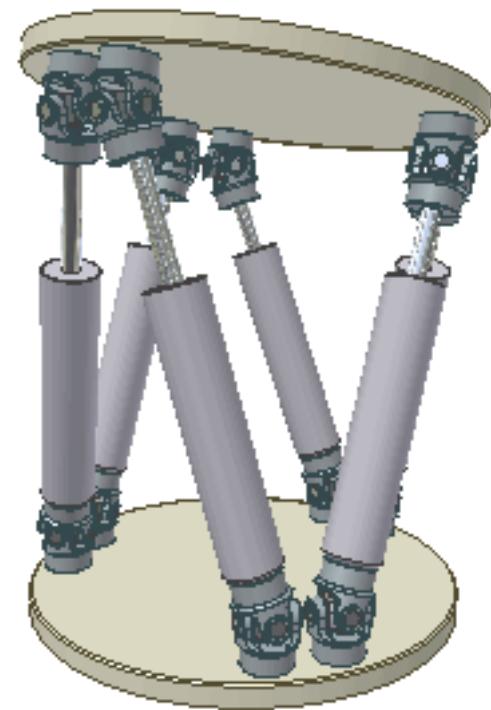
Step 3 – translation  
elimination

# Basic ways of modules moving

Using **unified** “Ilizarov hinges”



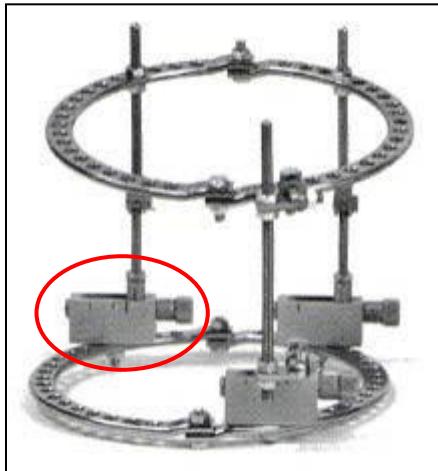
Using **universal** units  
(hexapods)



# Reduction units: unified and universal



Angular



Translation



Rotation



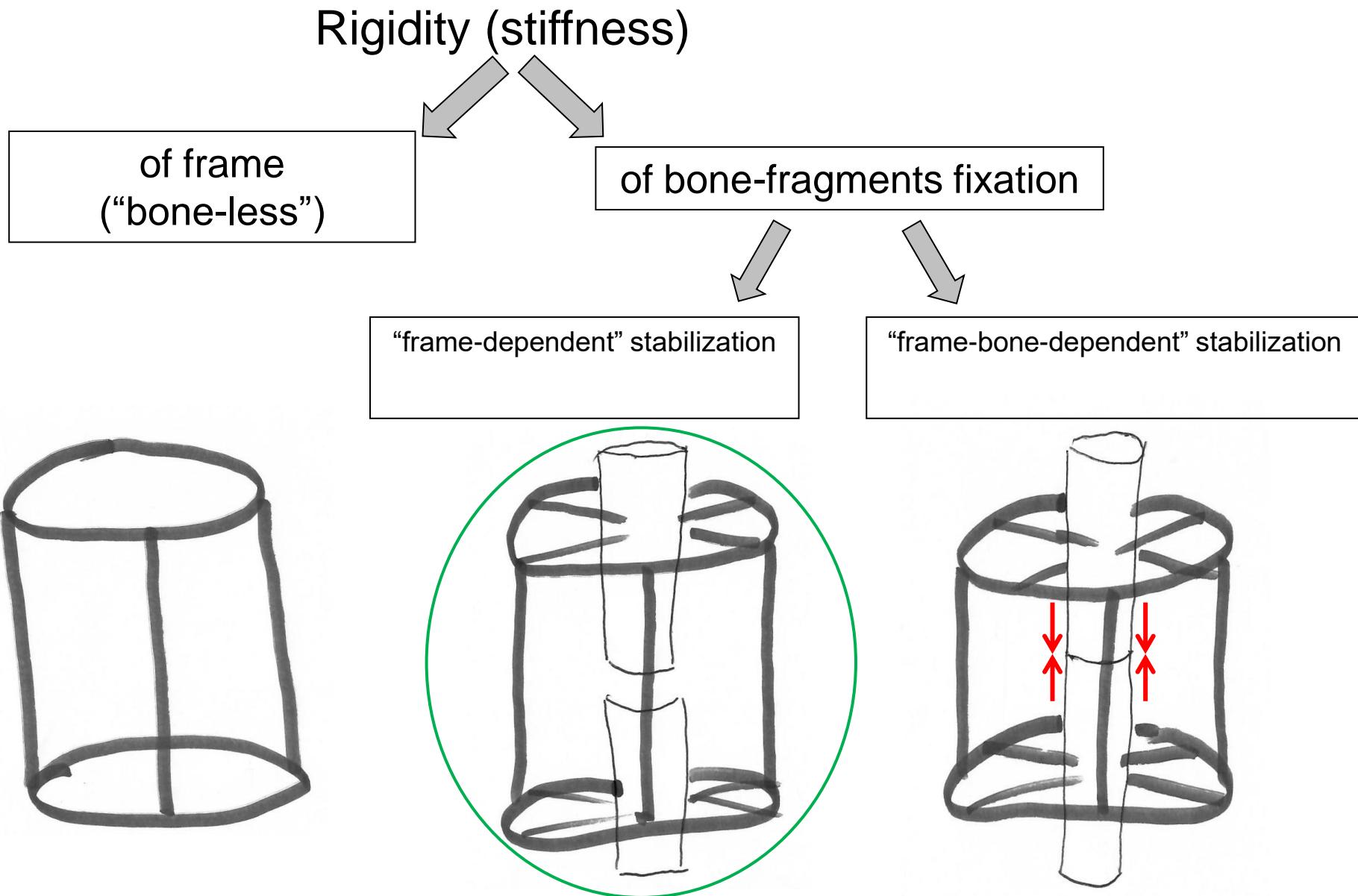
Lengthening



# Biomechanics of external fixation:

1. The relationships between the transosseous elements (wires, half-pins) and the surrounding tissues
2. Bone fragments reduction control
3. Bone fragments fixation control
  - frame module transformation

# Rigidity (stiffness) types



# Rigid frame!

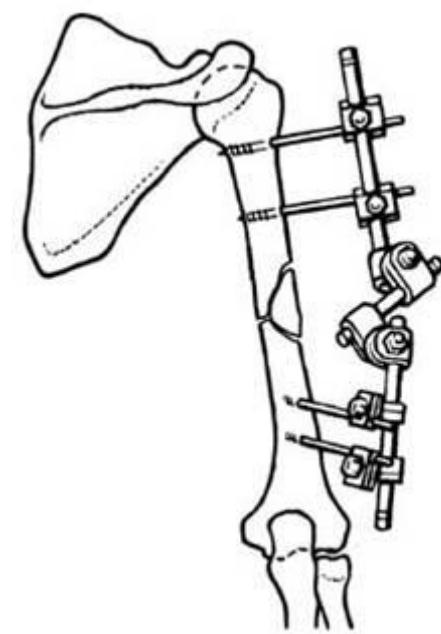
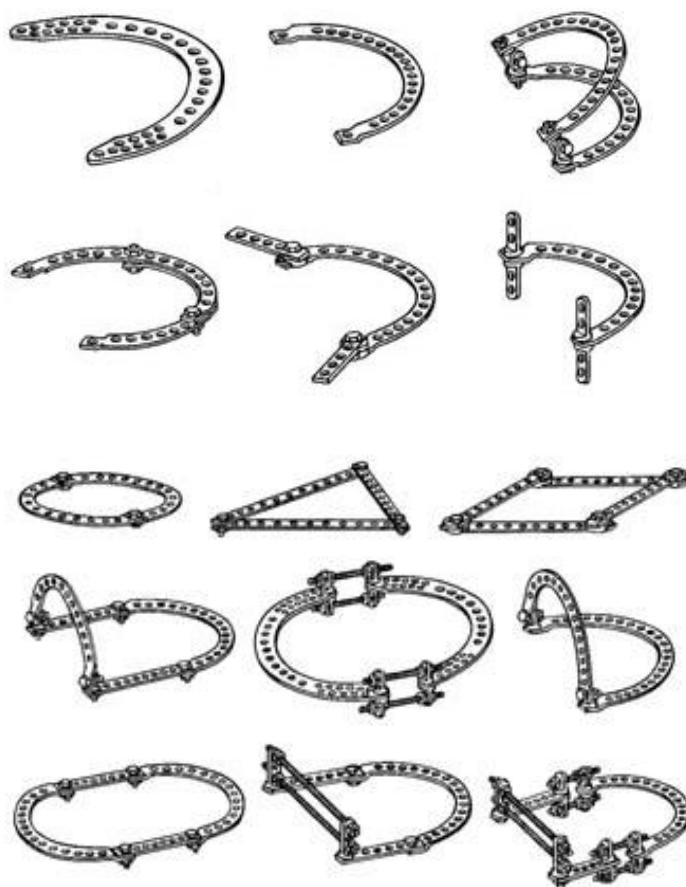
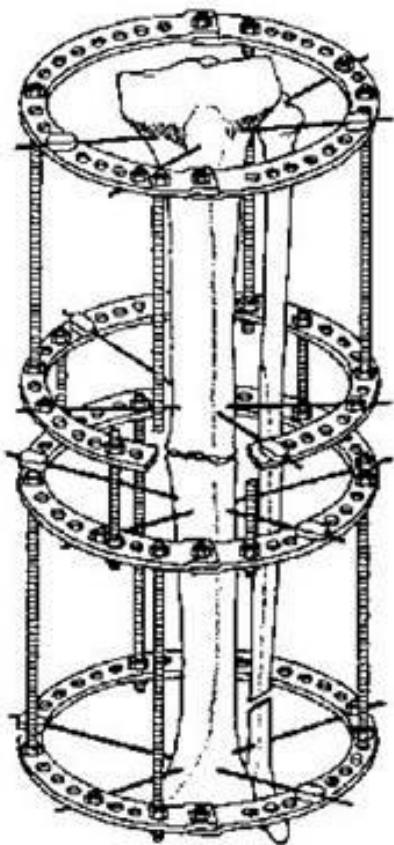


BUT  
rigidity of bone  
fragments fixation  
depends  
FIRSTLY on (bending of)  
wires and pins!

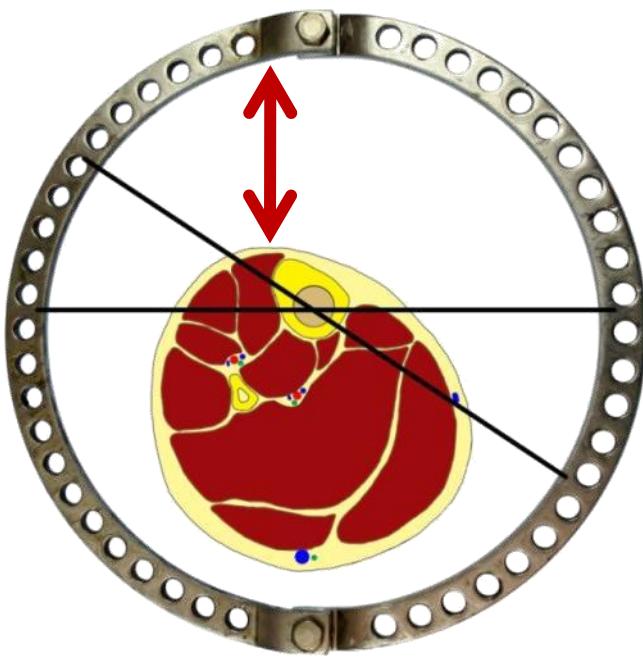
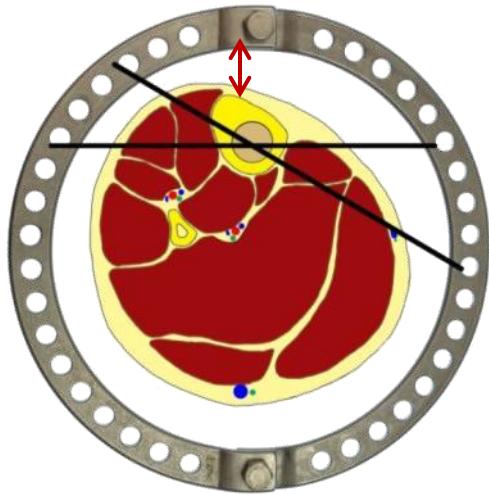
*Osteosynthesis rigidity depends on:*

## - external support geometry (not rigidity!)

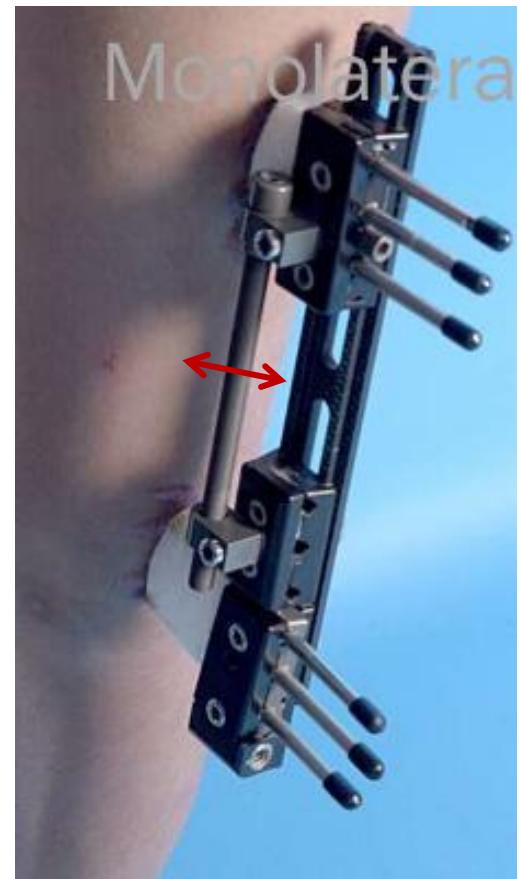
Circular > Semicircular > Sectorial > Monolateral



## - distance from bone to ring

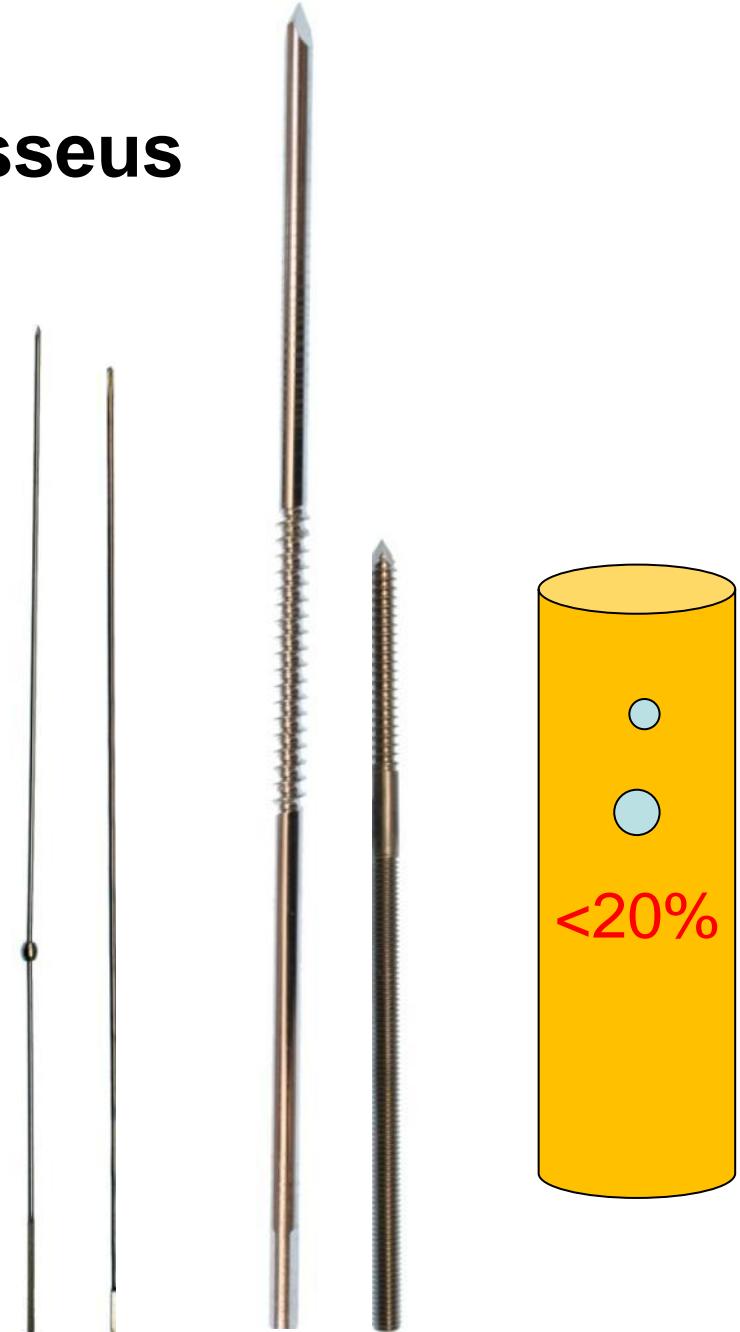


$1 > 2$

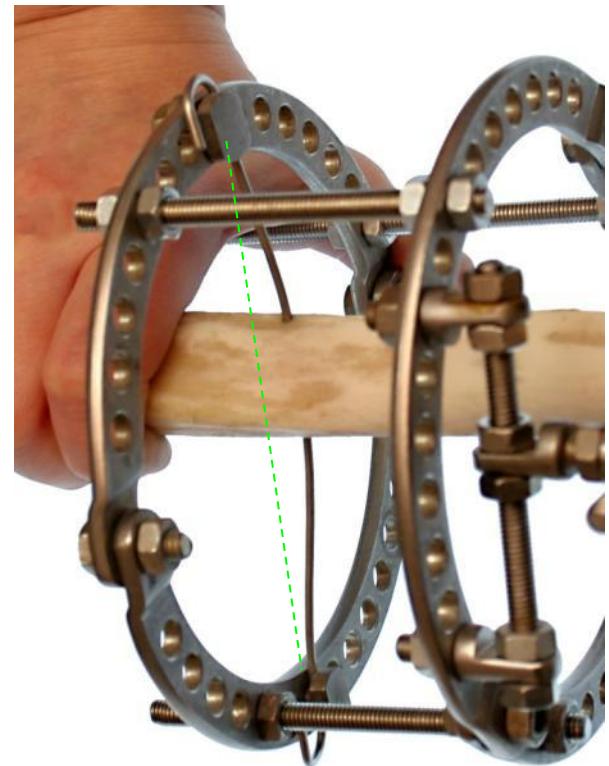
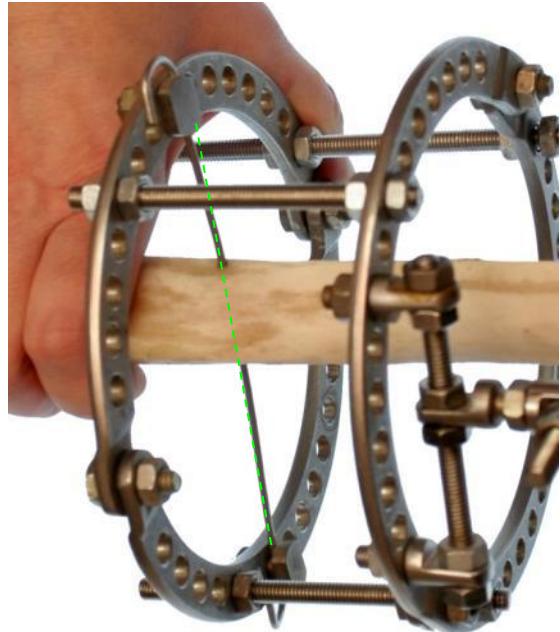


## - type and diameter of transosseous elements

- Equipped with stopper and thread > smooth
- Transsegmental > consol
- “Thick” > “thin”



## - degree of wire tension

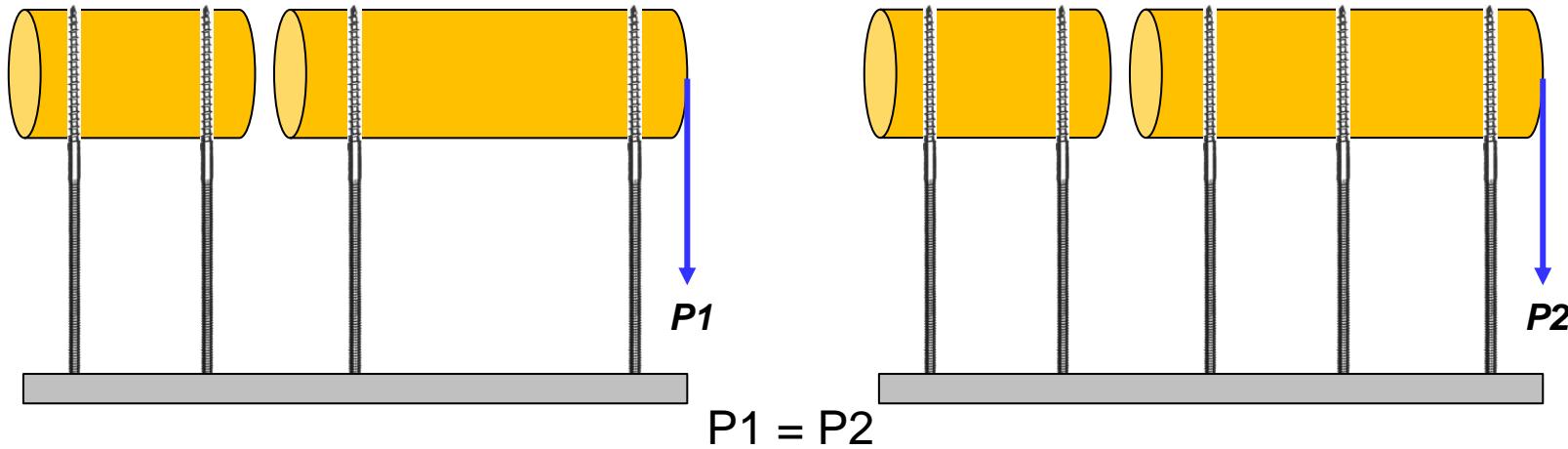


- in ring - 900–1100 N
- in half-ring - 500–700 N

## **- number of Transosseous Elements**

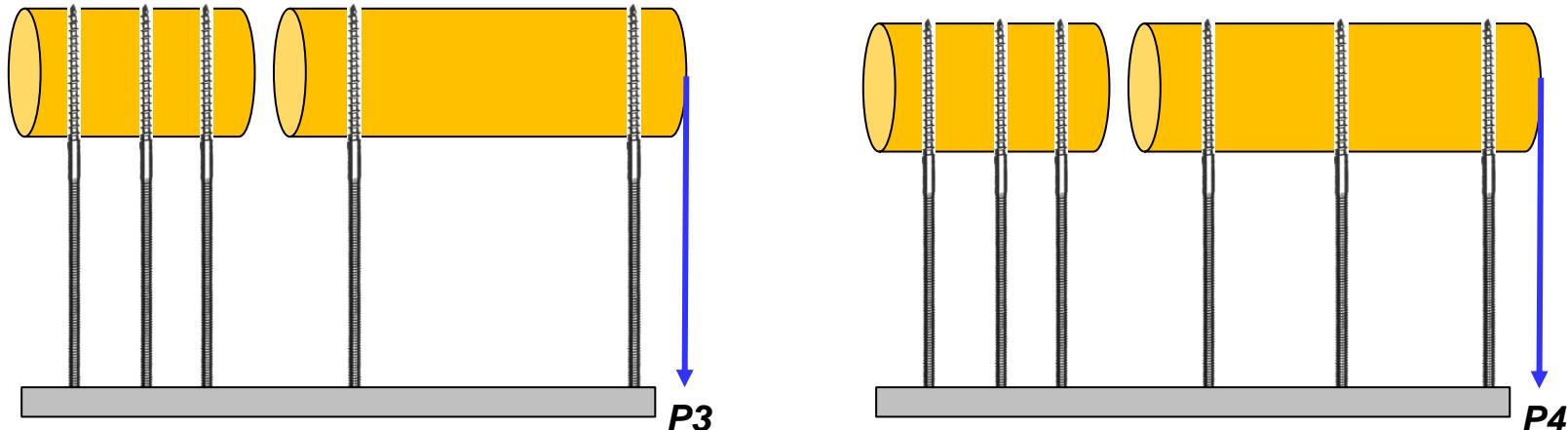
It would be better to have one half-pin (wire) more, than one half-pin (wire) less

## - fixation rigidity of proximal fragment

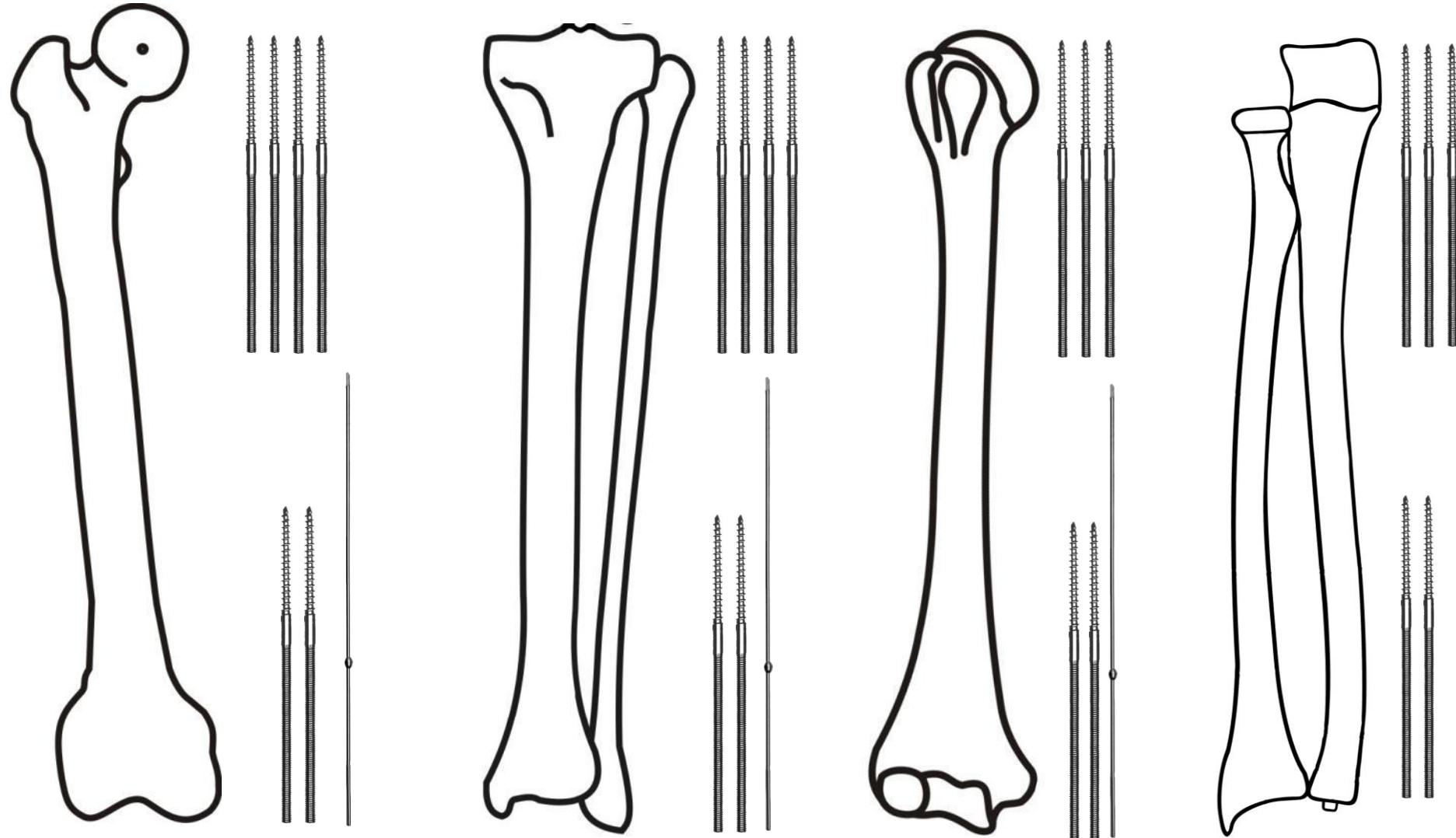


$P_3 > P_1$

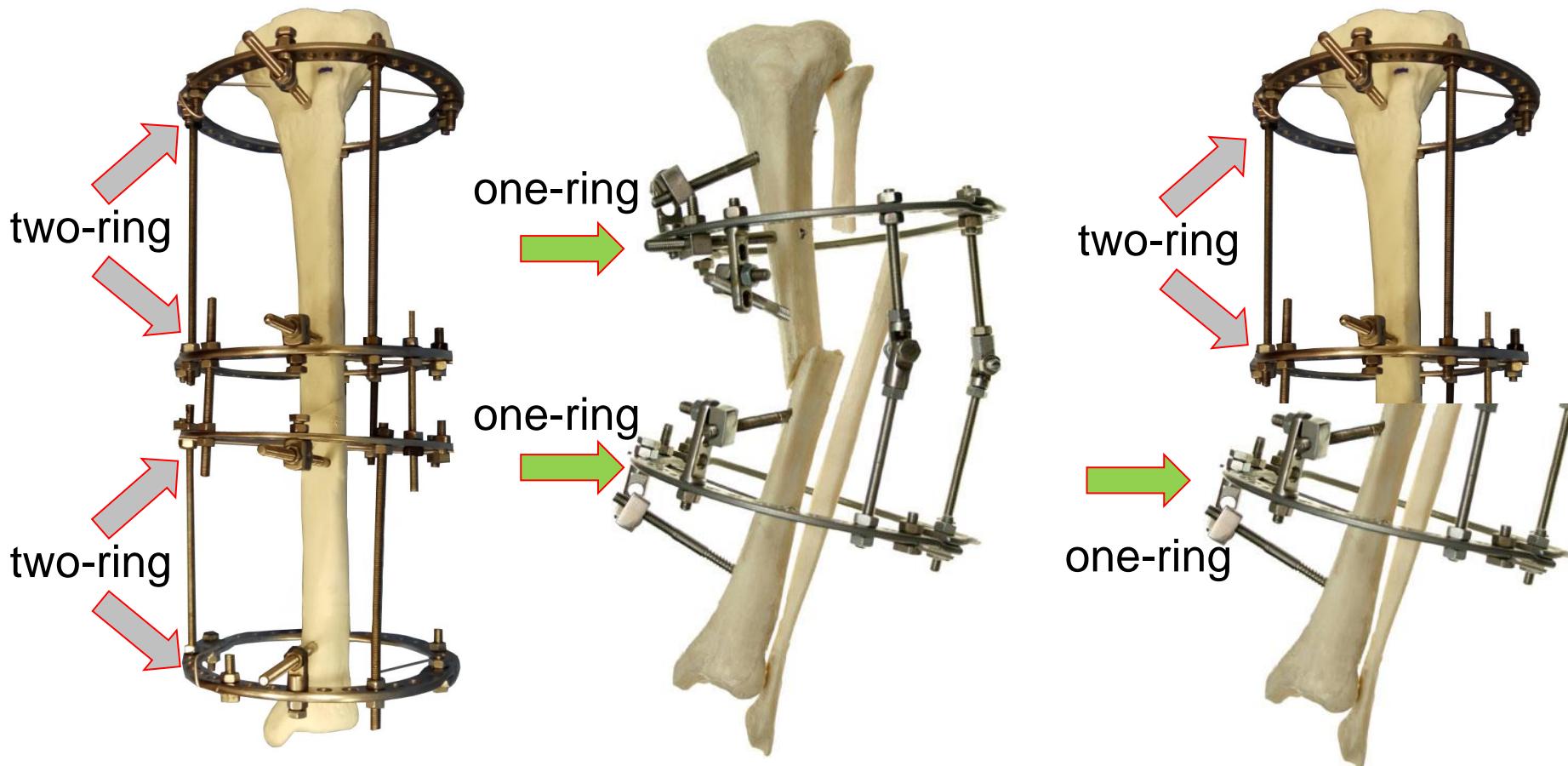
$P_3 = P_4$



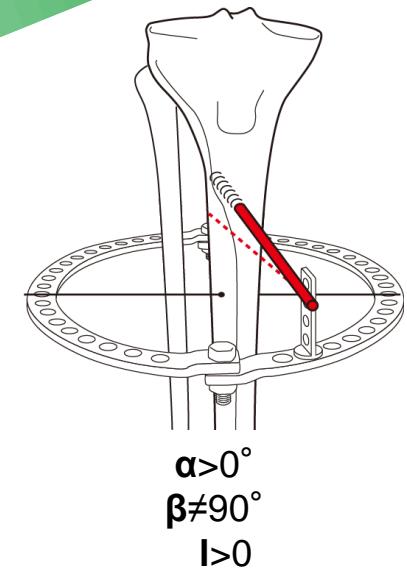
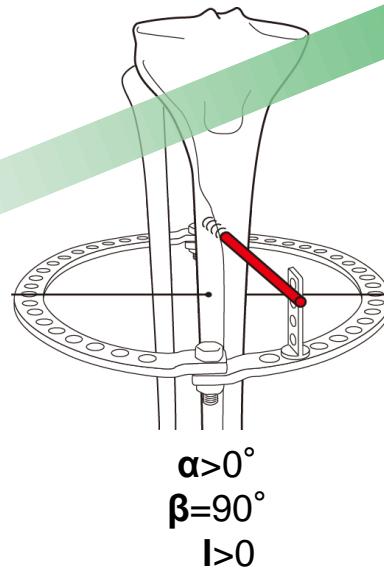
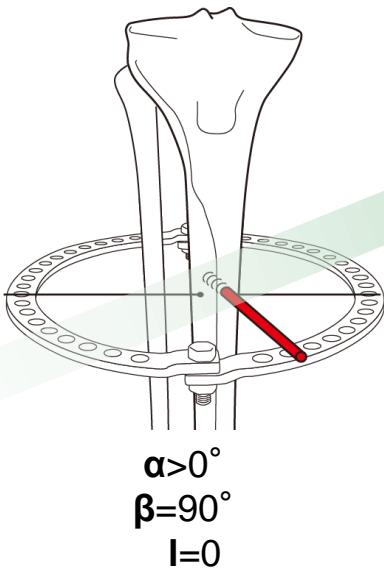
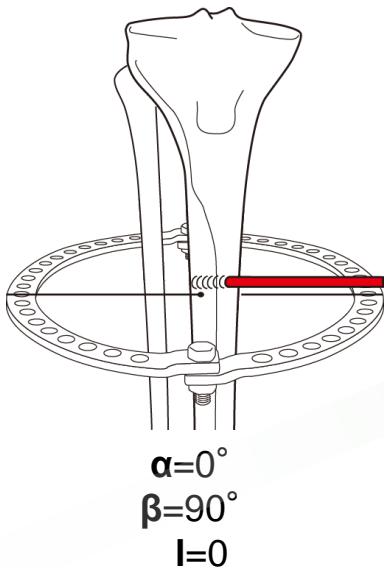
## - number of transosseous elements



# ExFix modules



## - orientation of wires and pins (one-ring module)



$\alpha$  - angle of bone components crossing

$\beta$  - angle of threaded pin inclination

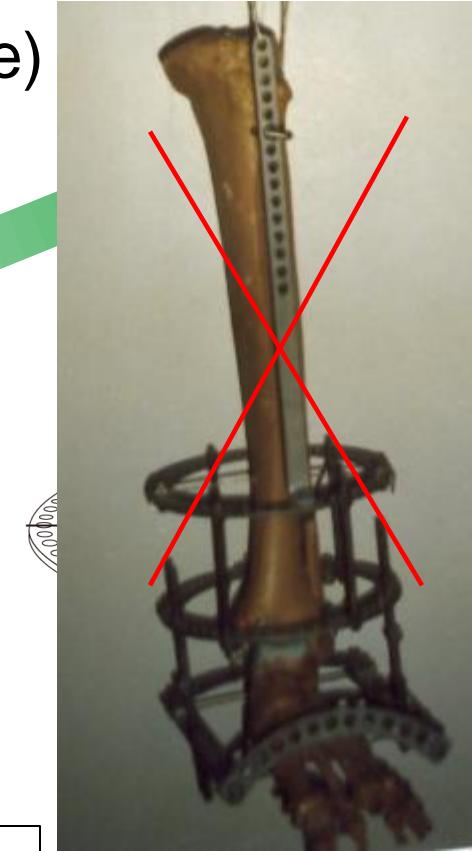
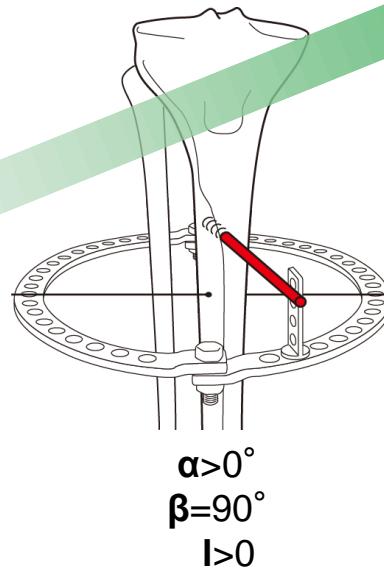
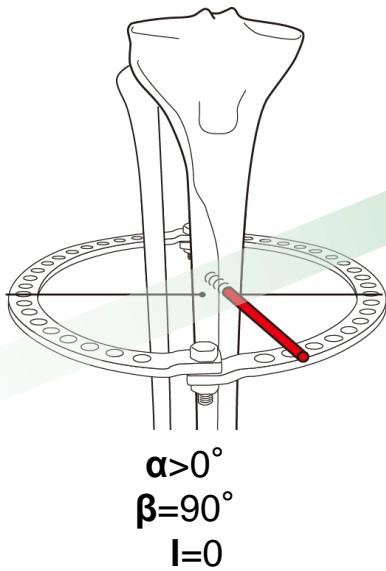
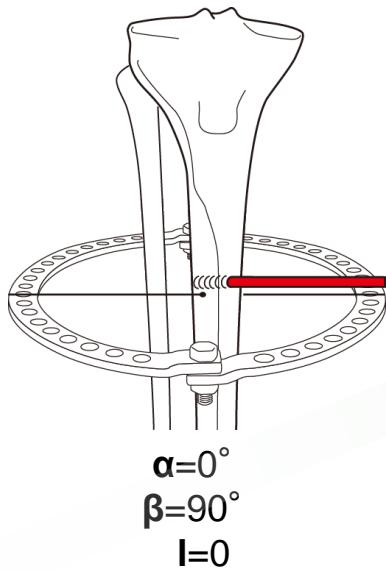
$I$  – lever (distance between bone components)

$\alpha>0^\circ$

$\beta\neq90^\circ$

**Four- hole post forever!**

## - orientation of wires and pins (one-ring module)



$\alpha$  - angle of bone components crossing

$\beta$  - angle of threaded pin inclination

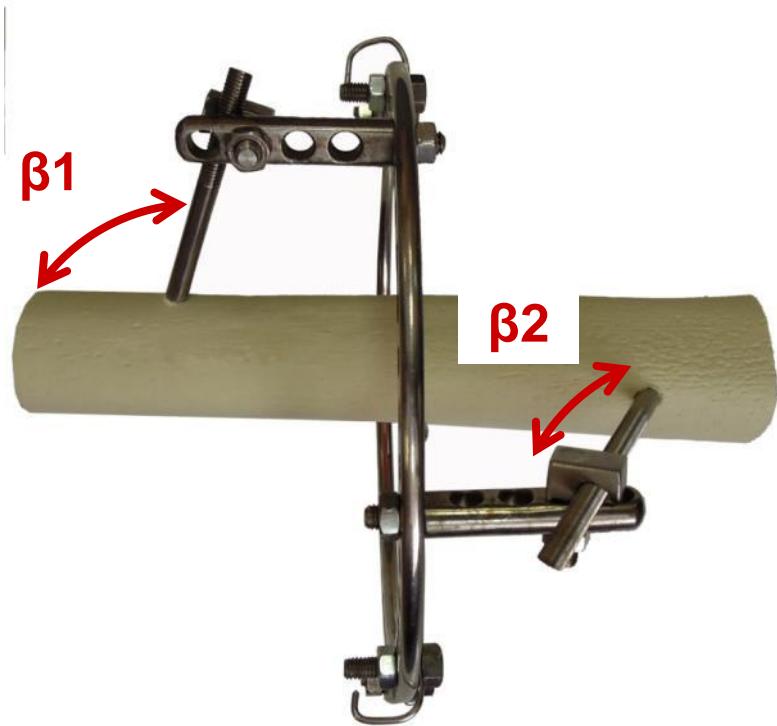
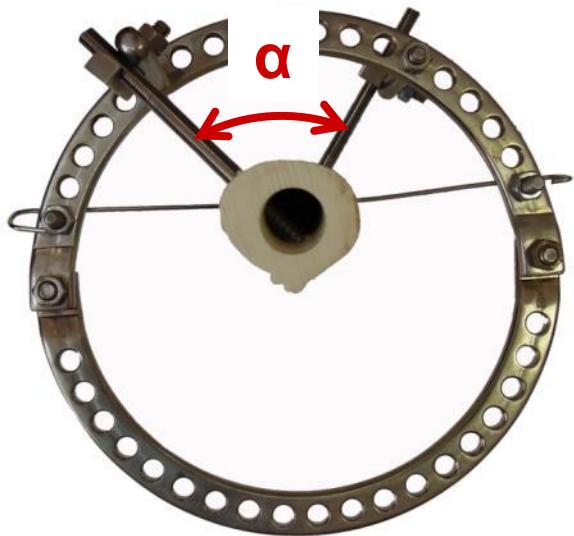
$I$  – lever (distance between bone components)

$\alpha>0^\circ$

$\beta\neq90^\circ$

**Four- hole post forever!**

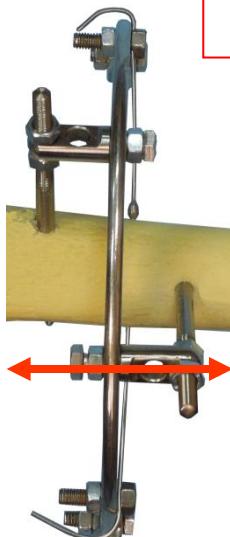
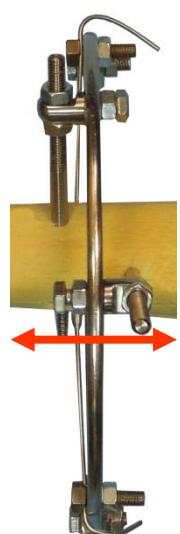
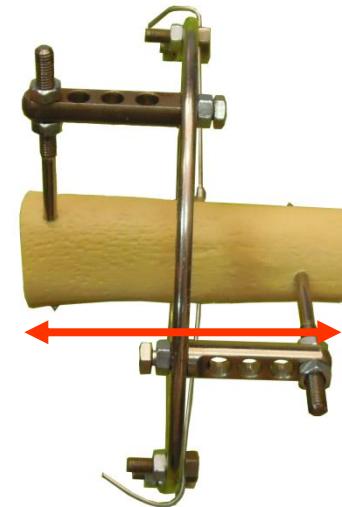
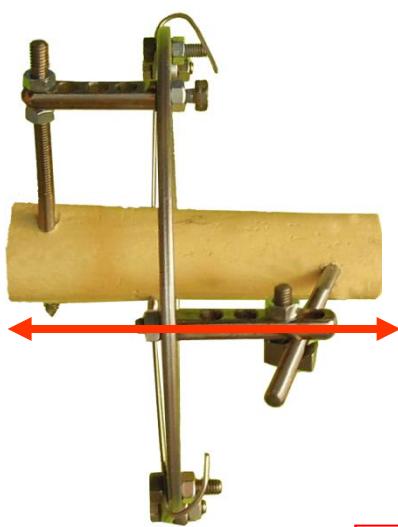
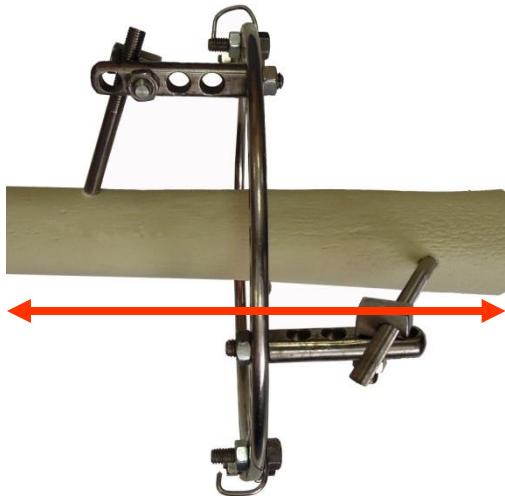
## - wires and pins orientation (one-ring module)



$$\begin{aligned}\alpha &= 60^\circ (75 \pm 15^\circ) \\ \beta_1 &= 120^\circ (105 \pm 15^\circ) \\ \beta_2 &= 70^\circ (85 \pm 15^\circ)\end{aligned}$$

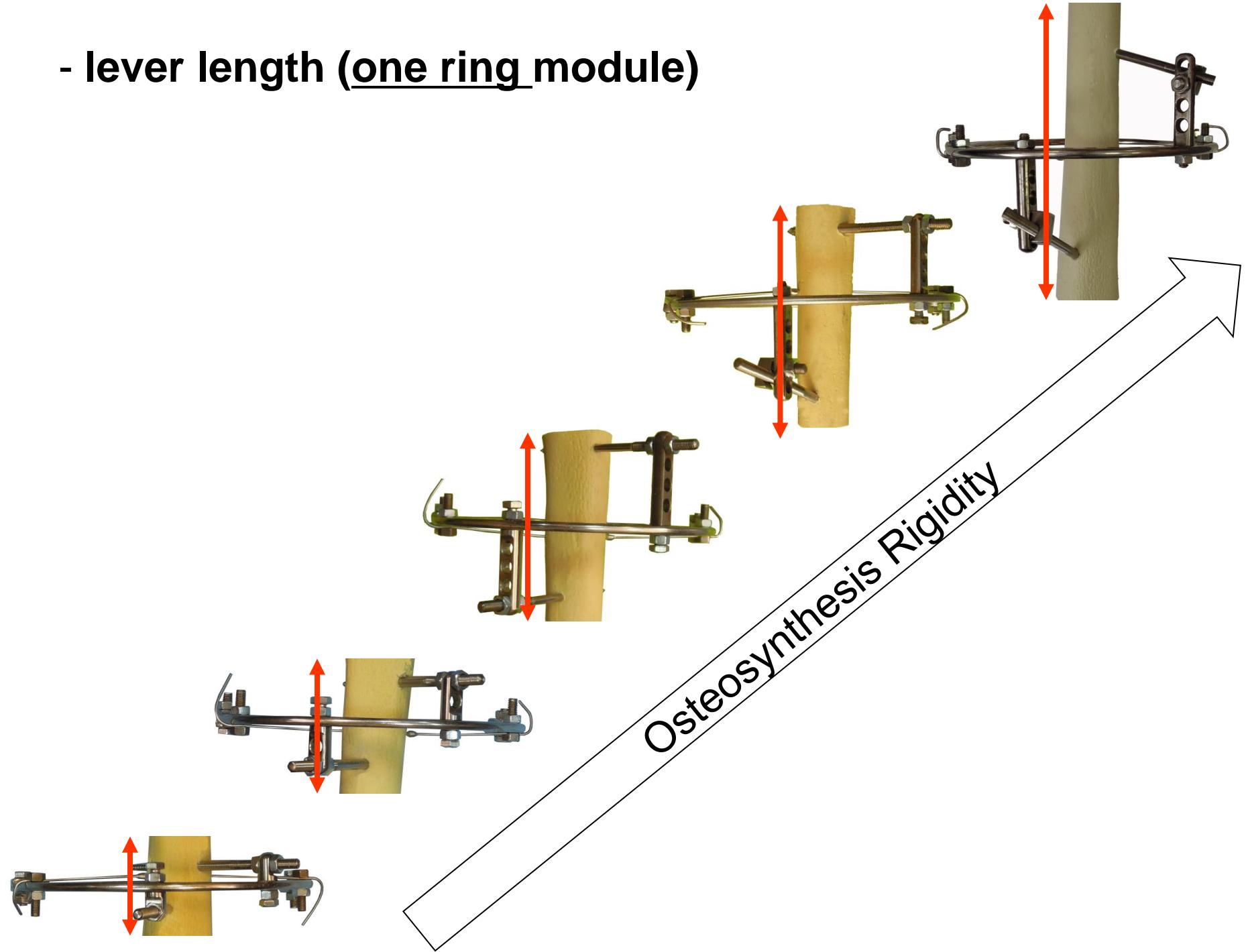
## - lever length (one ring module)

**Four- hole post forever!**

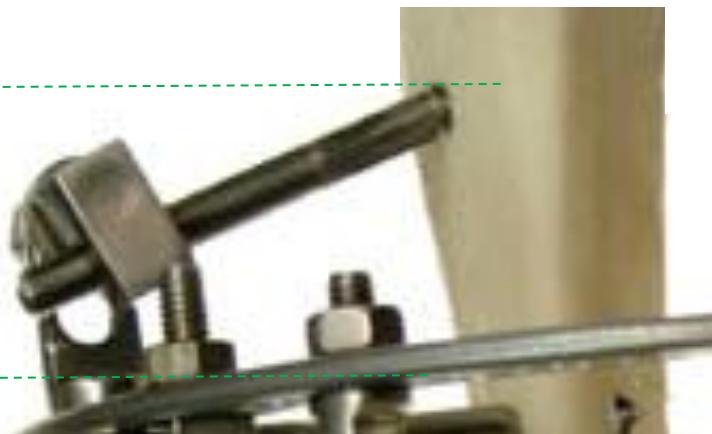
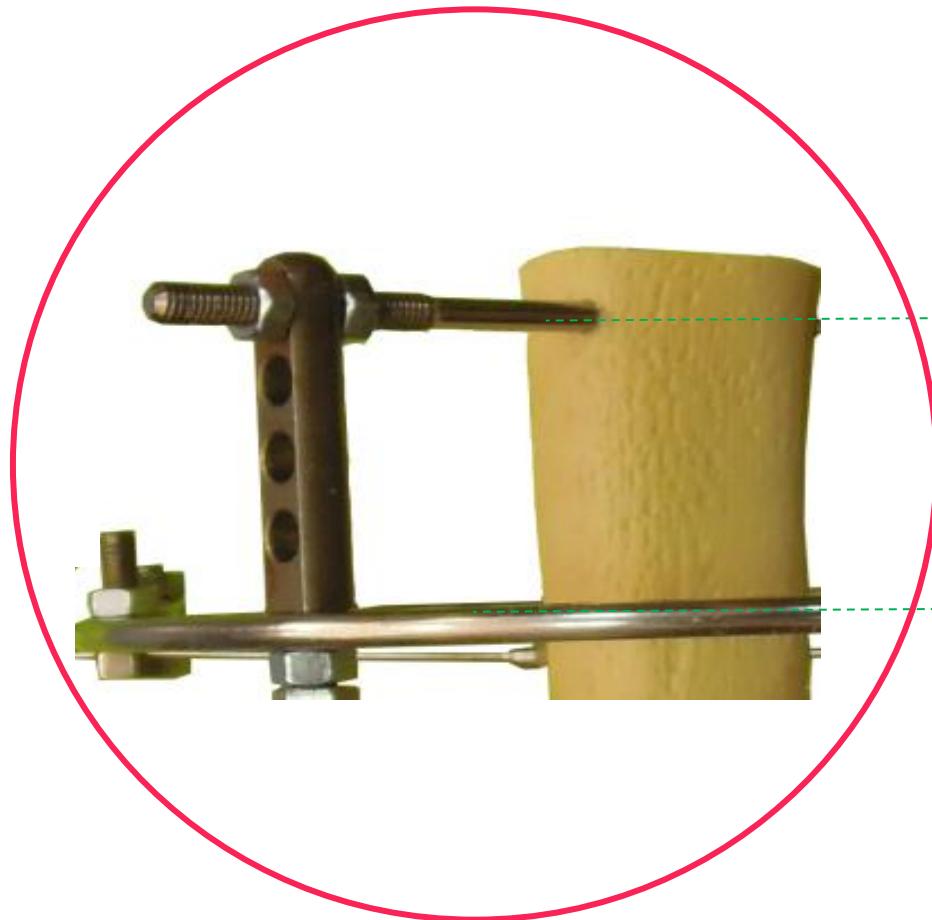


**... if possible**

## - lever length (one ring module)

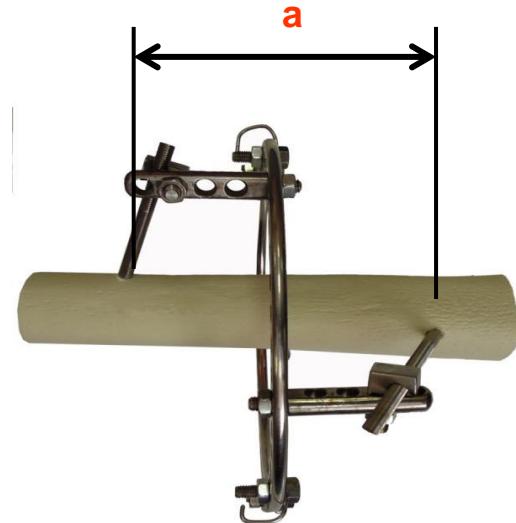


## - pin orientation



# ExFix modules

**Four- hole post forever!**



$$\begin{aligned}\alpha &= 60^\circ (75 \pm 15^\circ) \\ \beta_1 &= 120^\circ (105 \pm 15^\circ) \\ \beta_2 &= 70^\circ (85 \pm 15^\circ)\end{aligned}$$

**Four- hole post forever!**

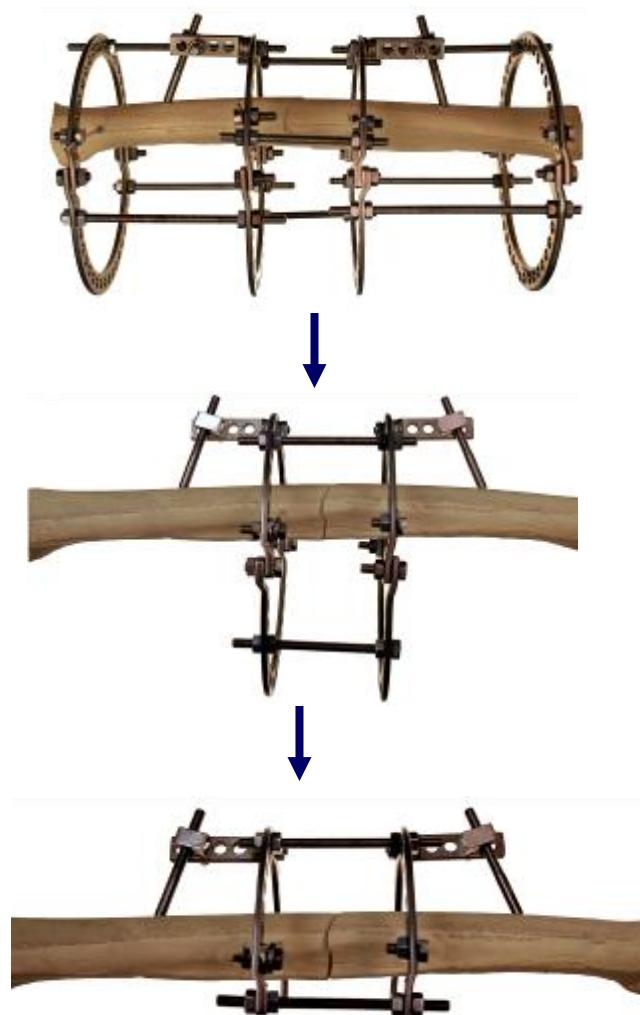


$$\begin{aligned}\alpha &= 60^\circ (75 \pm 15^\circ) \\ \beta &= 90^\circ\end{aligned}$$

# Frame Module Transformation (MT)

- step-by-step decrease in the quantity of wires, pins and rings

- change the geometry of the external supports



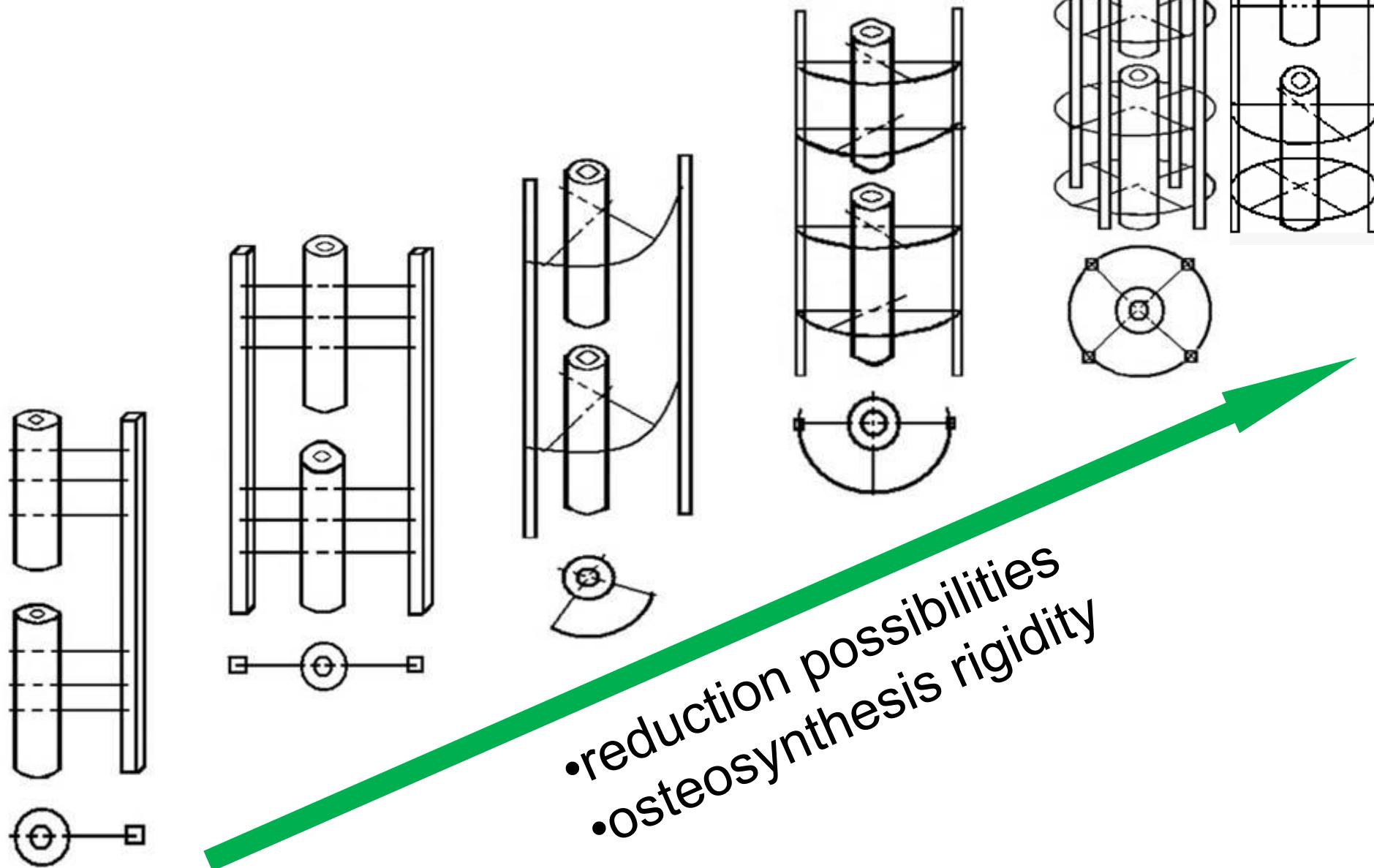
## MT provides:

- frame dinamisation
- decrease of danger of pin-induced joint stiffness and pin-tract infection
- decrease of frame bulkiness

# MT: step-by-step

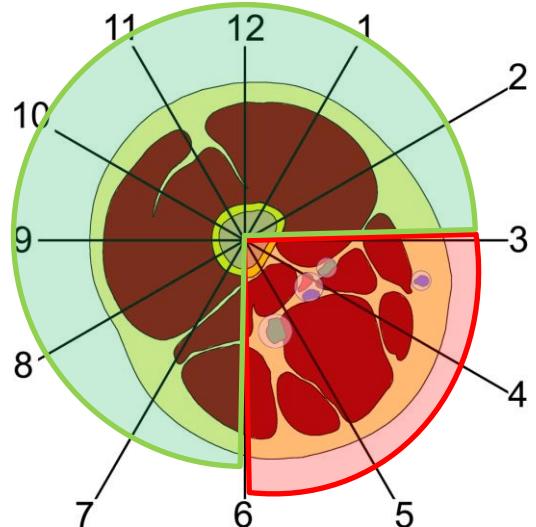


# Take-home message: frame types



# Take-home message: RP

The relationships between the osseous elements (wires, half-pins) and the surrounding tissues



# Take-home message: RP

The relationships between the osseous elements (wires, half-pins) and the surrounding tissues

**Safe  
Positions**

# Take-home message: RP

The relationships between the osseous elements (wires, half-pins) and the surrounding tissues

**Safe  
Positions**



# Take-home message

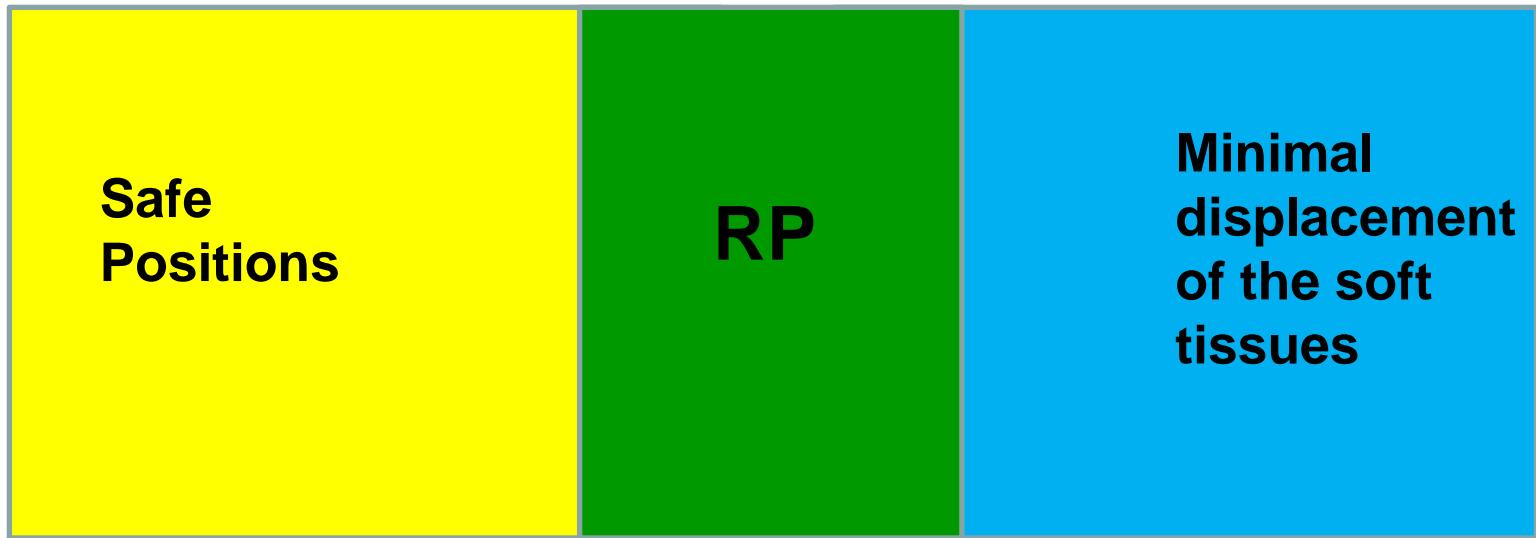
The relationships between the osseous elements (wires, half-pins) and the surrounding tissues

**Safe  
Positions**

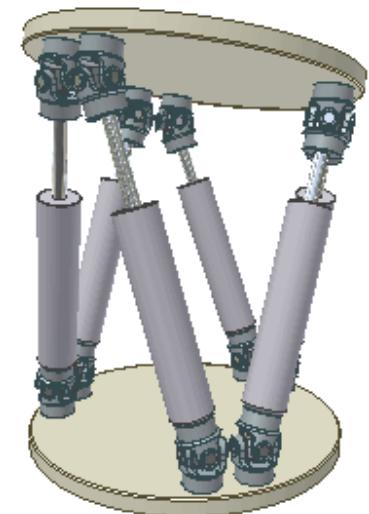
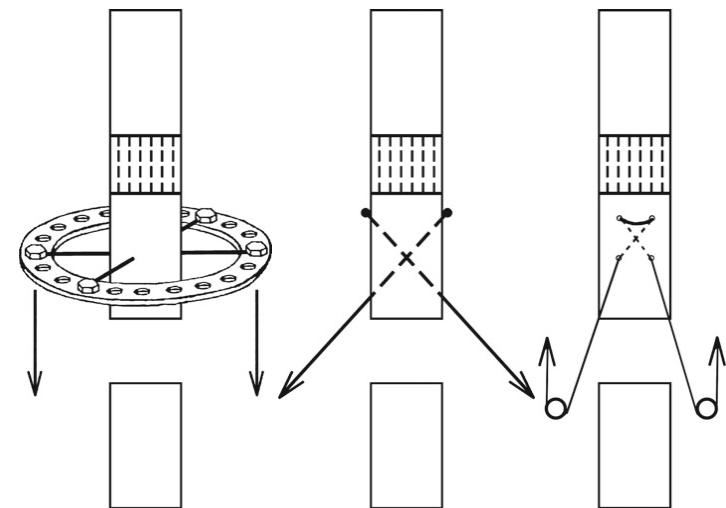
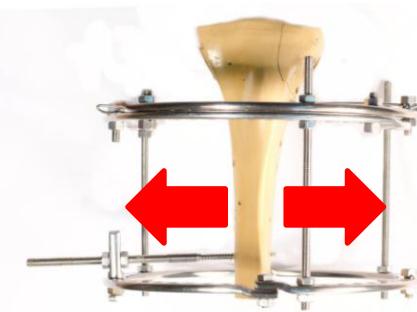
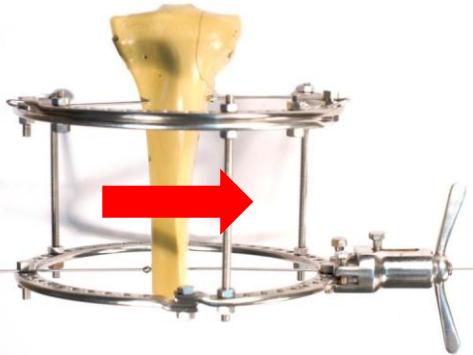
**Minimal  
displacement  
of the soft  
tissues**

# Take-home message: RP

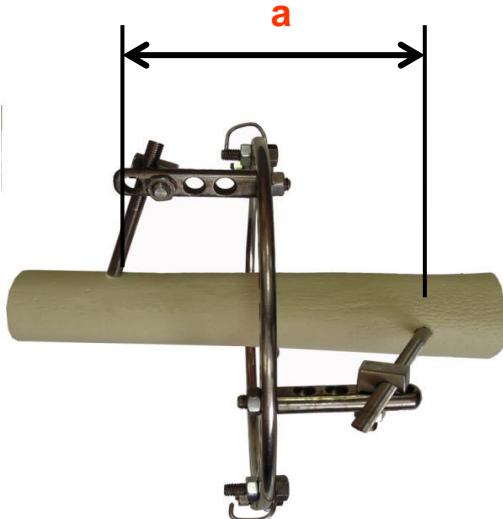
The relationships between the osseous elements (wires, half-pins) and the surrounding tissues



# Take-home message: bone fragment movement



# Take-home message

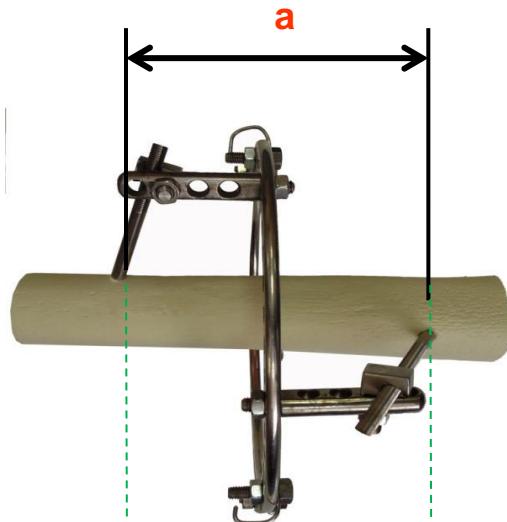


3. Bone fragments fixation control



# Take-home message: osteosynthesis rigidity

$$\alpha = 60^\circ (75 \pm 15^\circ)$$
$$\beta_1 = 120^\circ (105 \pm 15^\circ)$$
$$\beta_2 = 70^\circ (85 \pm 15^\circ)$$



Four- hole post forever!

$$\alpha = 60^\circ (75 \pm 15^\circ)$$
$$\beta = 90^\circ$$



direct ring fixation

# Stability spectrum

