Biomechanical concepts of total shoulder replacement

Richard W. Nyffeler
Orthopädie Sonnenhof
Bern

First total shoulder prosthesis

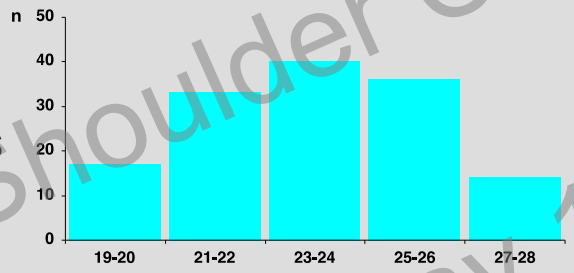
Jules Emile Péan, 1830-1898

Monobloc prostheses

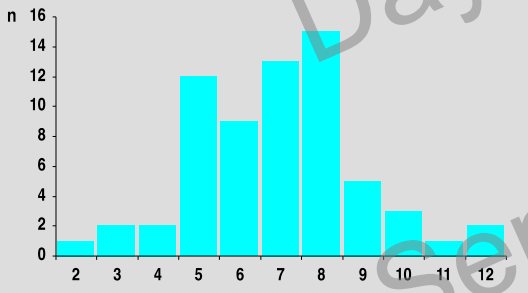
Charles Neer, 1917-2011

Anatomic prostheses

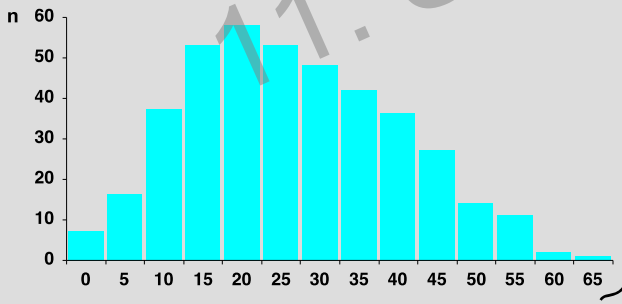
humeral head radius



medial offset



retrotorsion



+/- 1995

Stemless prostheses

trend towards resurfacing, stemless or short stem prostheses

Why no long stem ?

- it is not necessary

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- it is difficult
  - ➢ to remove the stem (infection, conversion into RSA)

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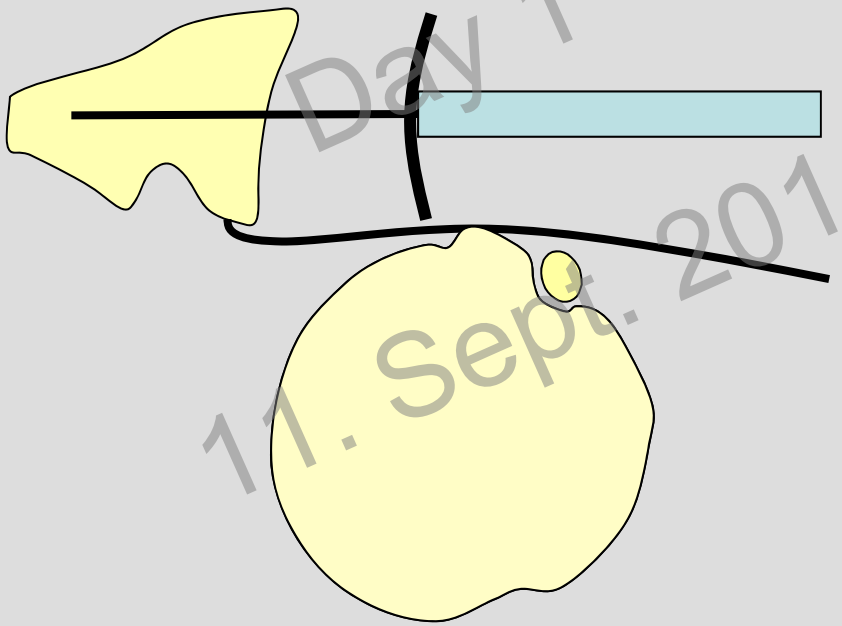
- it is difficult
  - ➢ to remove the stem (infection, conversion into RSA)
  - ➢ to treat a periprosthetic fracture
  - ➢ to implant a shaft after a fracture or an osteosynthesis

Cave !

- it is difficult
  - ➢ to expose the glenoid without resection of the humeral head



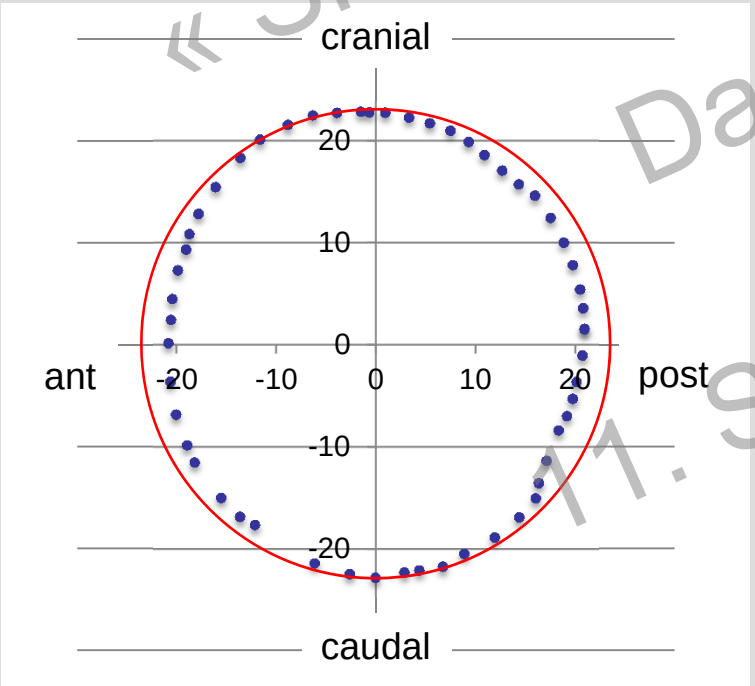
Cave !

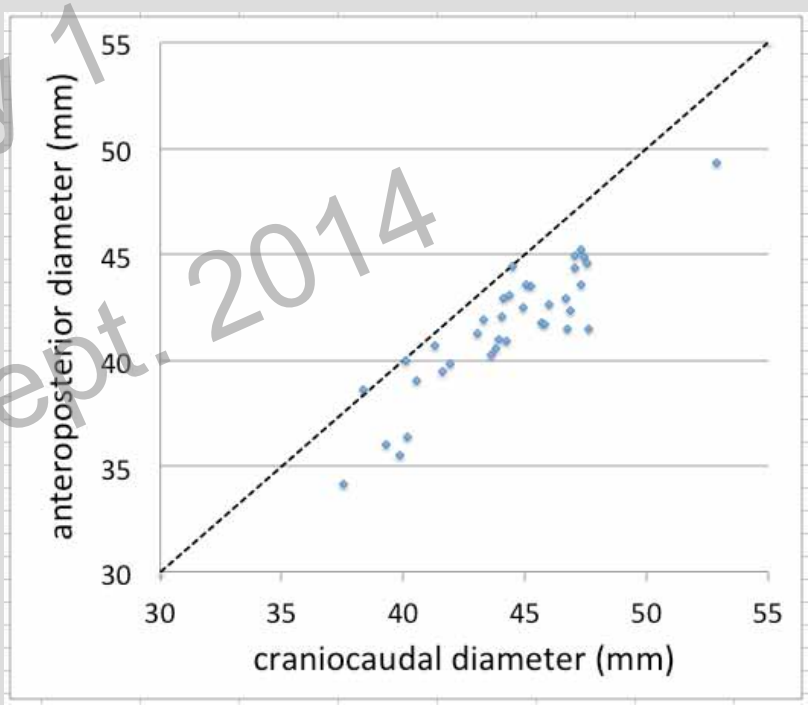
- it is difficult
  - to expose the glenoid without resection of the humeral head
  - to correctly position the prosthetic head

Humeral head

the humeral head is not spherical:

anteroposterior < craniocaudal

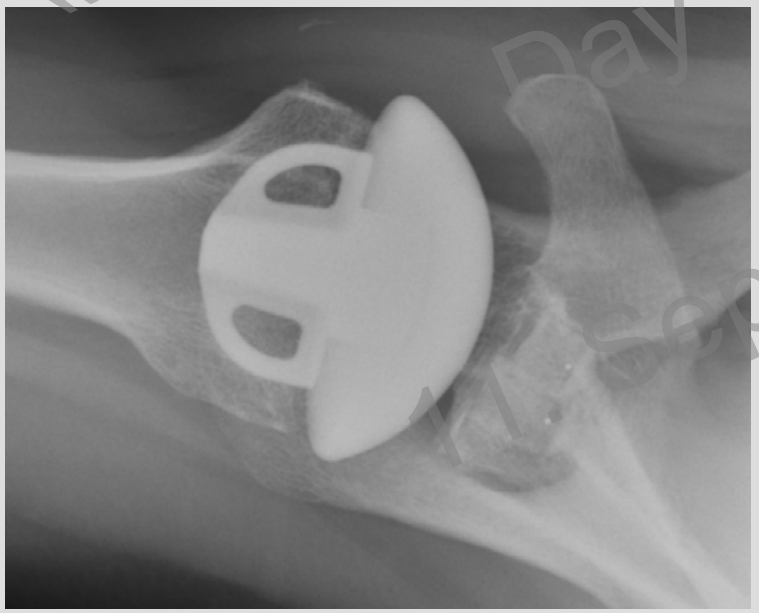




Humeral head

anterior or posterior prosthetic overhang

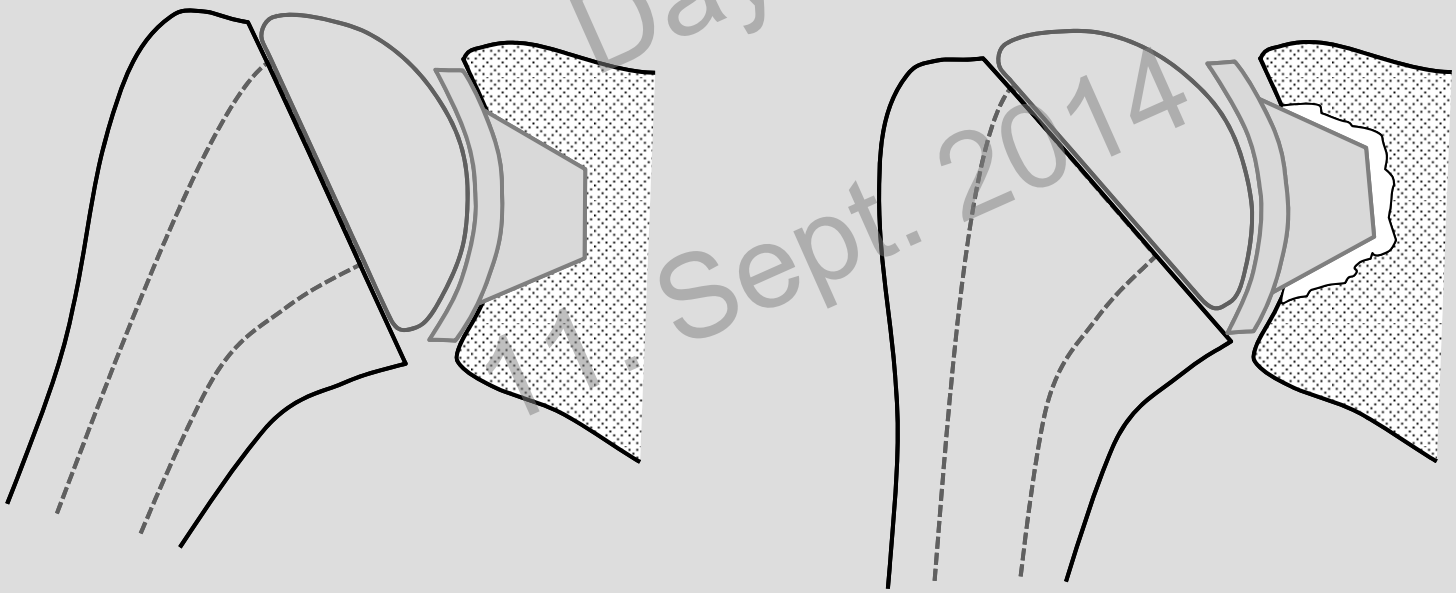
- potential lesion of the rotator cuff



Humeral head

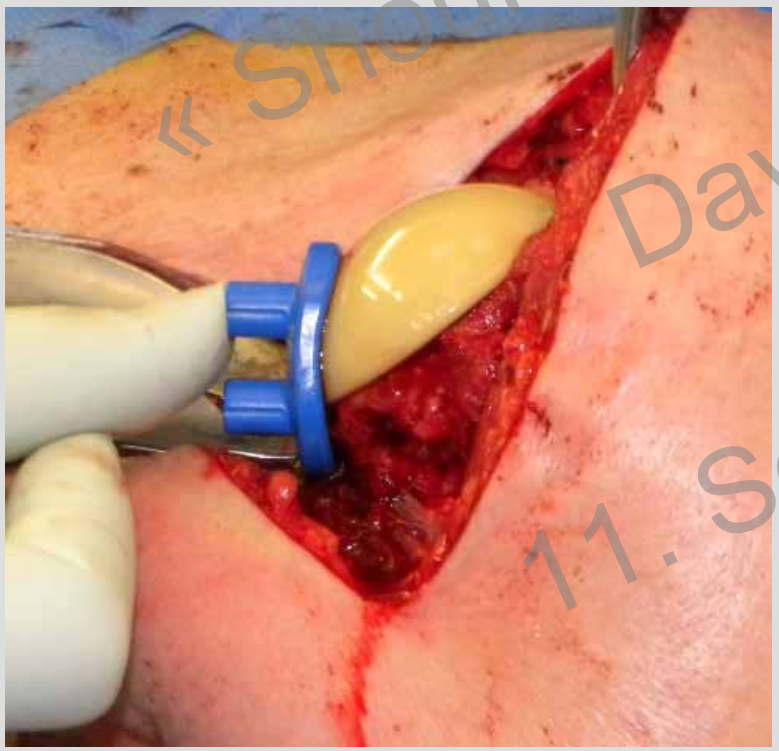
incomplete coverage of the anatomical neck

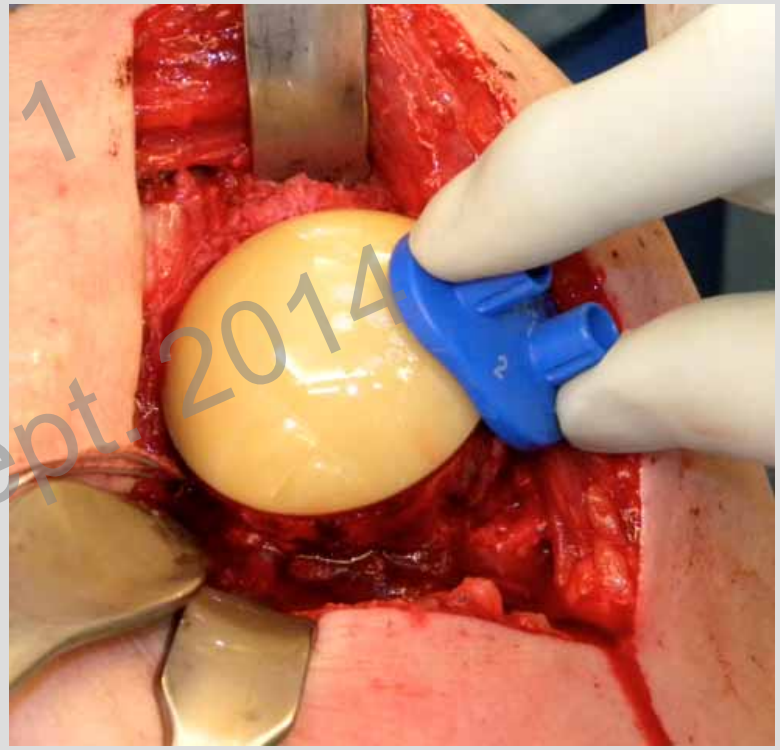
- inferior glenohumeral impingement and
- risk of aseptic loosening of the glenoid component



Glenohumeral impingement test

check that there is no bony overhang





Total shoulder replacement

Total shoulder replacement is better than hemiarthroplasty with respect to pain relief and ROM

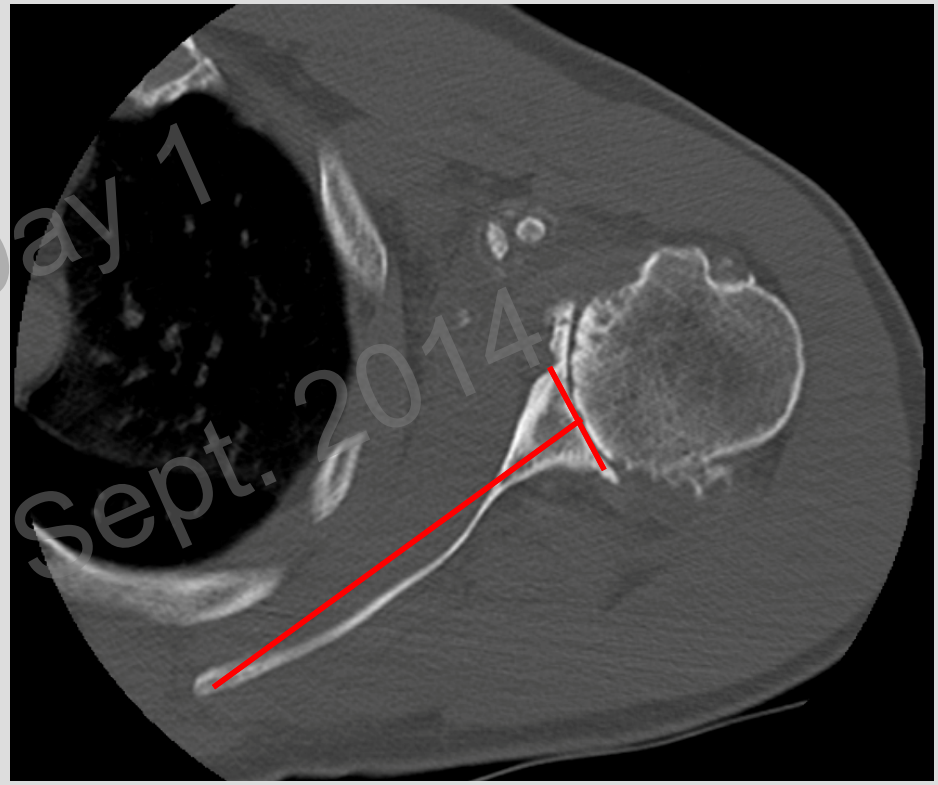
Total shoulder replacement

implantation of a glenoid component is

- technically demanding
- time consuming
- more expensive

Preoperative planing

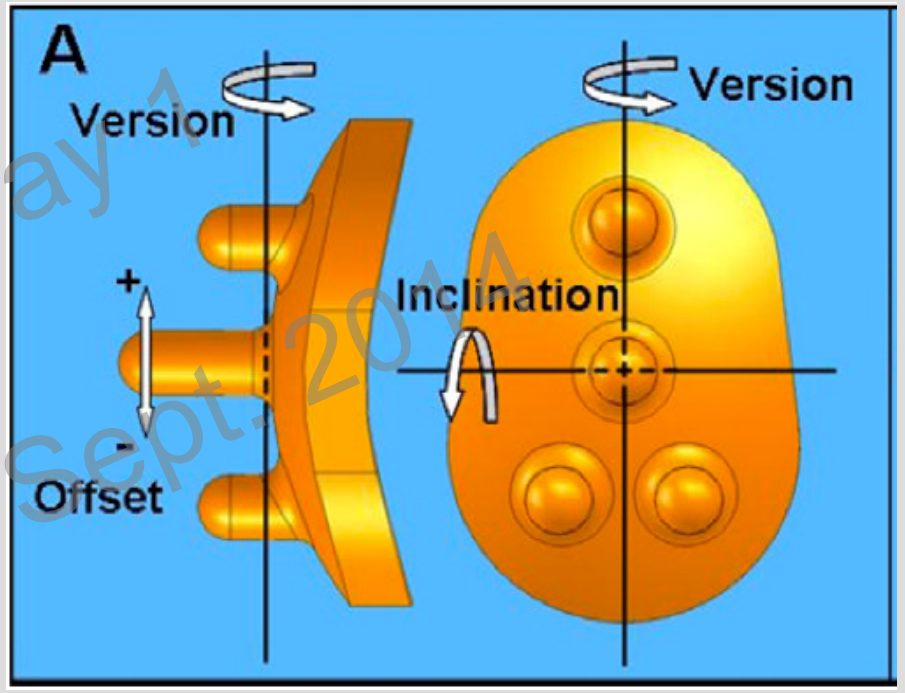
CT to assess:
bone stock and quality
cysts and osteophytes
glenoid version
muscle quality



Implantation technique

The surgeon must control the following parameters:

- anteroposterior position
- superoinferior position
- retroversion
- inclination



Favre et al. Clin Biomech 2008

Implantation technique

Malpositioning of the components may result in

- impingement
- eccentric loading
- cement fracture
- polyethylene wear
- aseptic component loosening

Implantation technique

Good exposure of the glenoid is crucial

Implantation technique

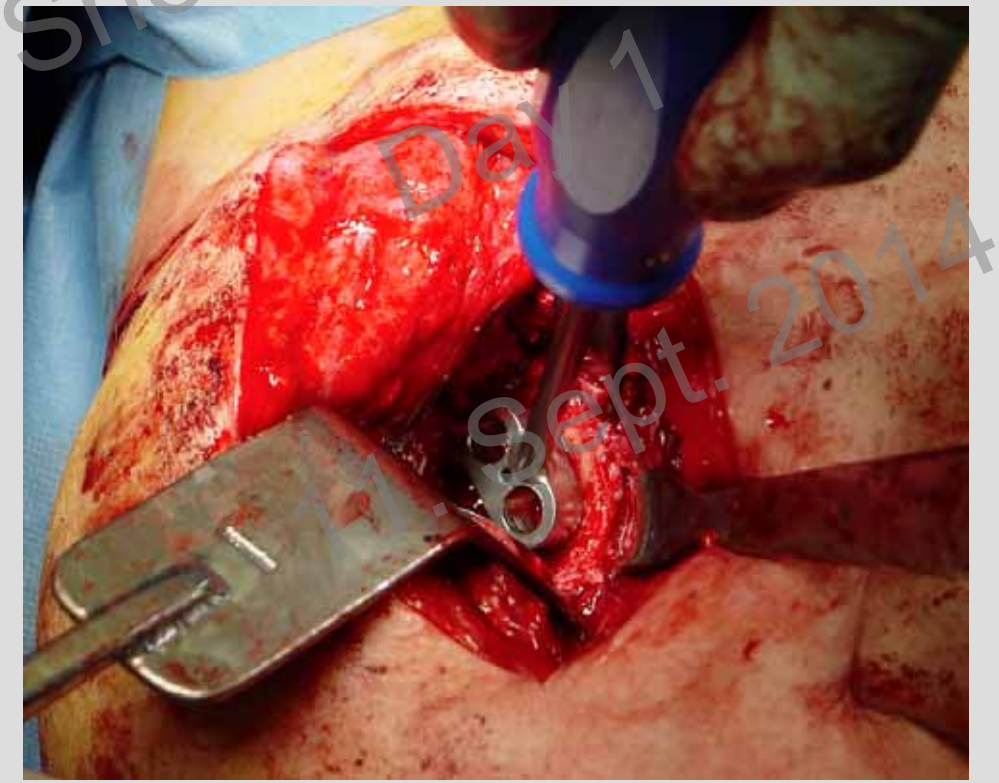
exposure of the glenoid and preparation of the bone are particularly difficult in:

- osteonecrosis with a medialized head
- arthritis with severe glenoid erosion
- humeral head resurfacing without resection of the head
- young muscular men

Positioning of the component

many aiming devices are smaller than the glenoid

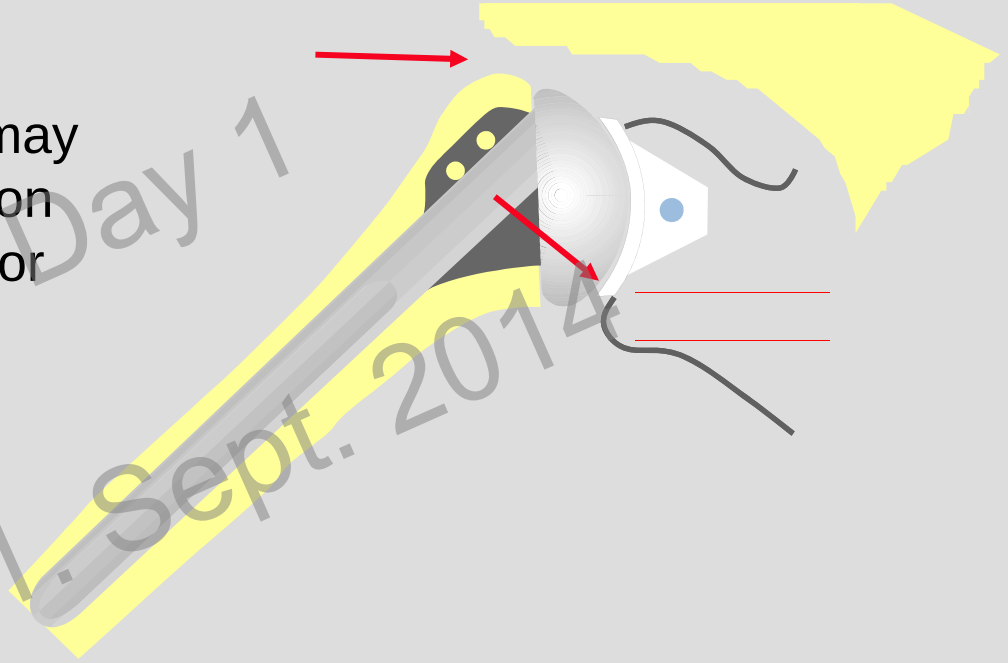
exact positioning and orientation may be difficult



Positioning of the component

component too high

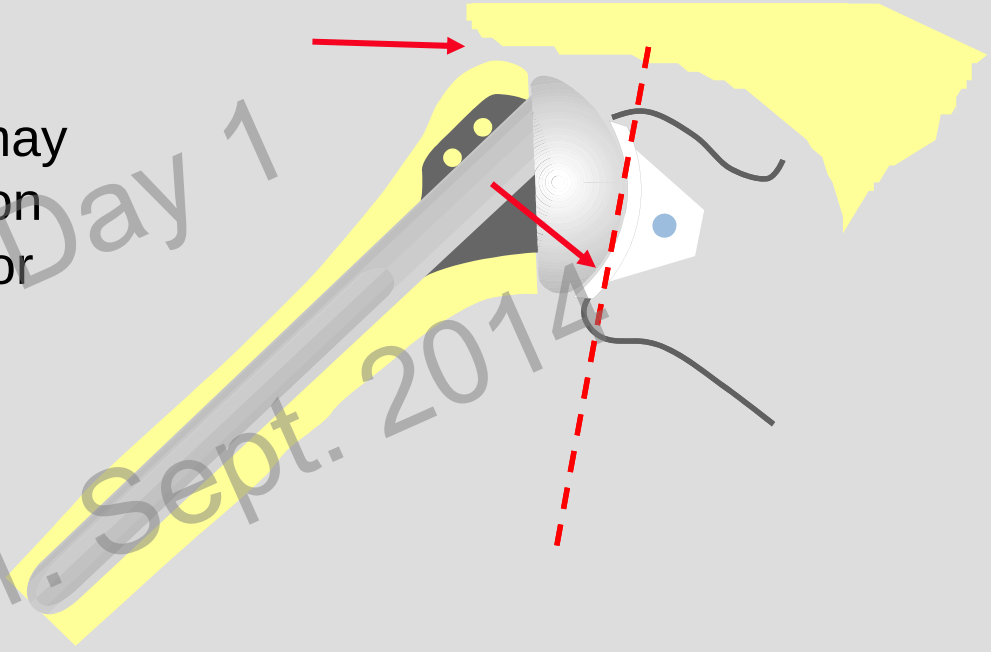
→ the greater tuberosity may impinge under the acromion and cause eccentric inferior loading of the glenoid component



Positioning of the component

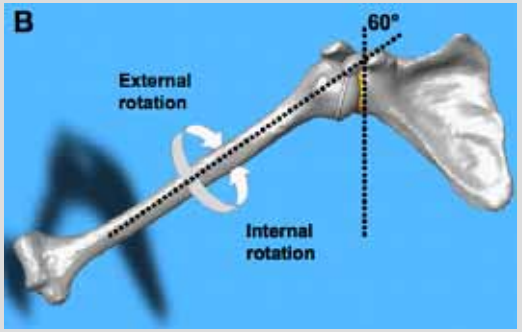
superior inclination

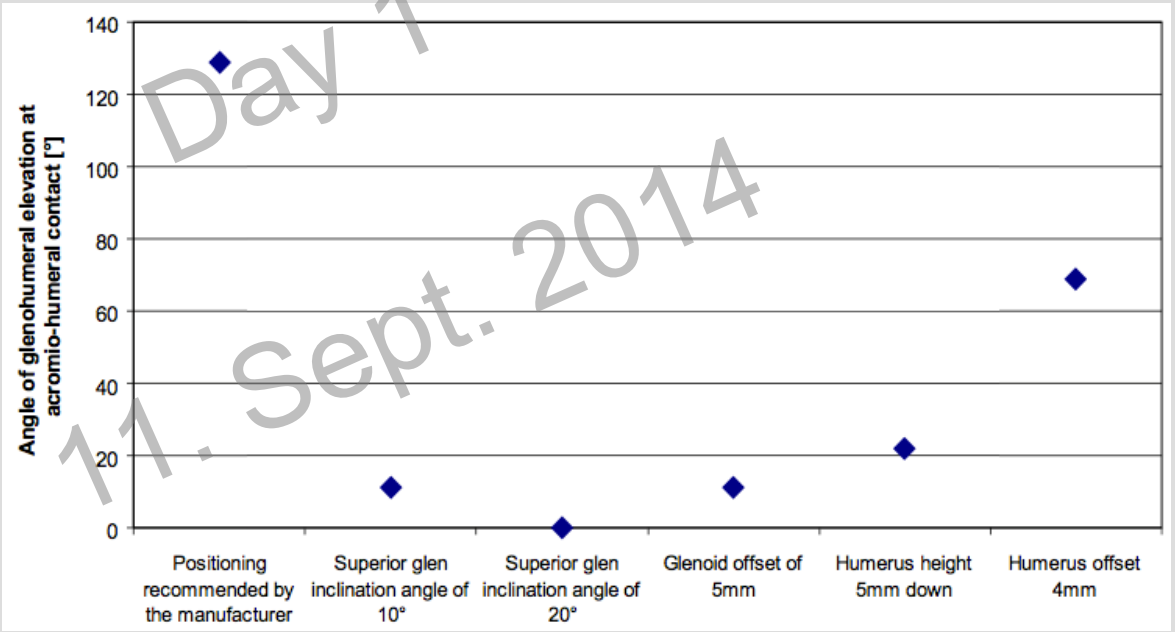
→ the greater tuberosity may impinge under the acromion and cause eccentric inferior loading of the glenoid component



Positioning of the component

a superior glenoid component inclination of 20 ° allowed no elevation at all, as acromiohumeral contact was detected even in the resting position

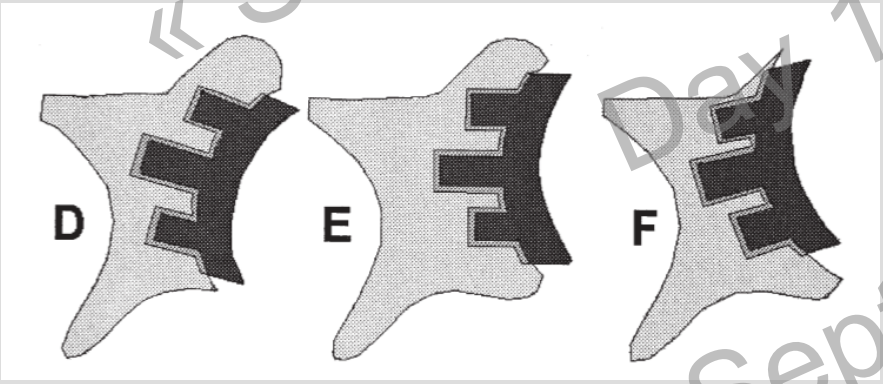




Favre et al. Clin Biomech 2008

Positioning of the component

superior or inferior inclination also increases the risk for mechanical failure of the cement mantle



Hopkins et al. JSES 2004

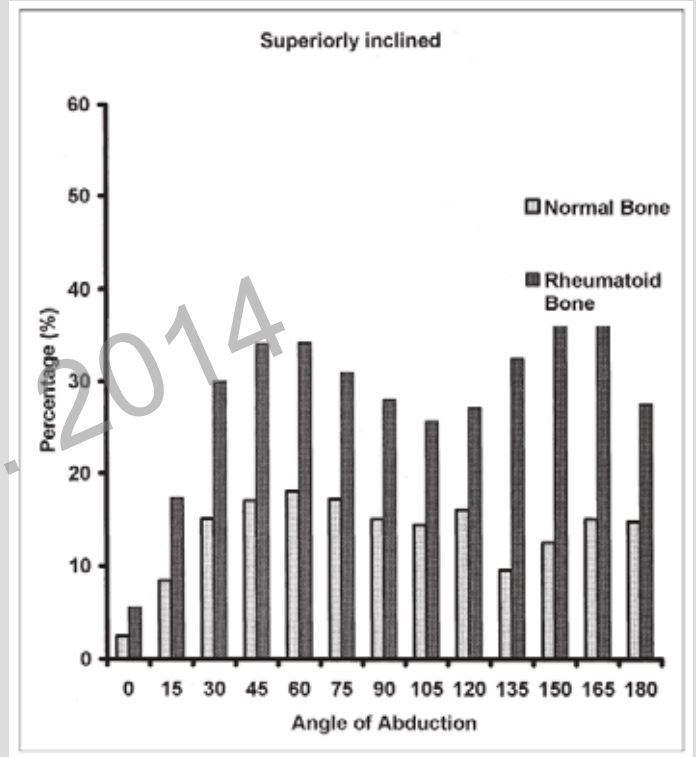
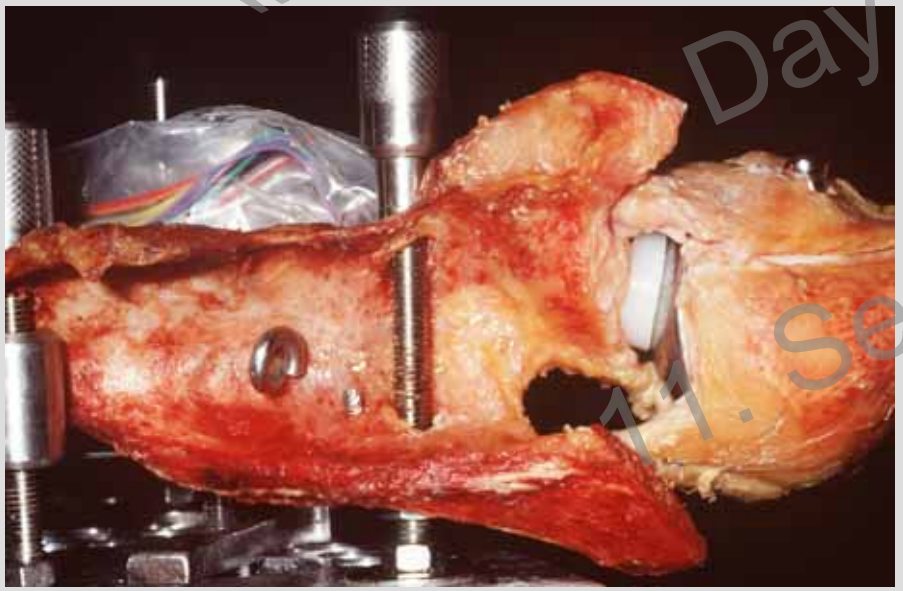
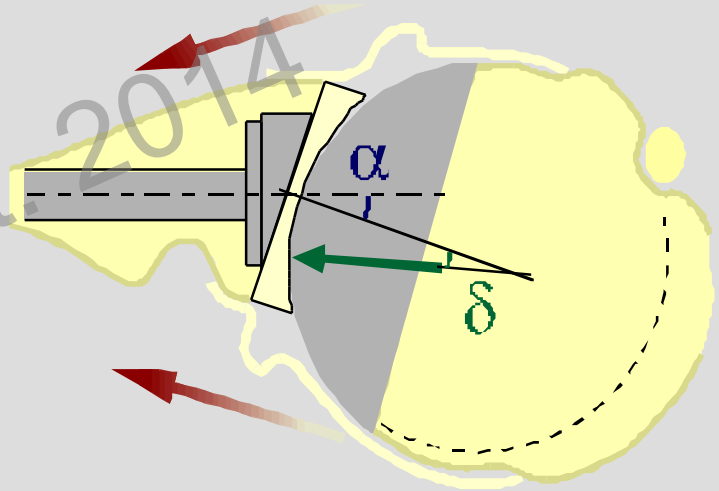


Figure 9 Percentage of cement mantle to have a greater than 95% probability of failure under cyclic loading: Superiorly inclined model.

Eccentric loading

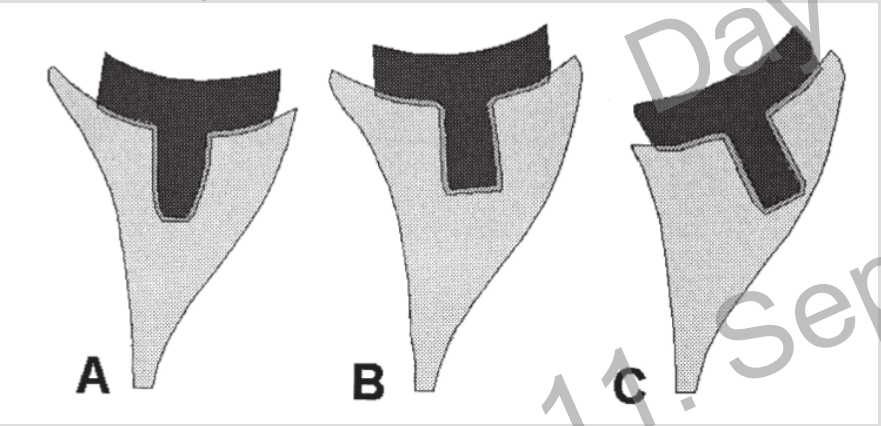
abnormal glenoid version results in eccentric loading





Eccentric loading

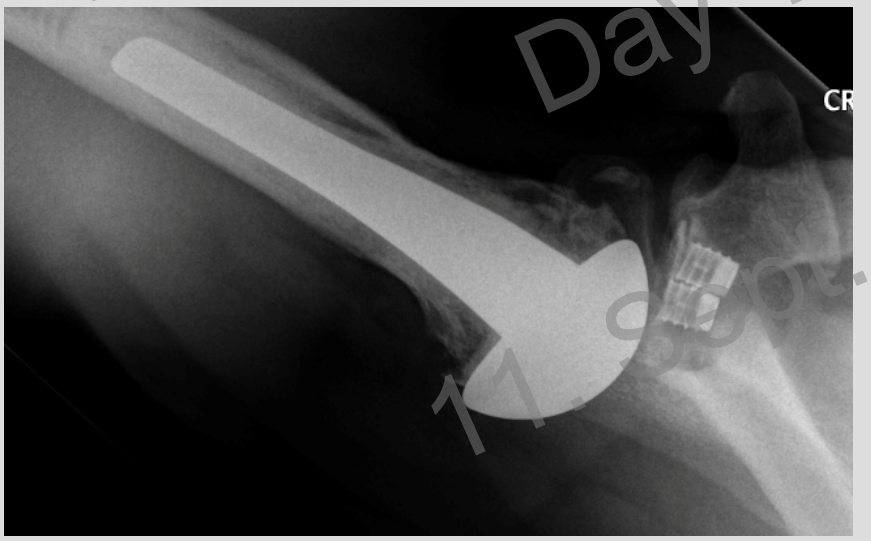
retroversion or anteversion increases the risk for mechanical failure of the cement mantle



Hopkins et al. JSES 2004

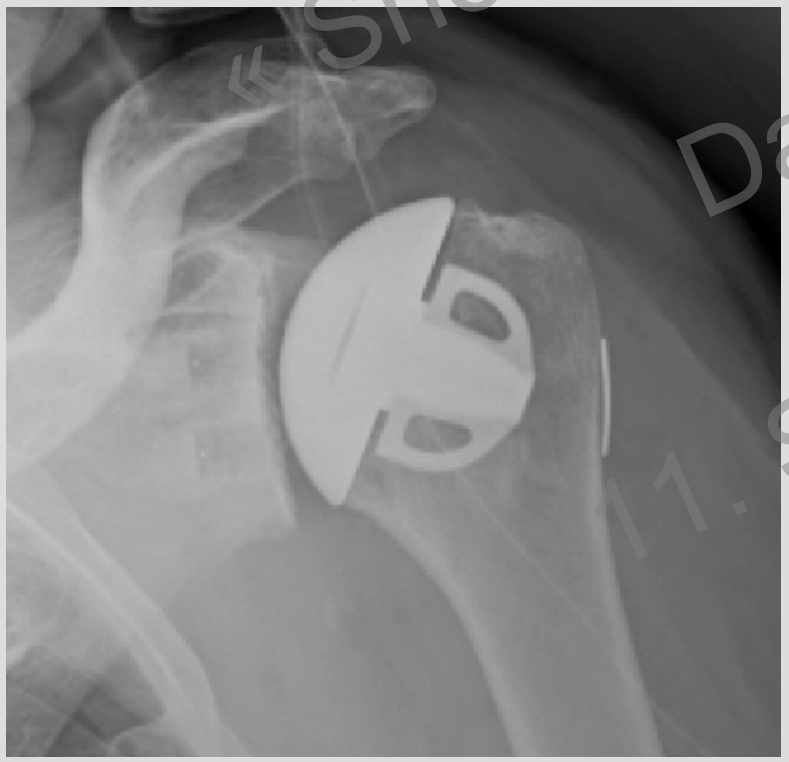
Eccentric loading

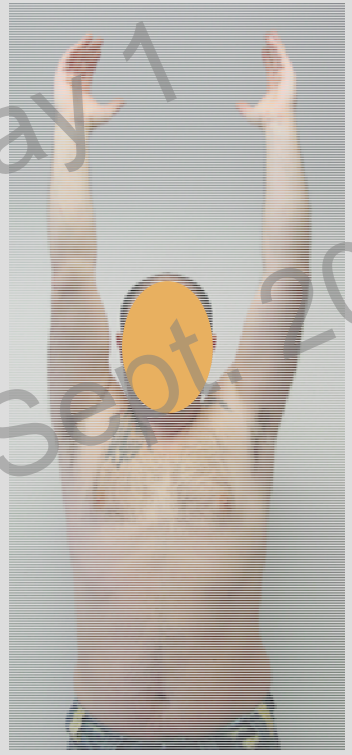
retroversion or anteversion increases the risk for instability and eccentric polyethylene wear



Results

good function can be expected if the center of rotation is restored and the rotator cuff preserved





Reverse prosthesis

for old patients with cuff tear arthropathy *(Grammont, 1987)*

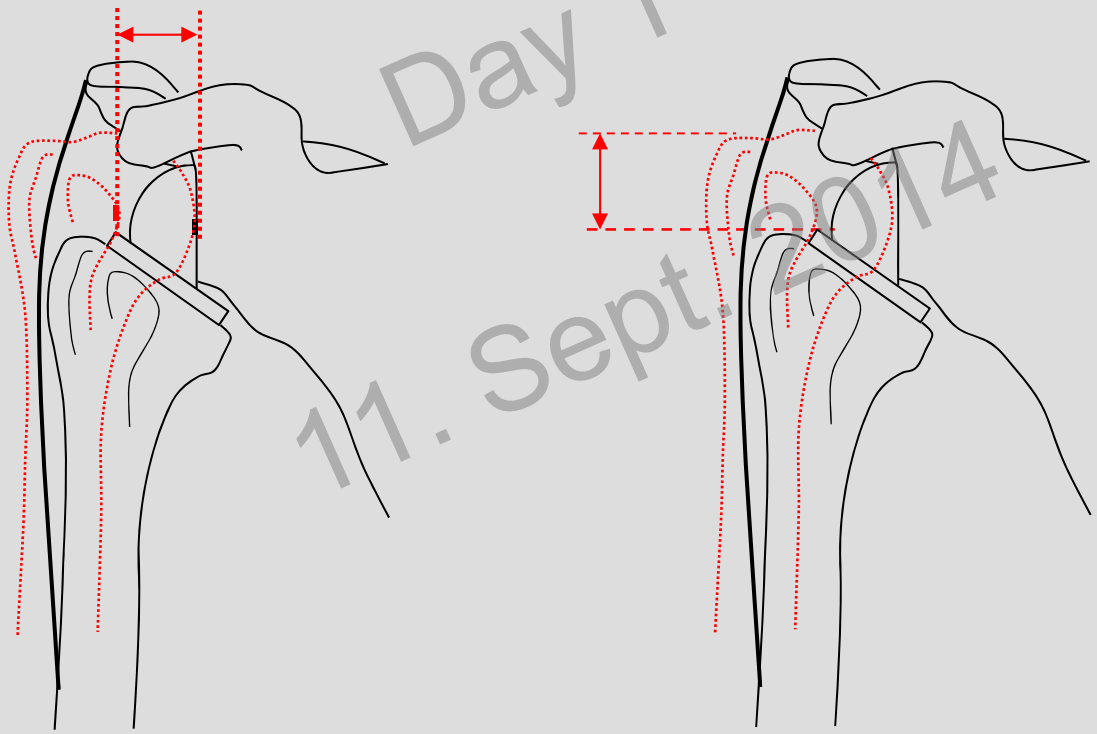
Other indications for RSA

2001	rheumatoid arthritis *(Rittmeister et al.)*
2001	revision surgery for failed hemi or TSA *(De Wilde et al.)*
2002	tumor surgery *(De Wilde et al.)*
2005	pseudoparesis without osteoarthritis *(Werner et al.)*
2005	*fracture sequelae* *(Boileau et al.)*
2005	acute fractures *(Cazeneuve et al.)*

Reverse shoulder arthroplasty

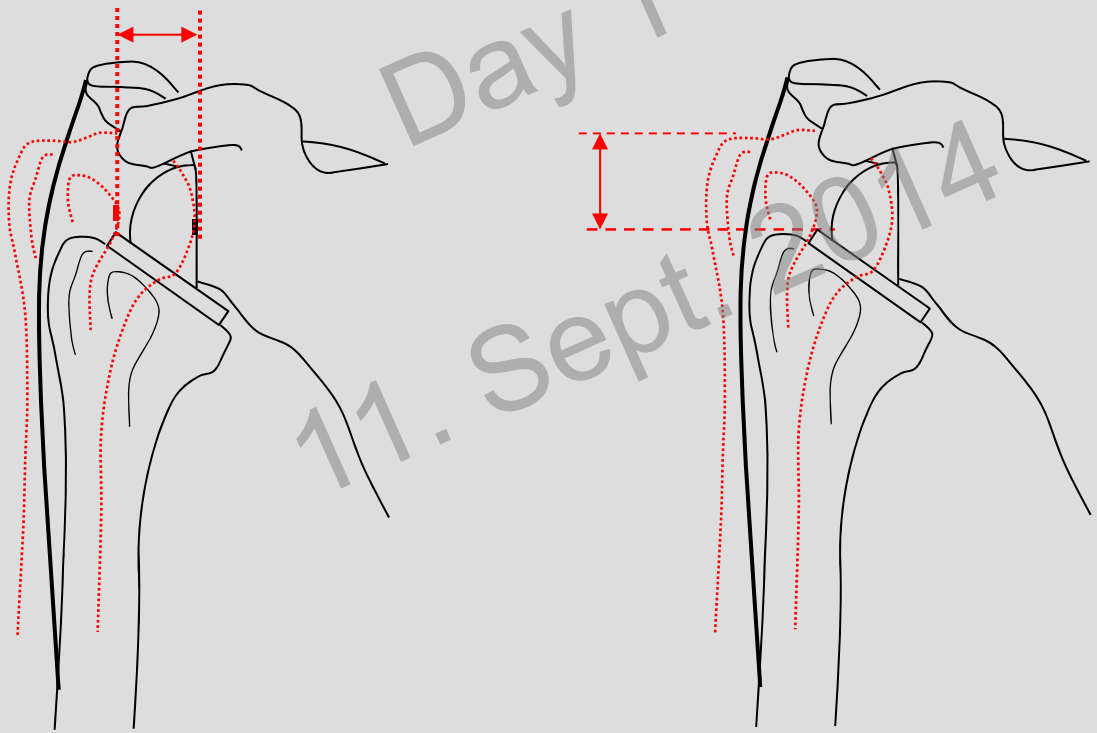
Medialization of the center of rotation

Distalization of the humerus



Reverse shoulder arthroplasty

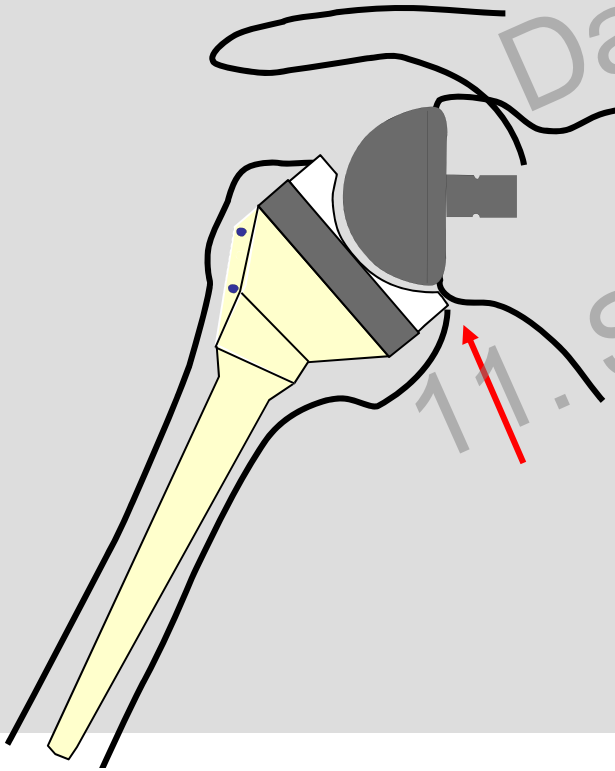
has implications on:
- range of motion
- lever arms and forces
- stability of the joint



Range of motion

glenohumeral motion is limited by a contact between:

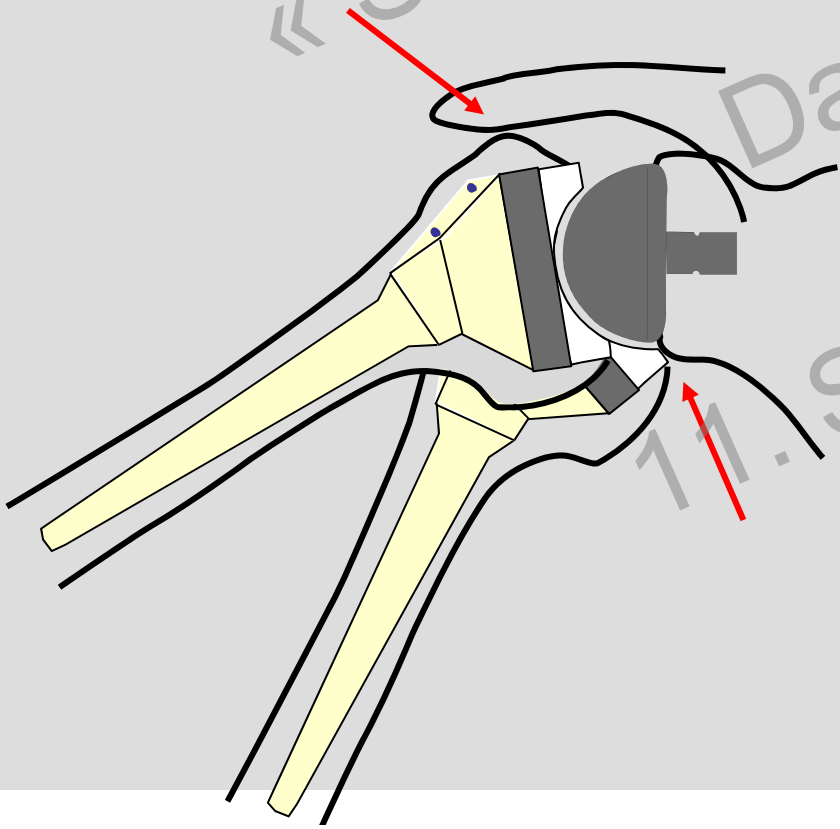
the polyethylene cup and the glenoid neck in adduction



Range of motion

glenohumeral motion is limited by a contact between:

- the polyethylene cup and the glenoid neck in adduction
- the greater tuberosity and the acromion in abduction



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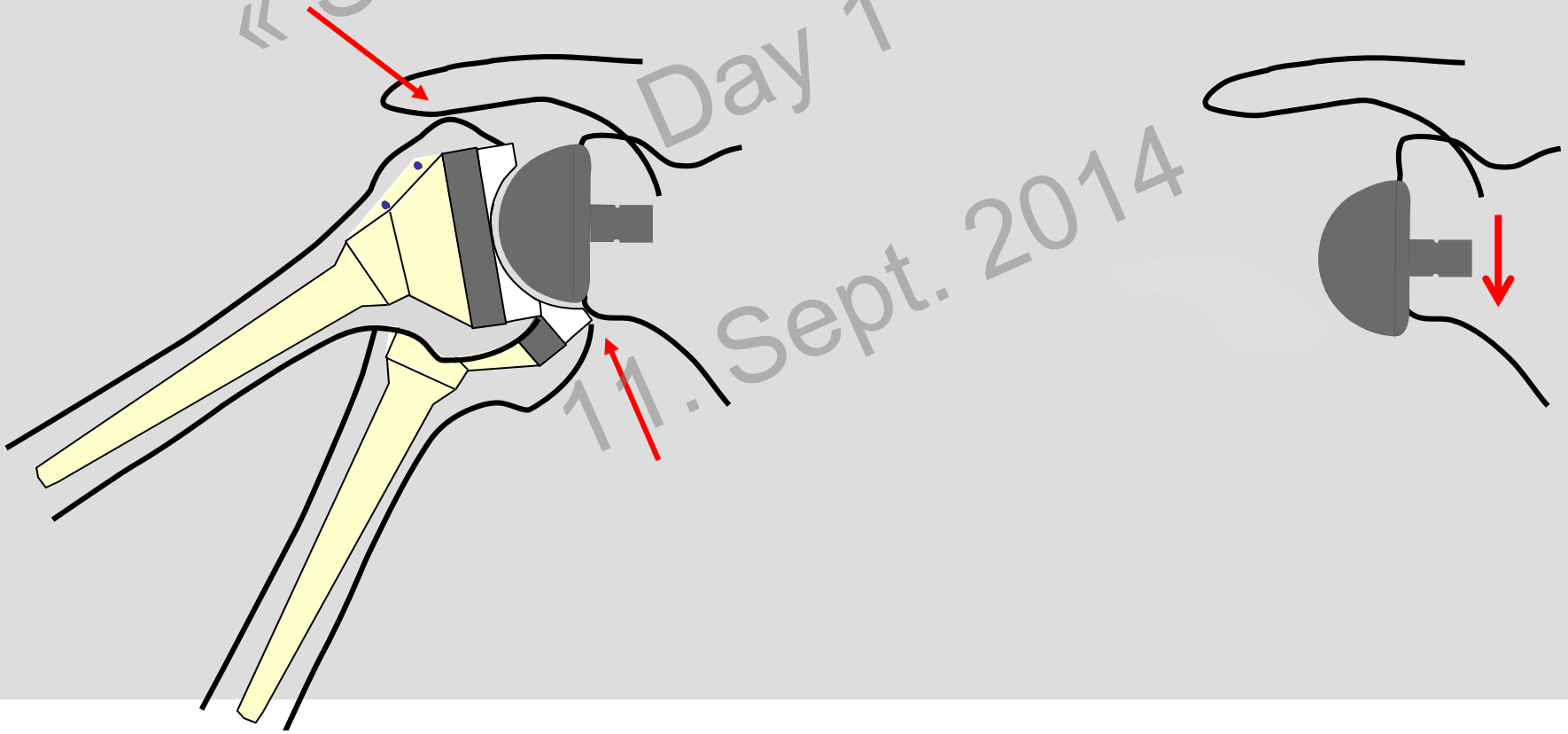

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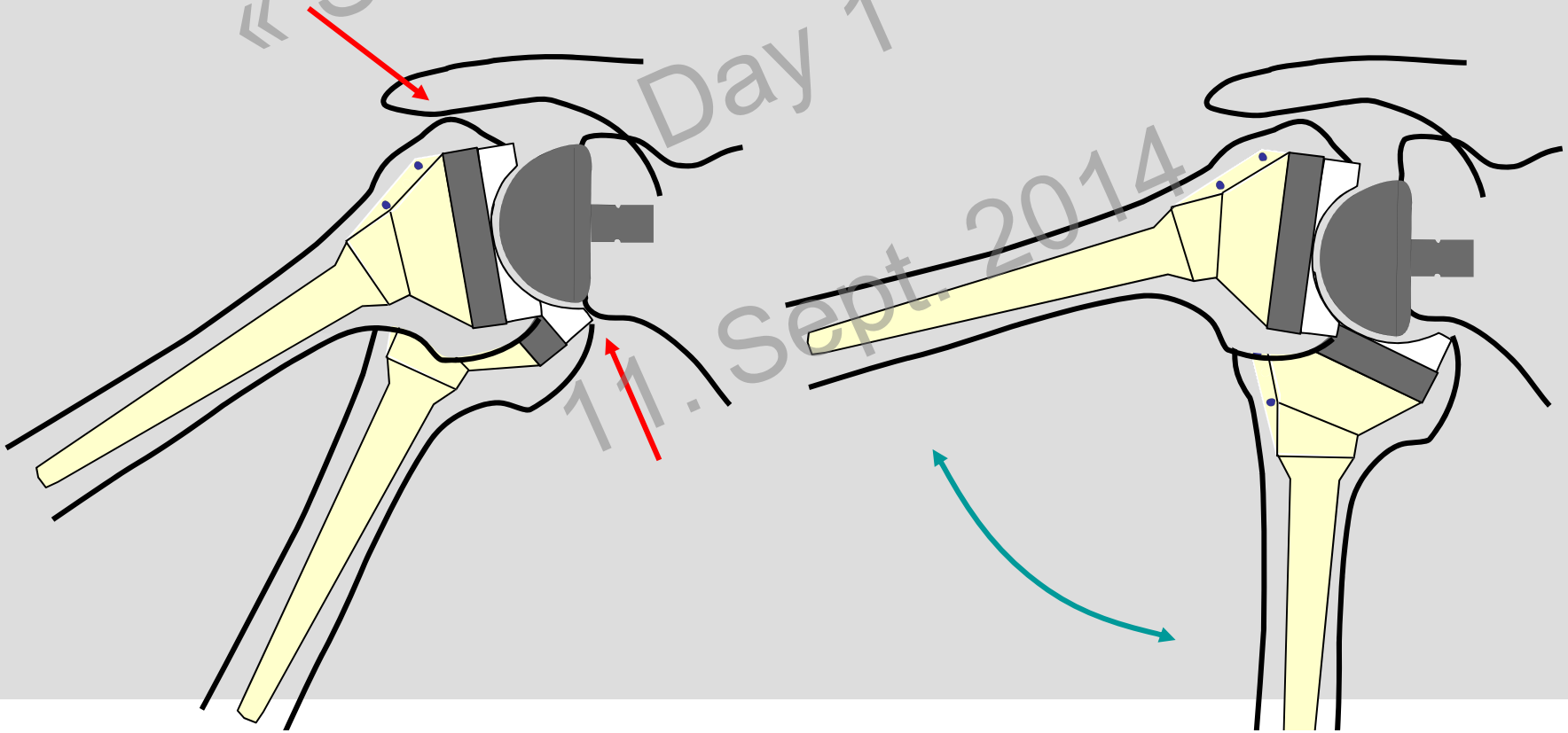
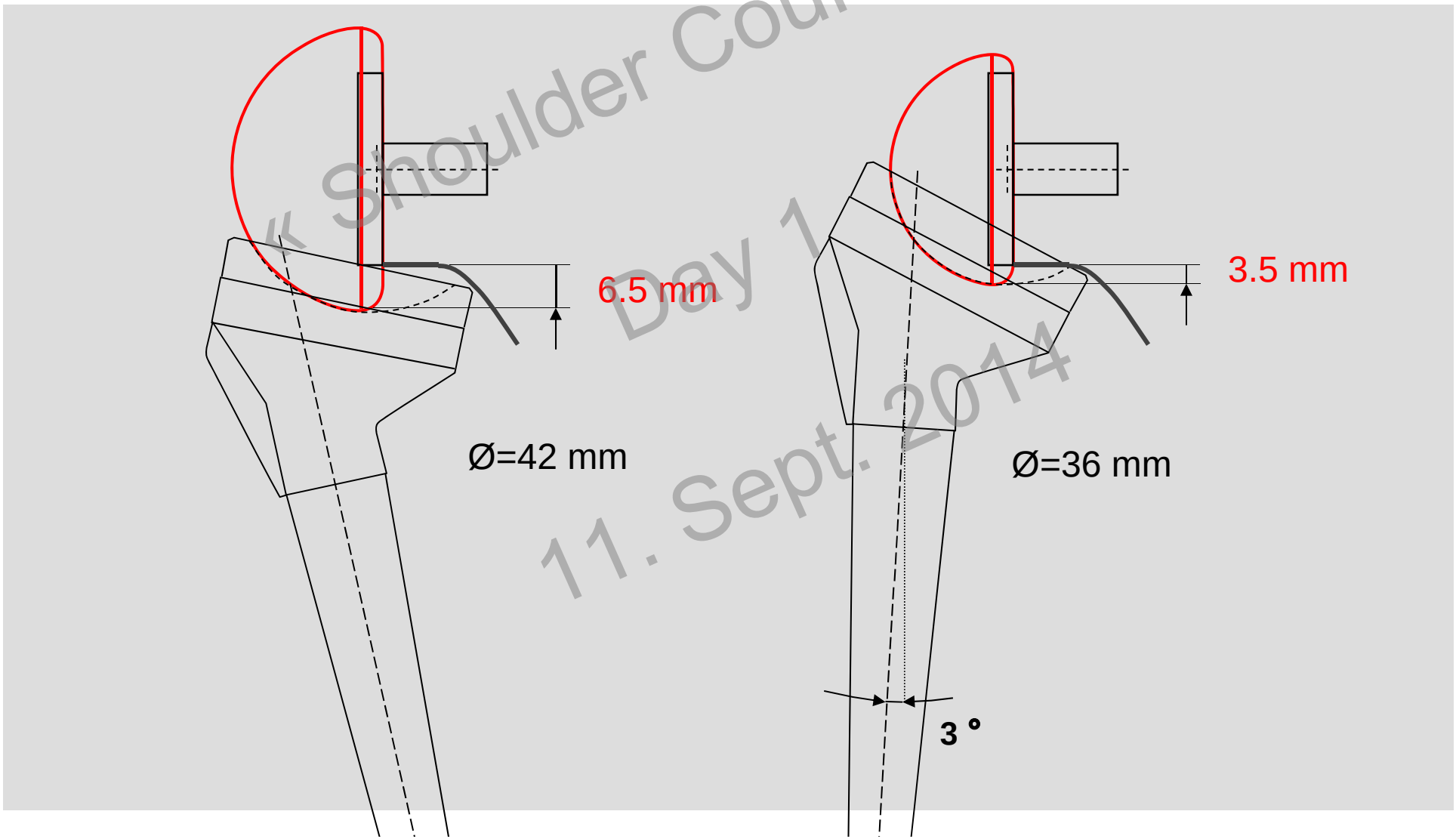
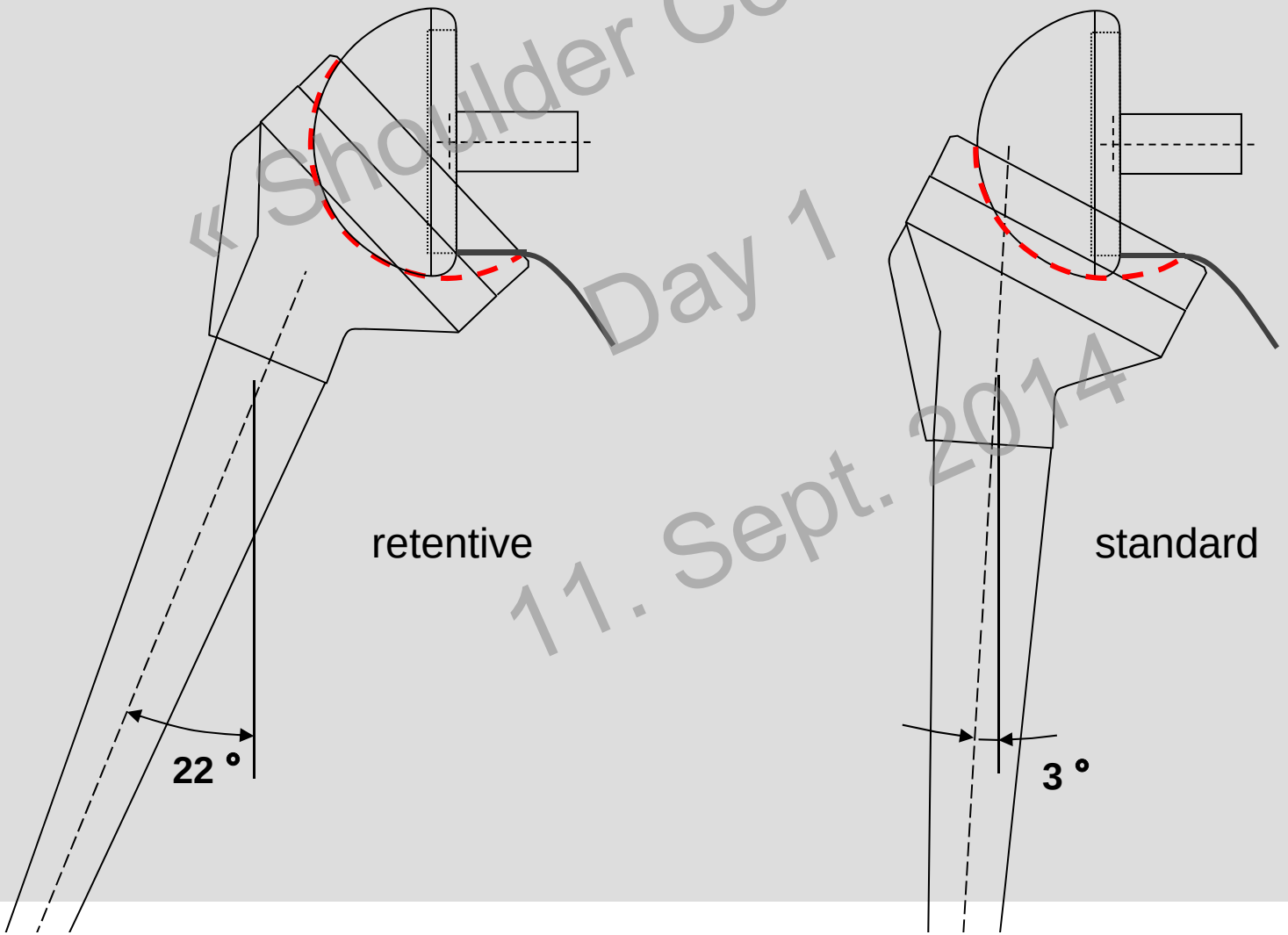


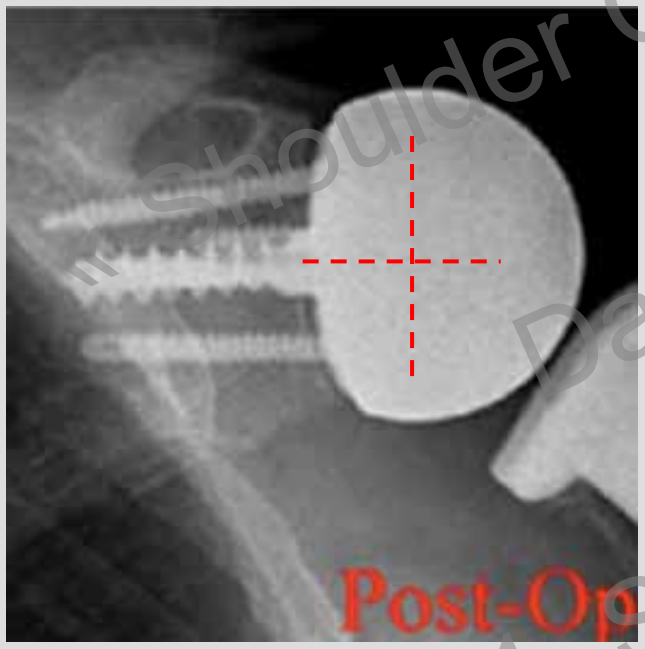
Larger and eccentric glenospheres

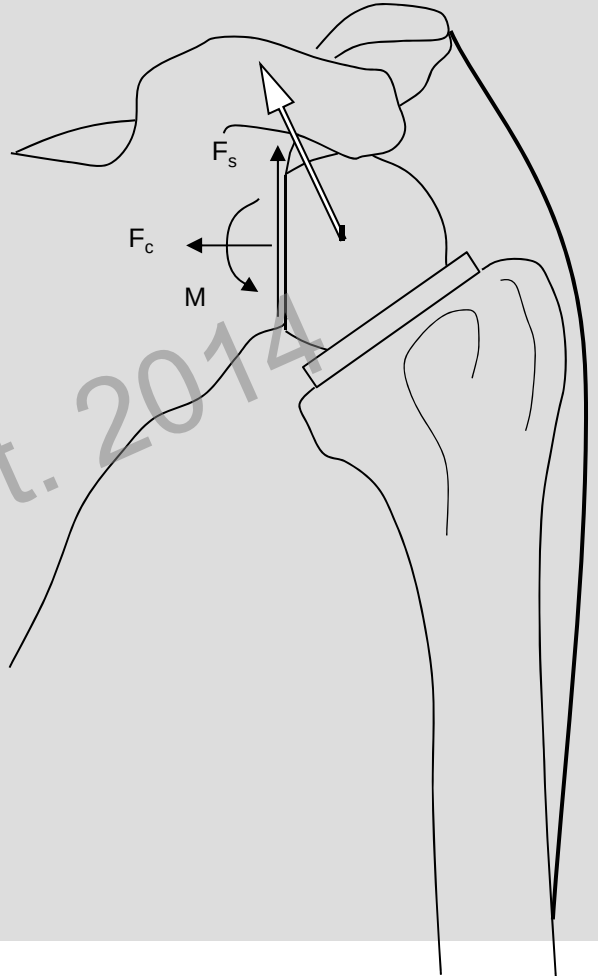


Depth of the cup



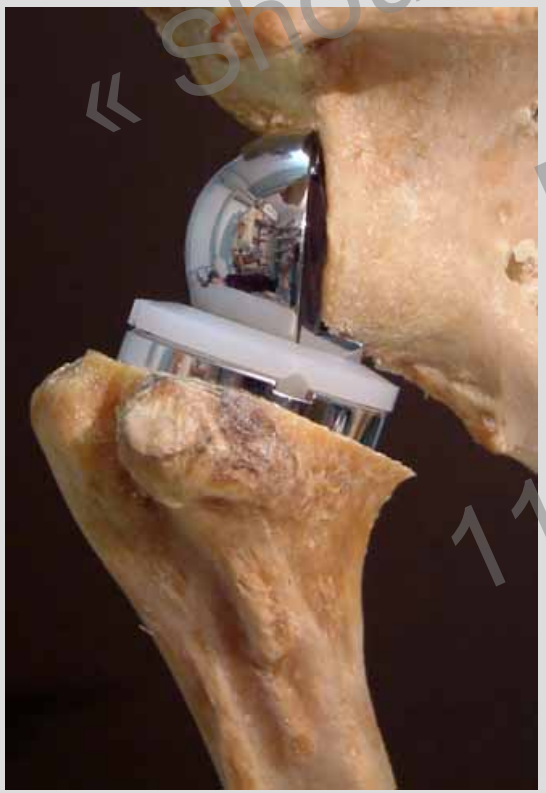
Lateralisation of the center of rotation





Lower neck-shaft angle

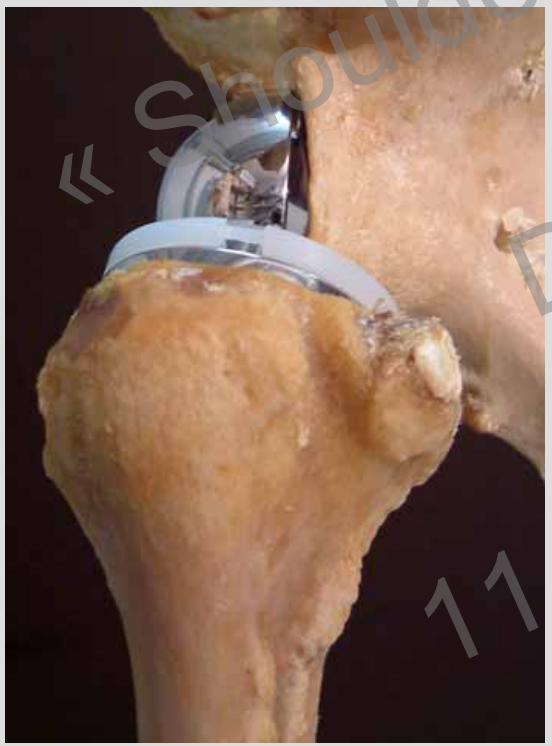
Duocentric 36mm



neck-shaft angle 145 °

Internal and external rotation

Duocentric



IR

ER

Internal and external rotation

Delta III geometry

IR

ER

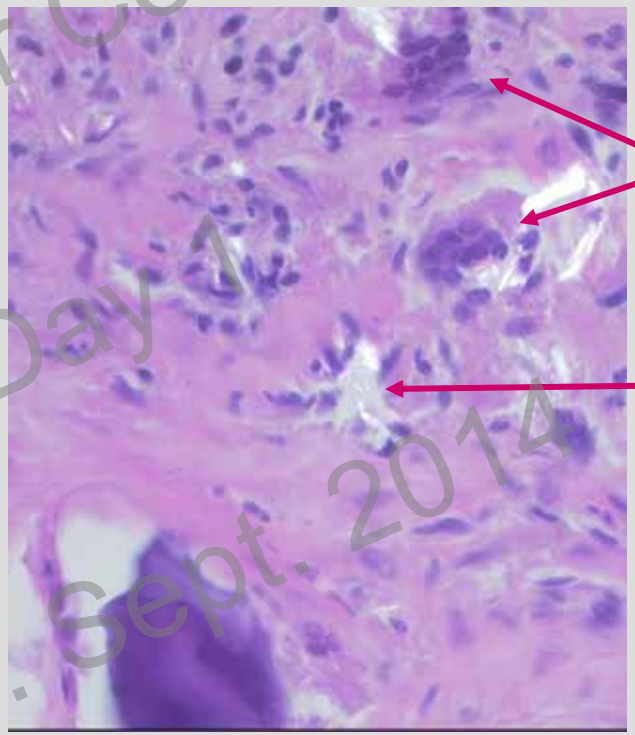
scapular notch

Scapular notching

- mechanical conflict between PE-cup and scapular neck

Consequences of notching

PE wear



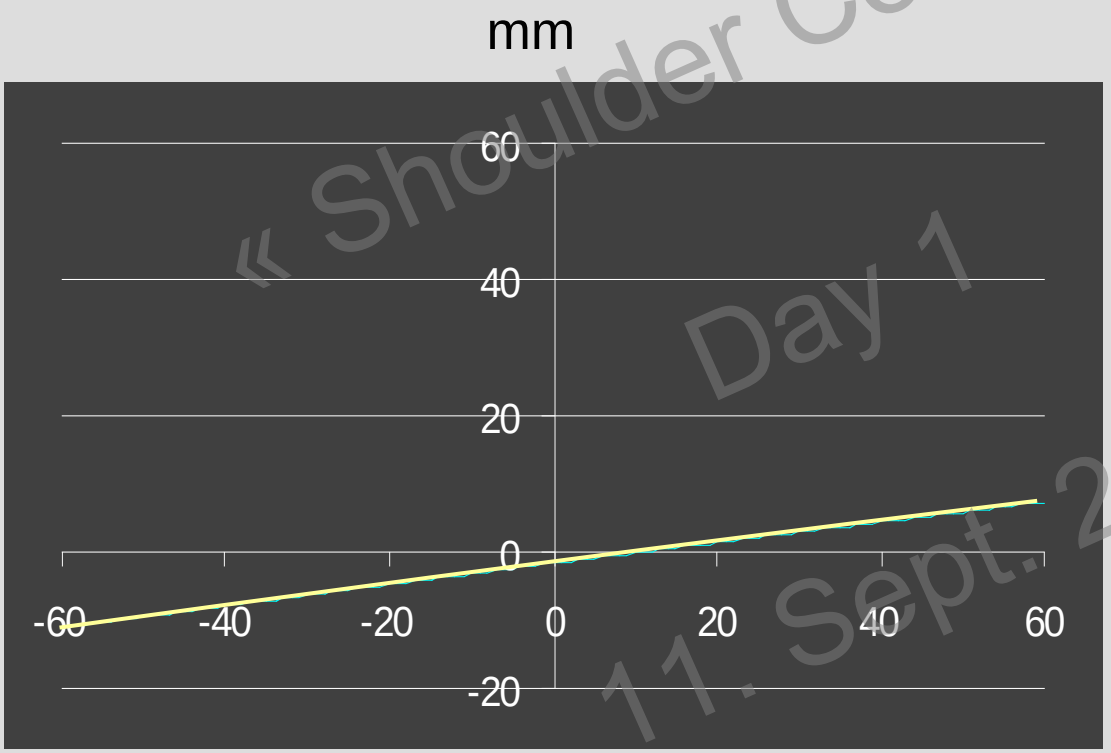
chronic inflammation

Nyffeler et al., JBJS-B, 2004

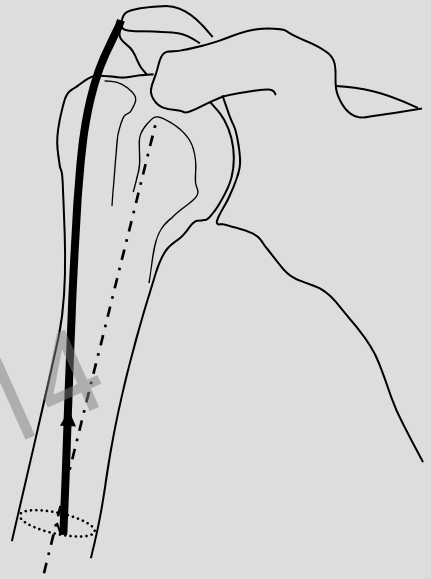
External rotation weakness

ER lag despite a good passive range of motion

Lever arm length for external rotation

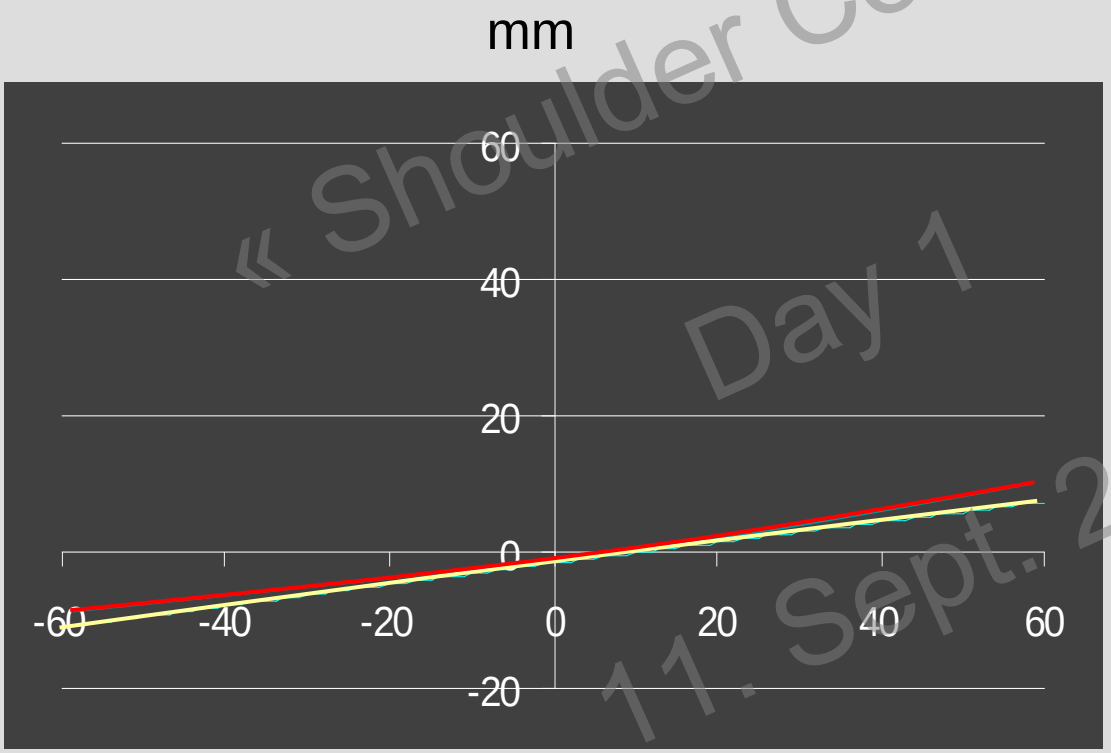


ER rotation angle (degrees)



middle deltoid

Lever arm length for external rotation



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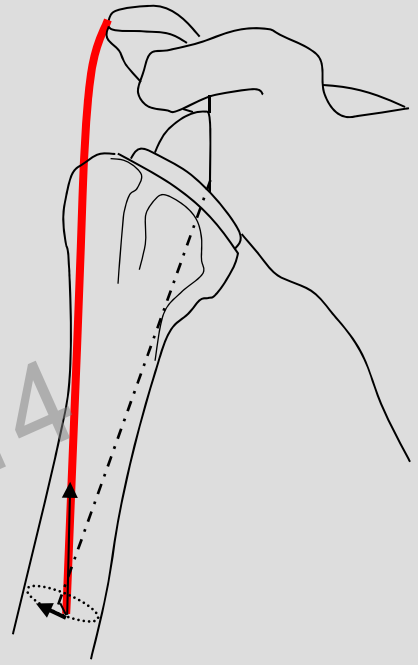

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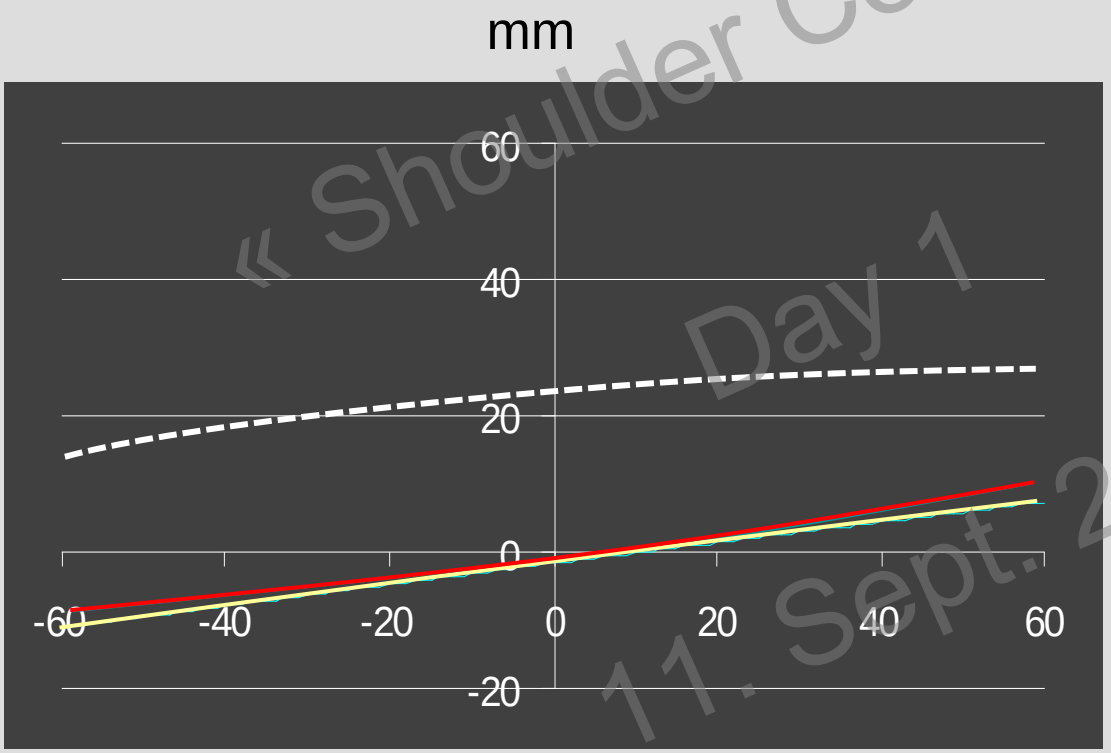
Lever arm length for external rotation



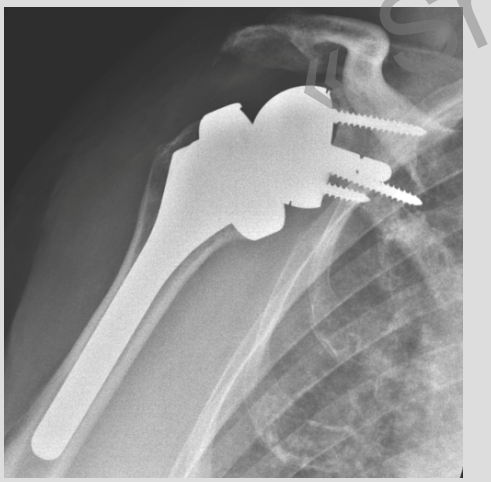
ER rotation angle (degrees)

teres minor

middle deltoid

RSA with Latissimus dorsi transfer

RSA with Latissimus dorsi transfer



Lat dorsi + Teres major
Transfer

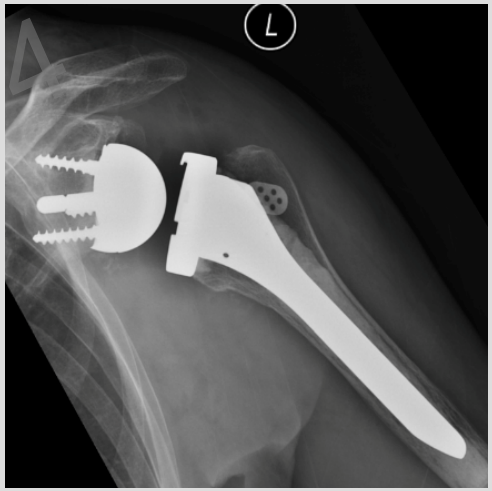
RSA with Latissimus dorsi transfer

cave!

the subscapularis tendon should be repaired after a latissimus dorsi / teres major transfer, otherwise internal rotation is poor

Bilateral reverse prosthesis

is possible and gives good results with new generation RSA



74y old female with reversed prostheses in both shoulders

Conclusions

Anatomical prostheses:

Restoration of the anatomical center of rotation, correct glenoid component orientation and stable fixation as well as a good rotator cuff are mandatory for a good function and a good long term result

Conclusions

Reverse shoulder prostheses:

Inferior positioning of the glenosphere with sufficient overhang decreases the risk of notching and polyethylene wear and increases the range of motion

An additional latissimus dorsi transfer improves external rotation strength if the teres minor is weak

Difficult cases should be addressed to high volume surgeons