

Consolidation des fractures:

Biomécanique osseuse



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Extraits de nos compte-rendus...

- *Contrôle d'évolution d'une fracture ...*
- *Aspect sans particularité du matériel d'ostéosynthèse...*
- *Consolidation en cours...*
- *Pas de modification par rapport a l'examen précédent...*

Objectifs

- A. Interruption corticale (fracture)
- B. Reconstruction corticale (consolidation osseuse)
- C. Le soutien à la reconstruction (θ chirurgical)
- D. Complications des fractures

Hors propos

- X Liste exhaustive des matériels de fixation
- X Complications liées au matériel utilisé
- X Fractures rachidiennes

Extraits de nos compte-rendus...

- *Contrôle d'évolution d'une fracture ...*
- *Aspect sans particularité du matériel d'ostéosynthèse...*
- *Consolidation en cours...*
- *Pas de modification par rapport a l'examen précédent...*



Mon ambition

Que votre quotidien

ne soit plus jamais comme avant...



Objectifs

A. Interruption corticale (fracture)

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C. Le soutien à la reconstruction (θ chirurgical)

D. Complications des fractures

Biomécanique des fractures



Interruption corticale : apparition inattendue d'un espace de mobilité

A. Biomécanique des fractures

Poids du
corps

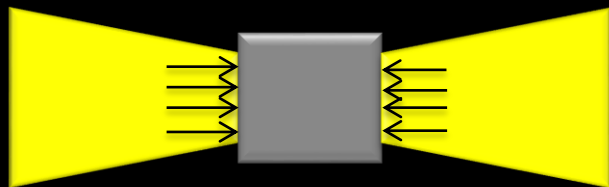
Mouvements
articulaires

Activités
musculaires

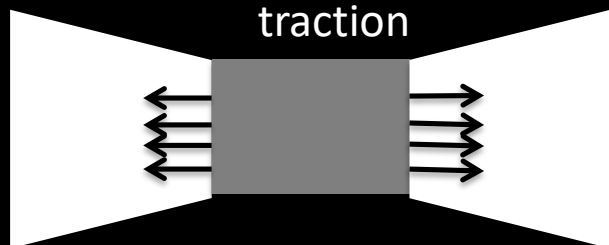


Types de contraintes biomécaniques - direction

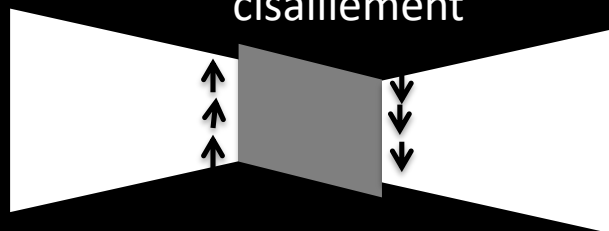
compression



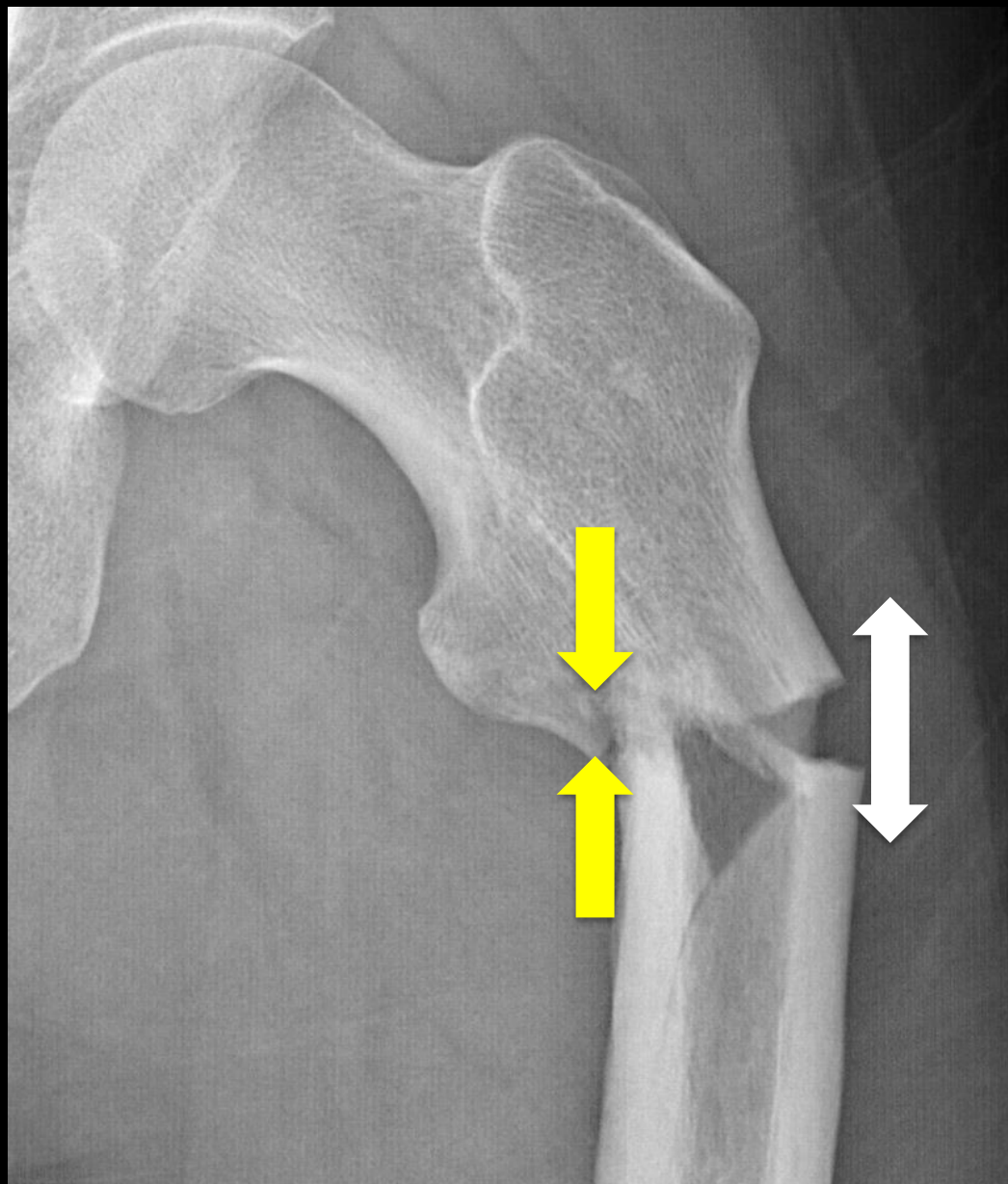
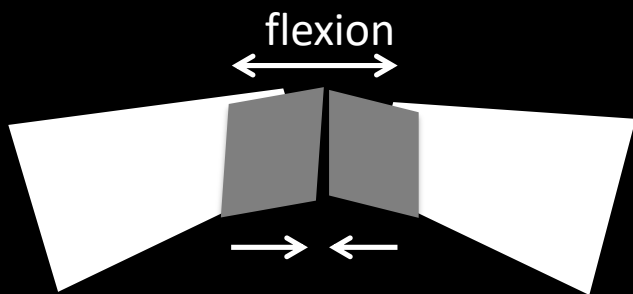
traction



cisaillement



flexion



Objectifs

- A. Interruption corticale (fracture)
- B. **Reconstruction corticale** (consolidation osseuse)
- C. Le soutien à la reconstruction (θ chirurgical)
- D. Complications des fractures

B. Consolidation des fractures

1. Phase inflammatoire (J0-J15)
 - Hémorragie
 - Angiogénèse et tissu fibreux
2. Phase fibreuse (J10-J20)
 - cal fibreux



Tibia J14

B. Consolidation des fractures

3. Cal osseux primaire (J20-J60)
os immature (os tissé / woven bone)
pas d'ostéone , moins compact



Tibia J60

B. Consolidation des fractures

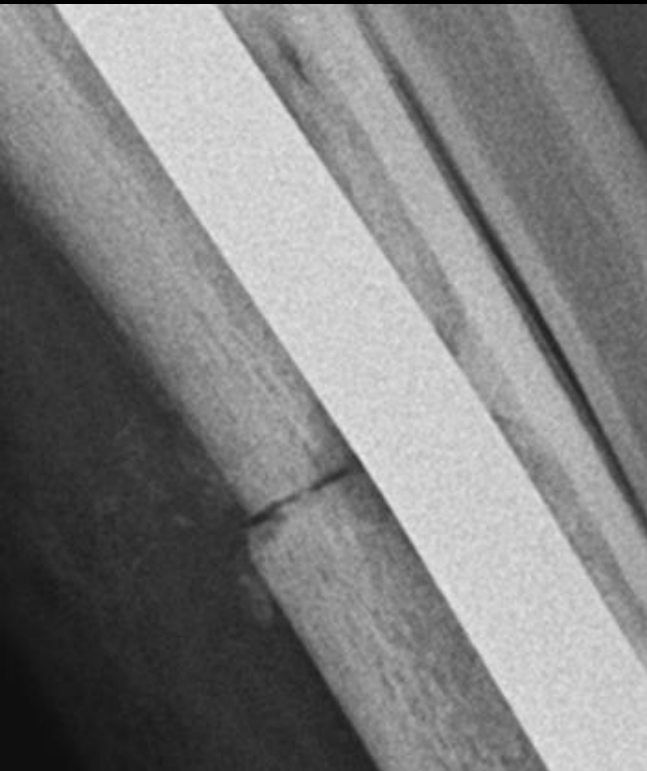
- 4. Cal osseux secondaire
os cortical mature
ostéones



Concept de remodelage osseux

Tibia J270

Ostéo-formation intriquée à ostéo-résorption.
Stabilisation de la fracture (enclouage) favorise consolidation.



J14
Cal fibreux



J60
Os tissé

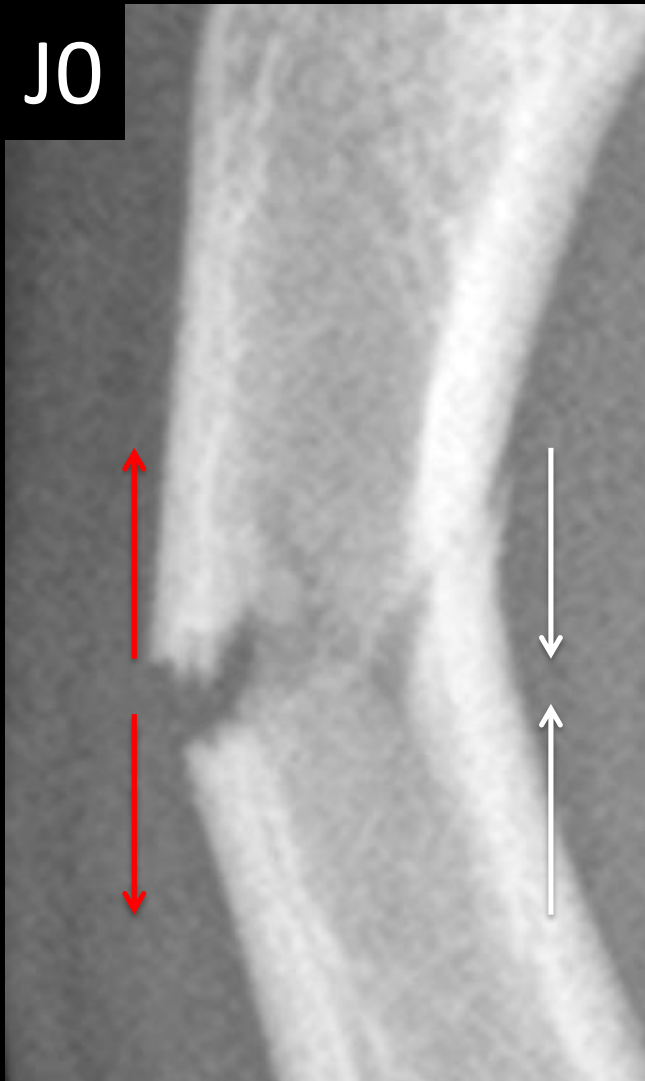


J270
Os cortical

Orientation des contraintes

Compression (favorable) $\gg$ traction, cisaillement, rotation (defavorables)

J0



J30

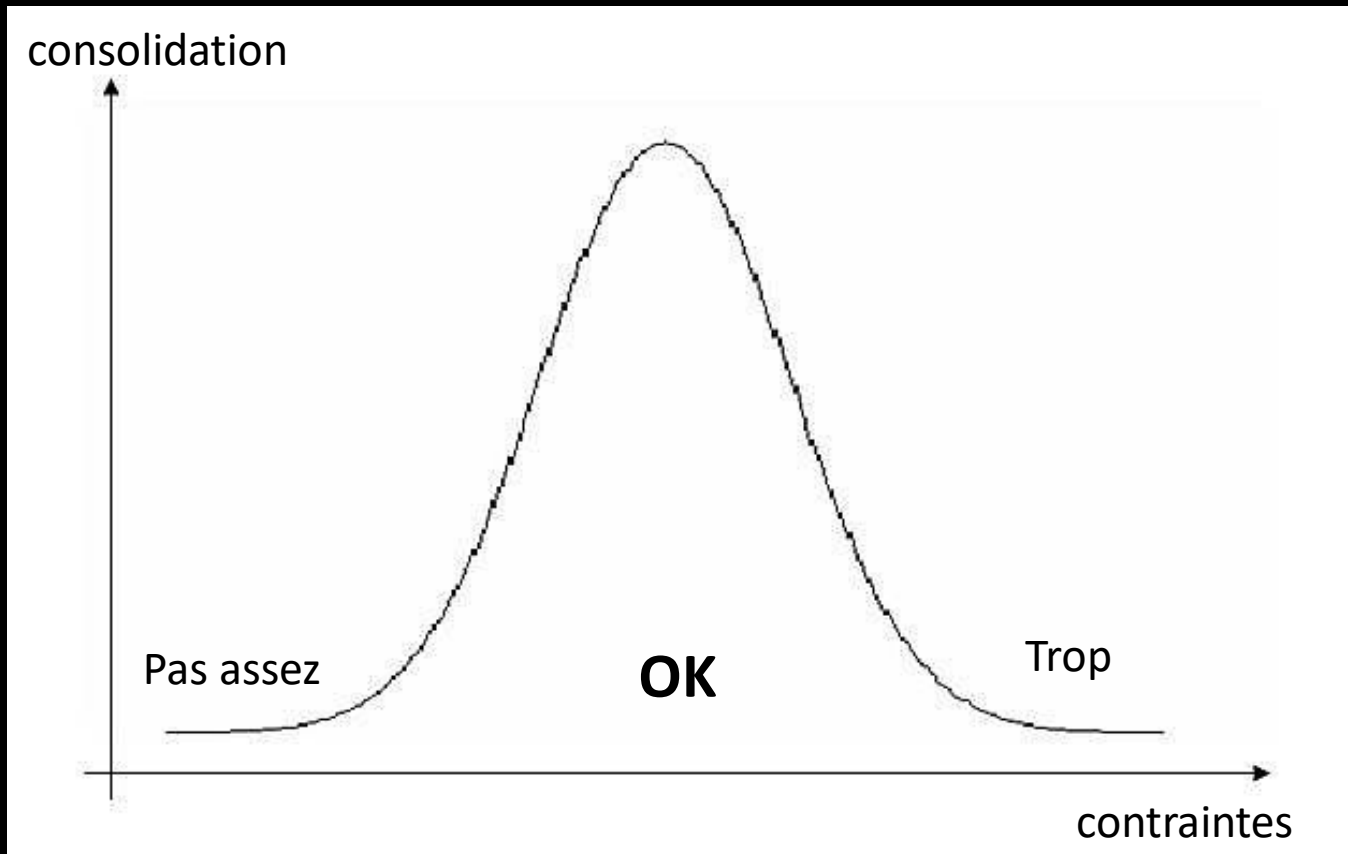


J60



Importance des contraintes

Trop peu (défavorable) > < assez (favorable) > < trop (défavorable)



Exercices



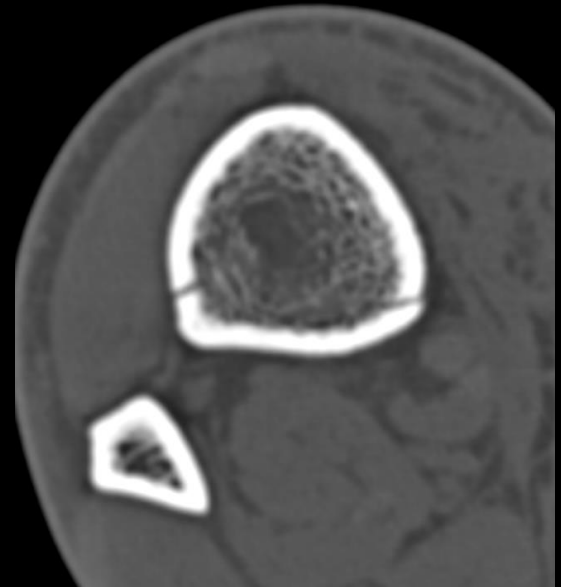
Exercices



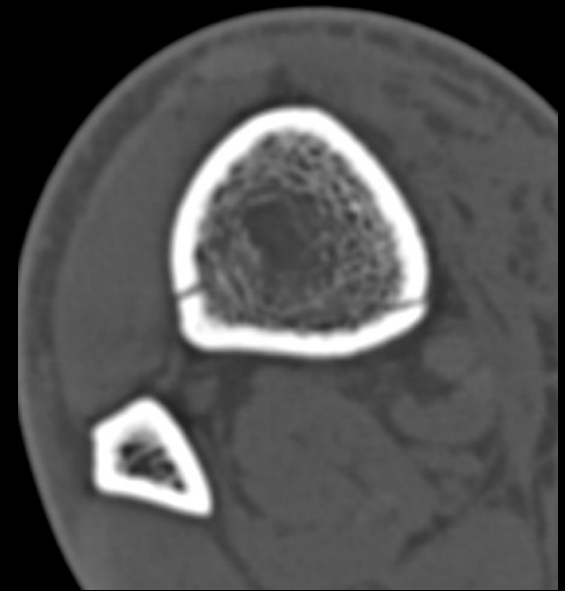
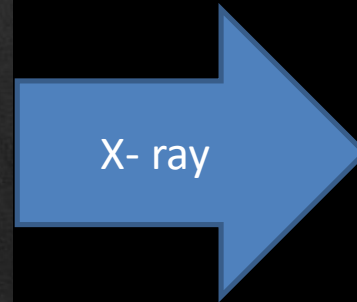
Pas de fracture diaphysaire visible



X-ray



Fracture diaphysaire visible



Pas de tangence

Superposition d'autres os/métal



Consolidation de la fracture



J0

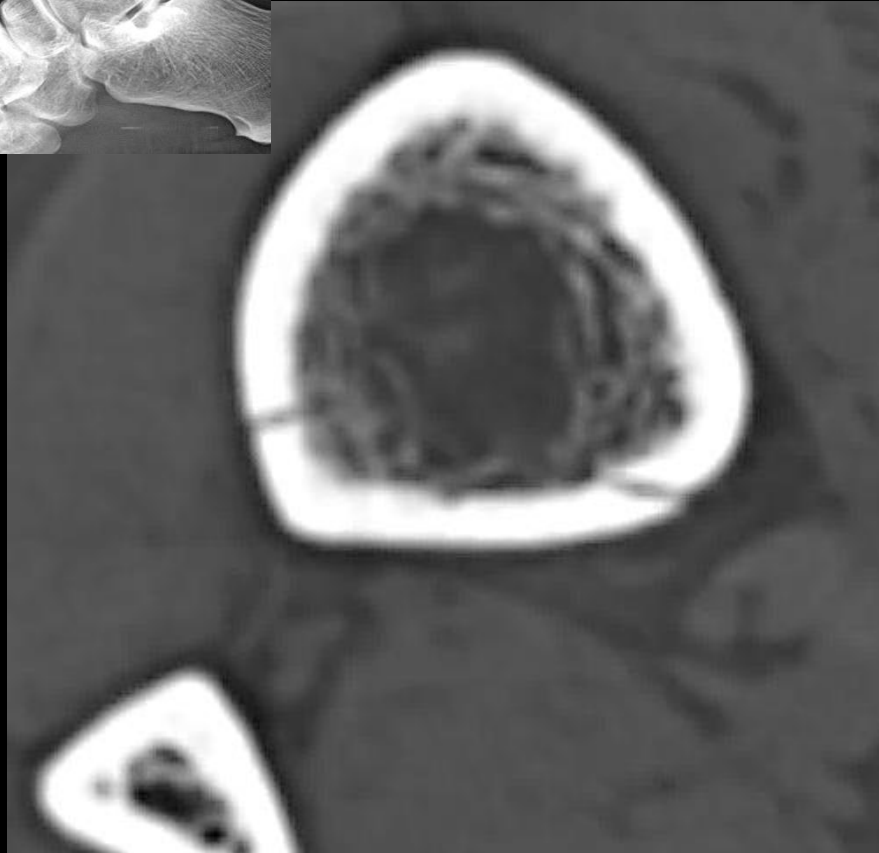


+ 2 mois

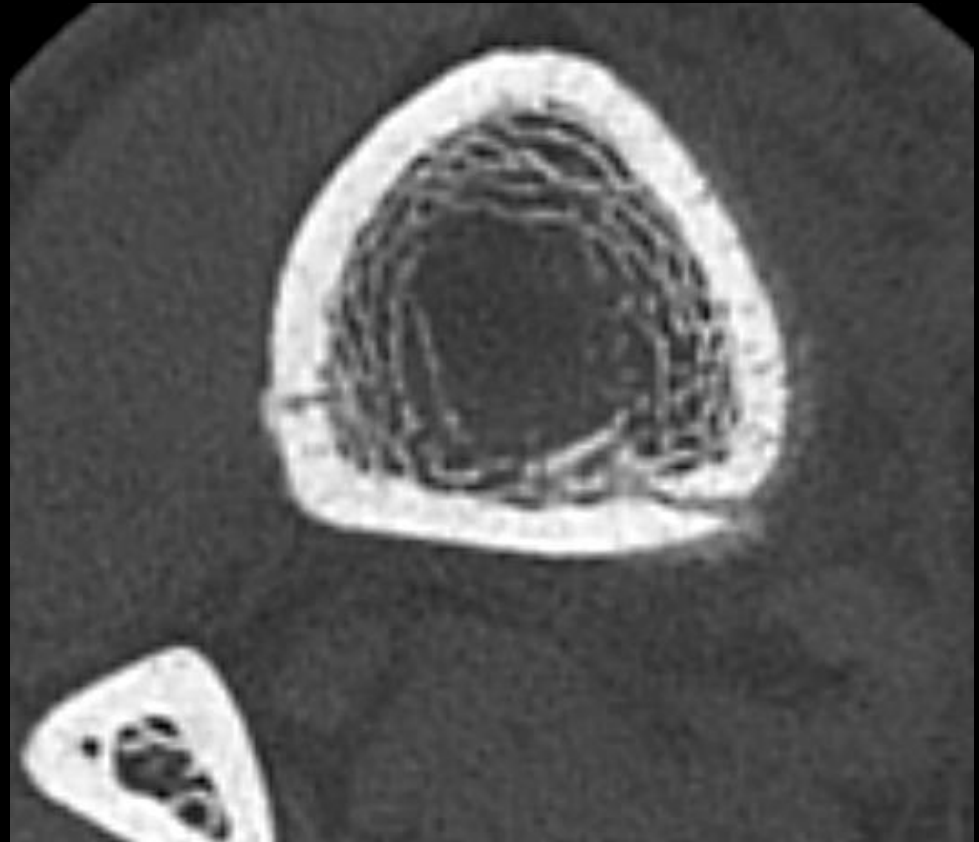


+ 5 mois

Consolidation de la fracture



CT J + 0



J + 3,5 mois

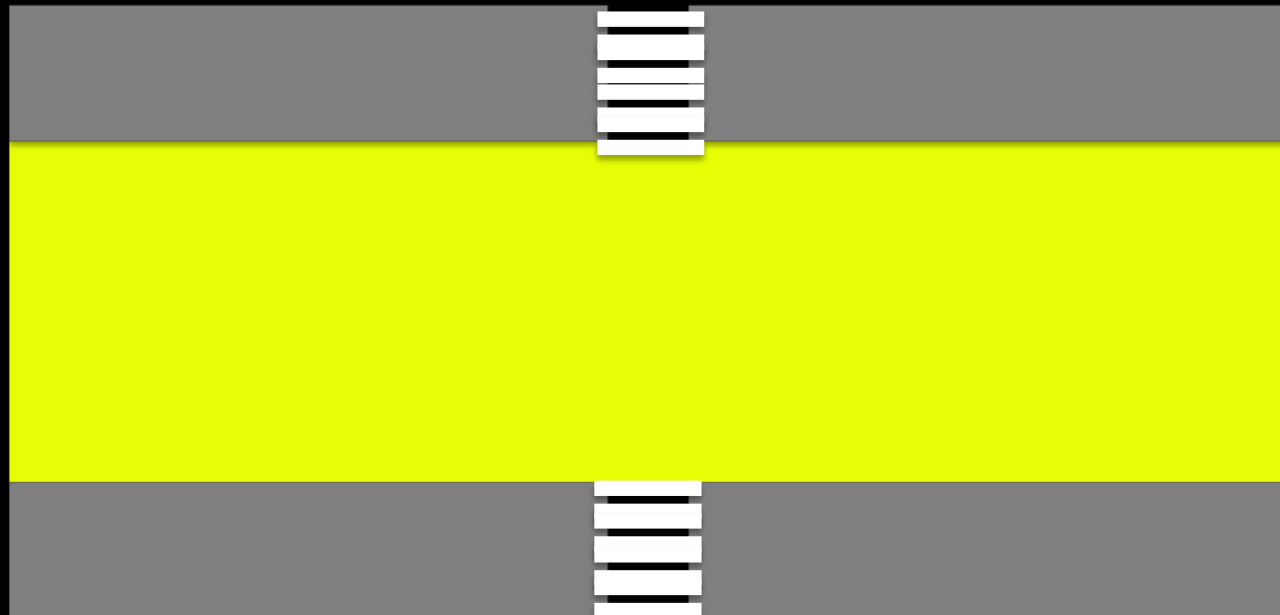
B. Consolidation des fractures

	Consolidation directe
Type de cal	
Micromobilite résiduelle	
Diastasis tolérable	



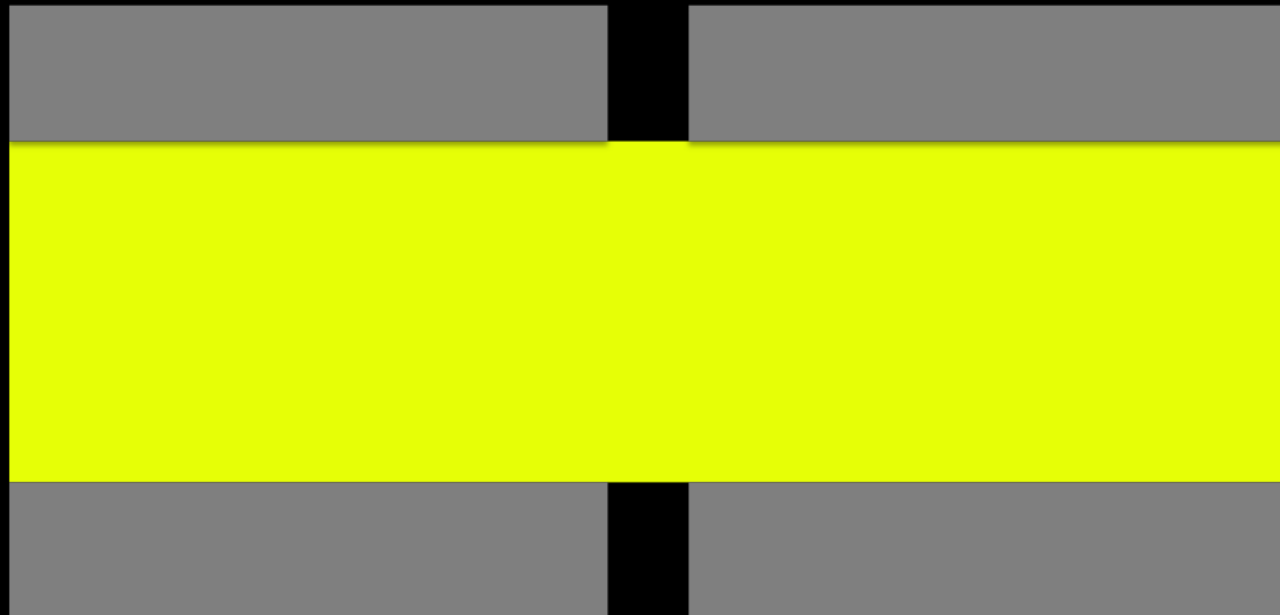
B. Consolidation des fractures

	Consolidation directe
Type de cal	Cal cortical
Micromobilite résiduelle	Effet inhibiteur
Diastasis tolérable	Aucun



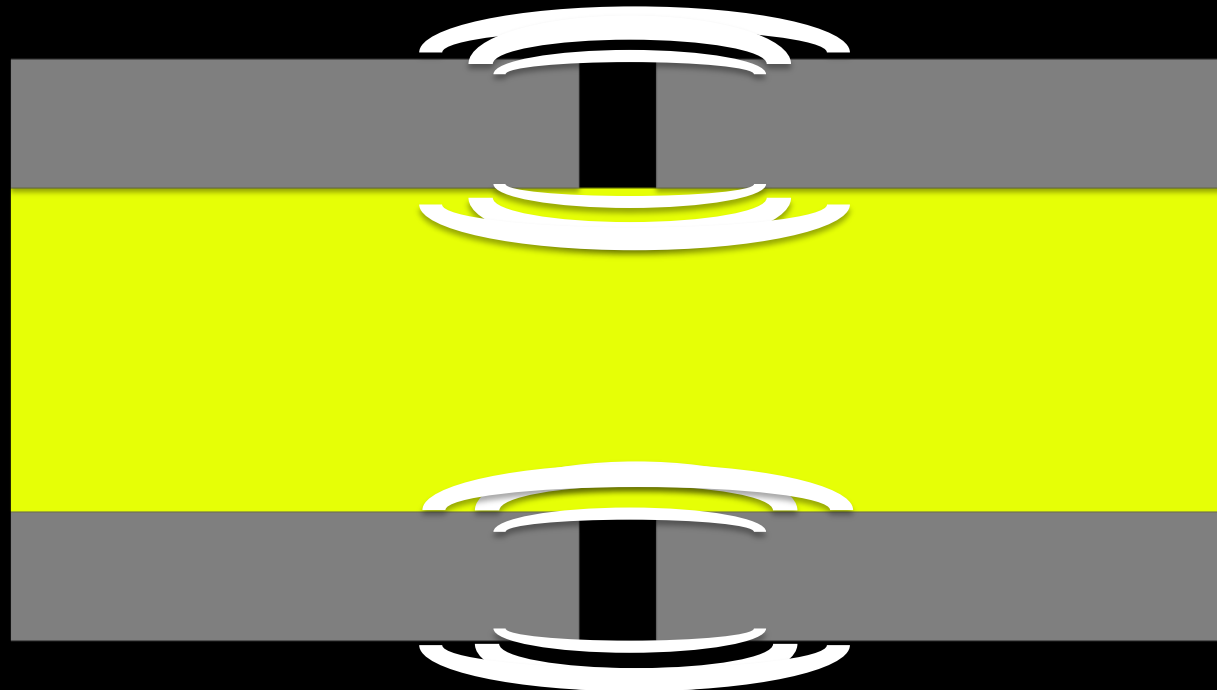
B. Consolidation des fractures

	Consolidation indirecte
Type de cal	
Micromobilité résiduelle	
Diastasis tolérable	



B. Consolidation des fractures

	Consolidation indirecte
Type de cal	Cal périosté
Micromobilité résiduelle	Effet stimulateur
Diastasis tolérable	Quelques mm



Fracture non déplacée de l'humérus

Traitement orthopedique sans materiel chirurgical

Consolidation indirecte



Fracture non déplacée de l'humérus

Traitement orthopedique sans materiel chirurgical

Consolidation indirecte



Fracture non déplacée de l'humérus

Traitement orthopedique sans materiel chirurgical

Consolidation indirecte



B. Consolidation des fractures

Consolidation acquise de la fracture

- Délai variable selon os et traitement
- Clinique OK
- Continuité corticale sur $\geq$ trois-quart de la circonférence osseuse

(Pontage osseux continu sur 3 des 4 secteurs vus sur incidences de face et de profil [méd., lat., ant., post.]).

Objectifs

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D. Complications des fractures



C. Biomécanique de la fixation

1. Réduction de la fracture

2. Stabilisation de la fracture

C. Biomécanique de la fixation

1. Réduction

2. Stabilisation

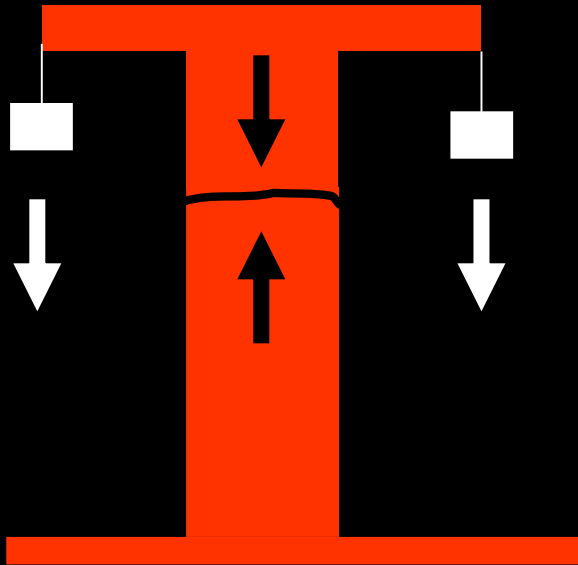
a. Fixation statique- consolidation directe

b. Fixation dynamique- consolidation indirecte

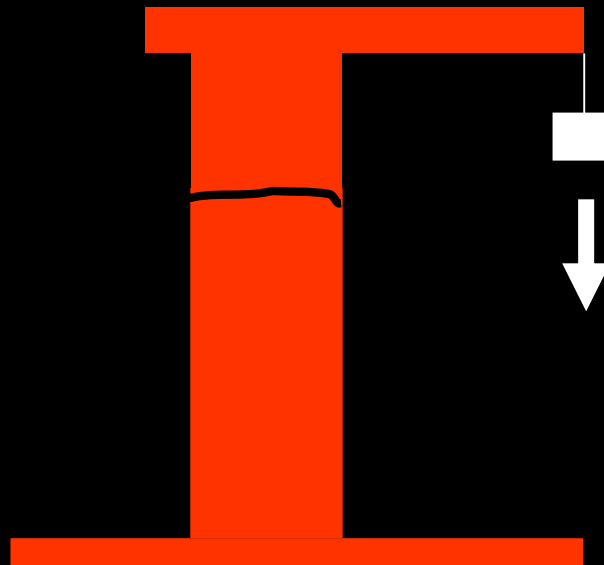
C. Biomécanique de la fixation

1. Réduction du déplacement des fragments
2. Fixation des fragments osseux si réduction instable.

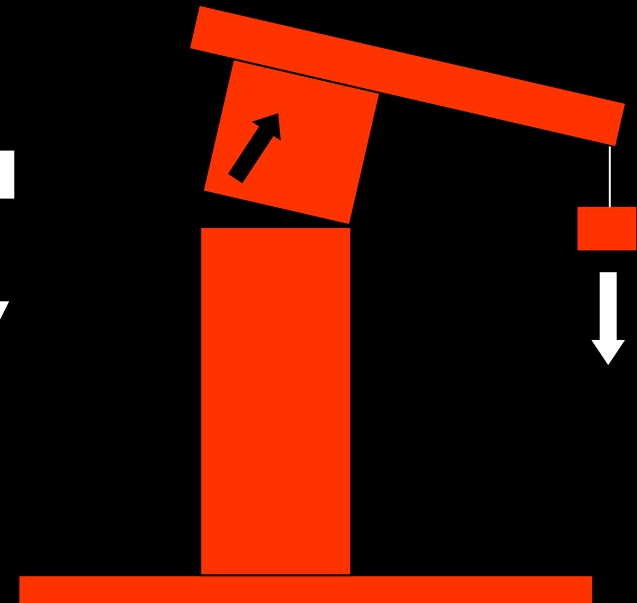
Fracture stable



Fracture instable
non déplacée



Fracture instable
déplacée

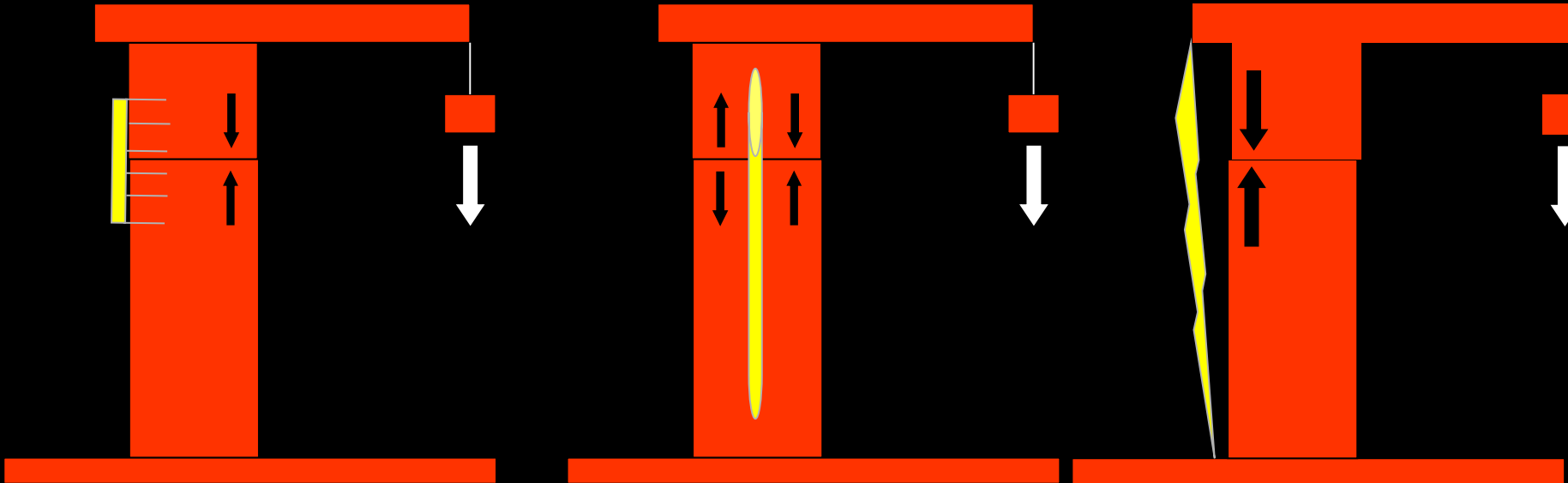


C. Biomécanique de la fixation

Plaque

enclouage

haubannage



Ostéosynthèse chirurgicale des fractures instables

C. Biomécanique de la fixation

1. Réduction

2. Stabilisation

a. **Fixation statique :**

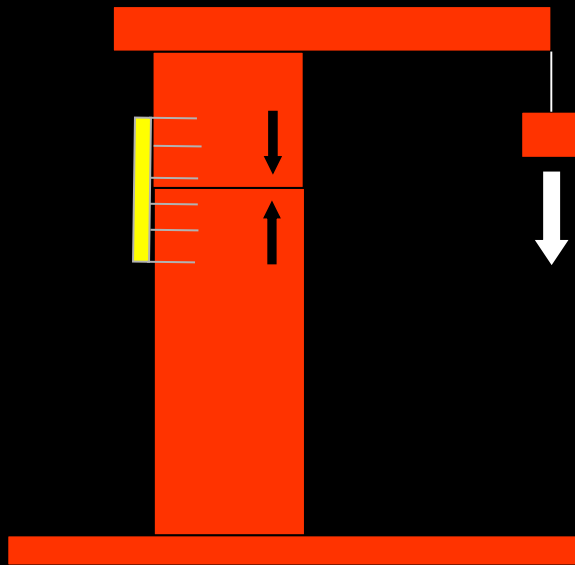
raideur du site fracturaire induite par le matériel est constante au cours du temps.

b. **Fixation dynamique:**

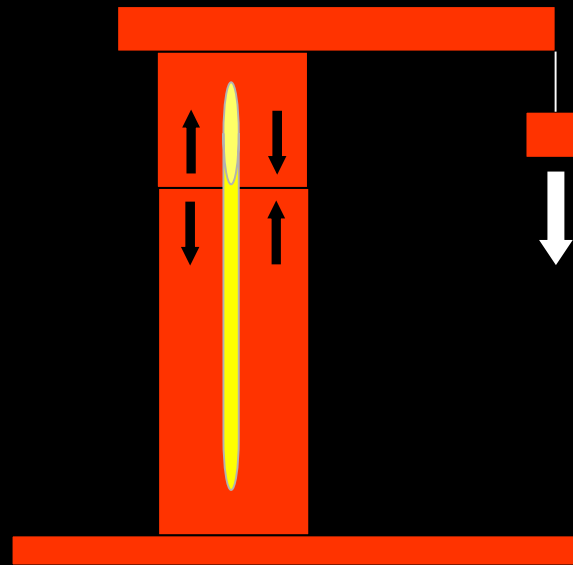
raideur du site fracturaire induite par le matériel varie au cours du temps.

Fixation statique:
raideur du site fracturaire induite par le matériel
est constante au cours du temps.

Plaque

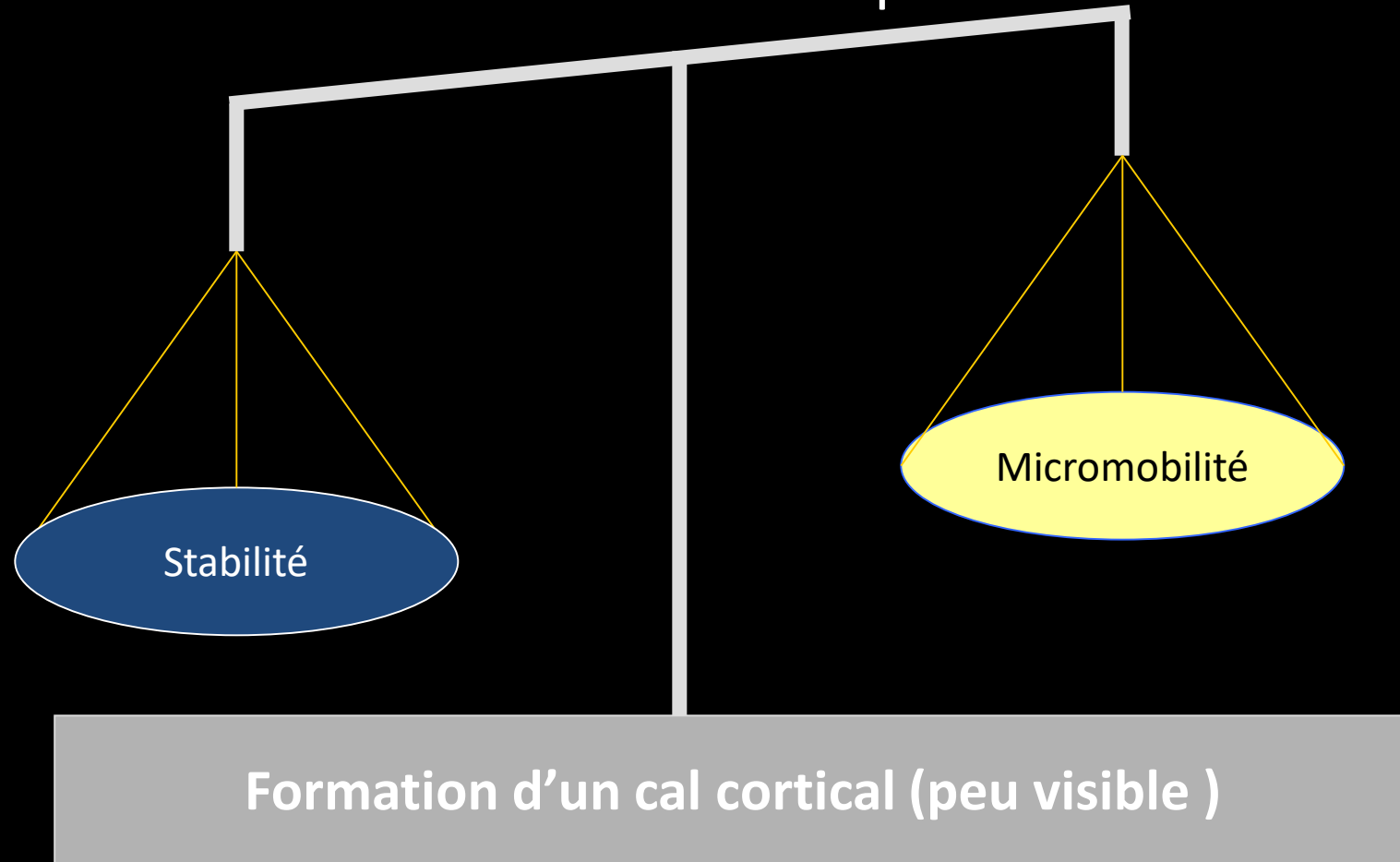


enclouage



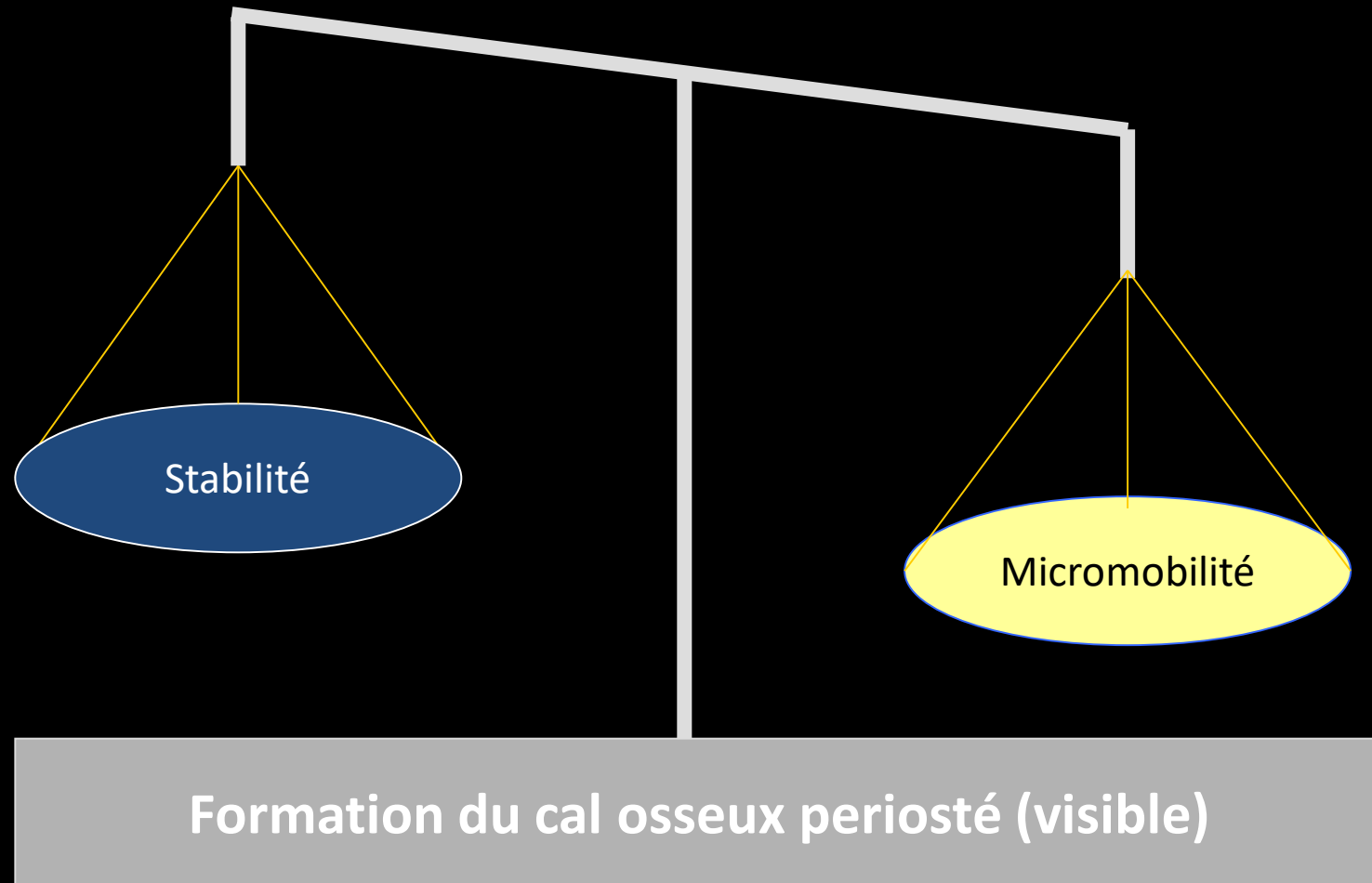
Fixation statique:

raideur du site fracturaire induite par le matériel est constante au cours du temps.



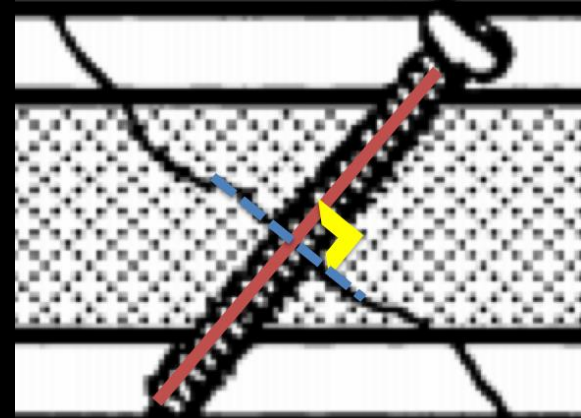
Fixation dynamique:

La raideur du site fracturaire induite par le matériel varie au cours de temps



Fixation statique :

1. Vis



J0



J30



J180

Vis d'Herbert



Stabilise et met en compression les fragments osseux (différences de pas de vis)

Fixation statique:

2. Plaque

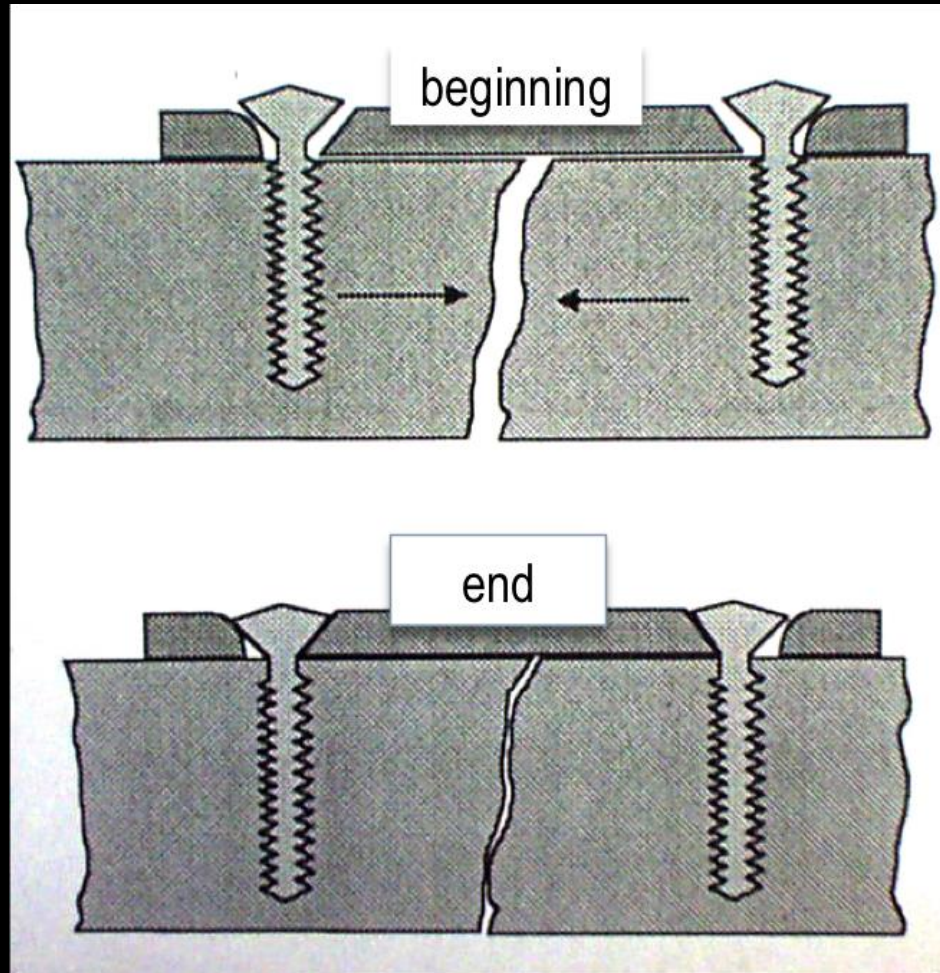


3 mois

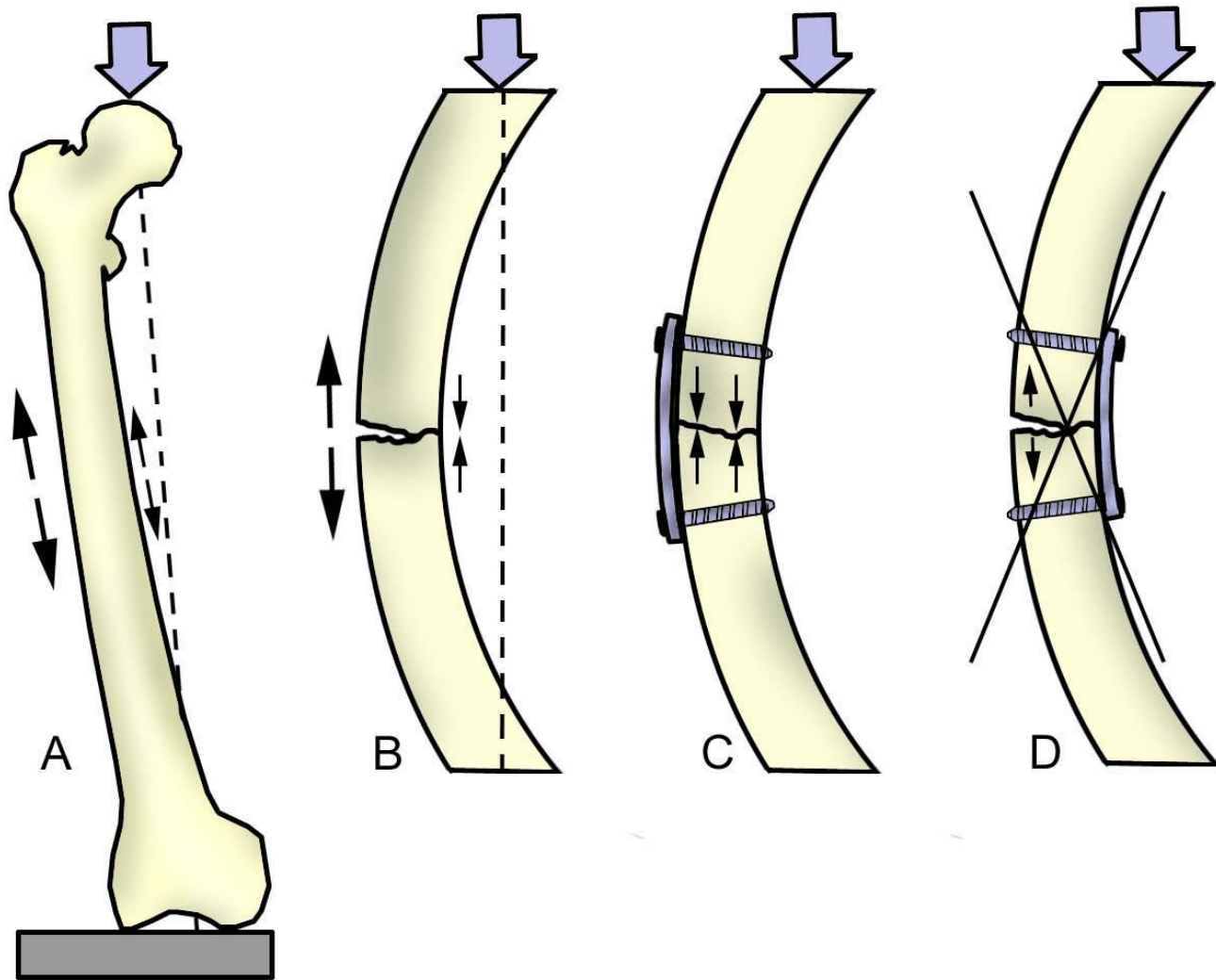
6 mois

12 mois

Plaque-vis compressive (DCP): stabilité et compression



Positionnement de la plaque sur le versant en traction de la fracture



Fixation statique

→ consolidation directe

	Consolidation directe
Type de cal	Cal cortical
Micromobilite résiduelle	Effet inhibiteur
Diastasis toléré	Aucun

Fixation dynamique

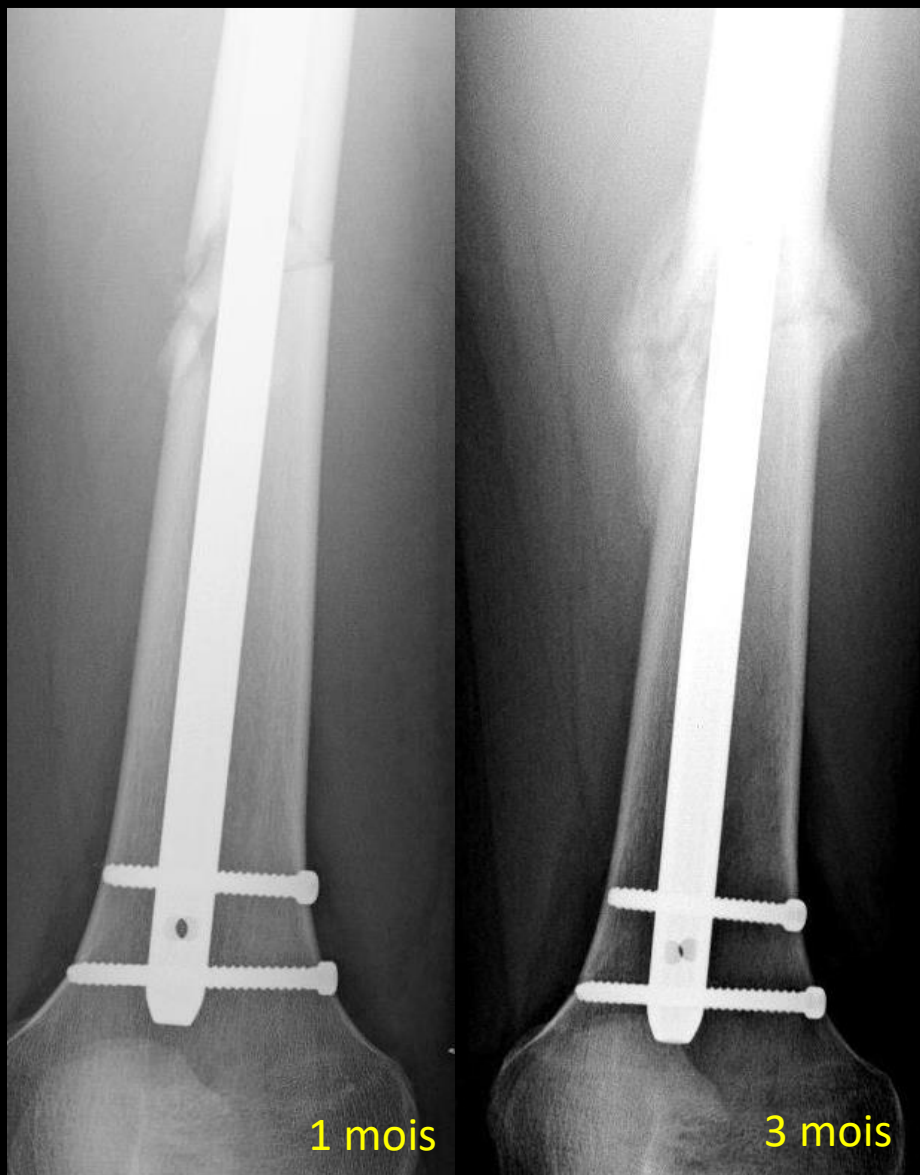
→ consolidation indirecte

	Consolidation indirecte
Type de cal	Cal périosté
Micromobilité résiduelle	Effet stimulateur
Diastasis toléré	Quelques mm

Fixation dynamique: Clou



Fixation dynamique: Clou



Fixation dynamique: Clou

Os de 1^o génération
Os tissé (woven bone)

Os de 2^o génération
Os différencié (Cx/trab)







Dynamisation
clou



Fixation
dynamique:
Clou gamma
et
DHS

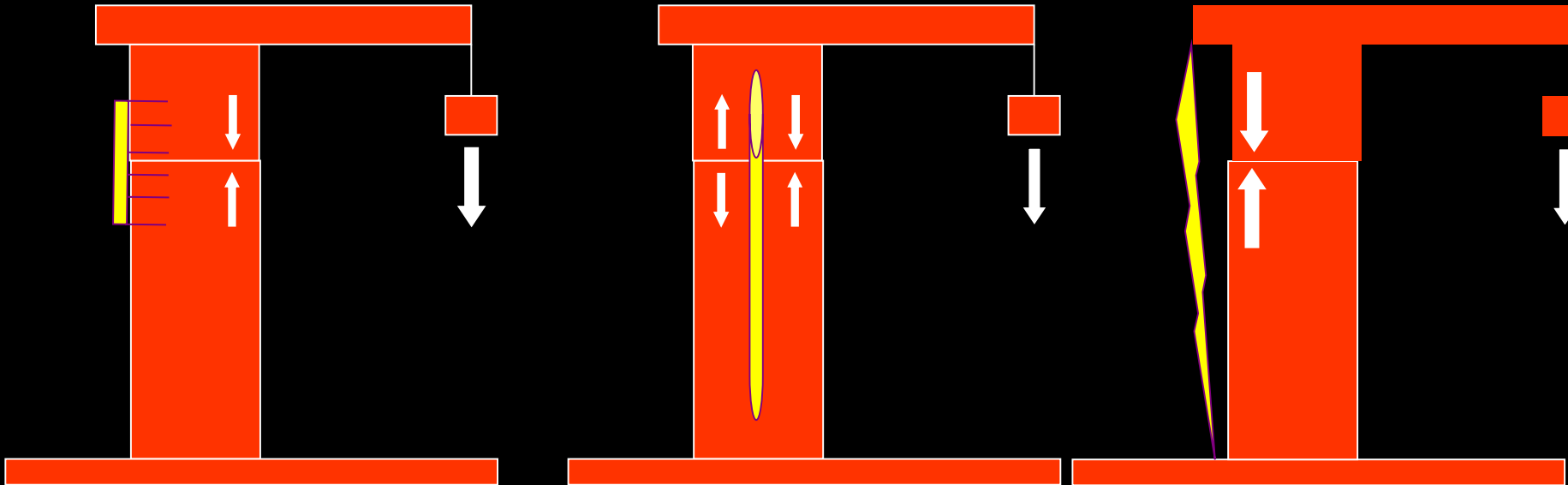


C. Biomécanique de la fixation

Plaque

enclouage

haubanage



Ostéosynthèse chirurgicale des fractures instables

Fractures de l'olécrane



Fixation dynamique: *Haubanage*



Fixation dynamique:

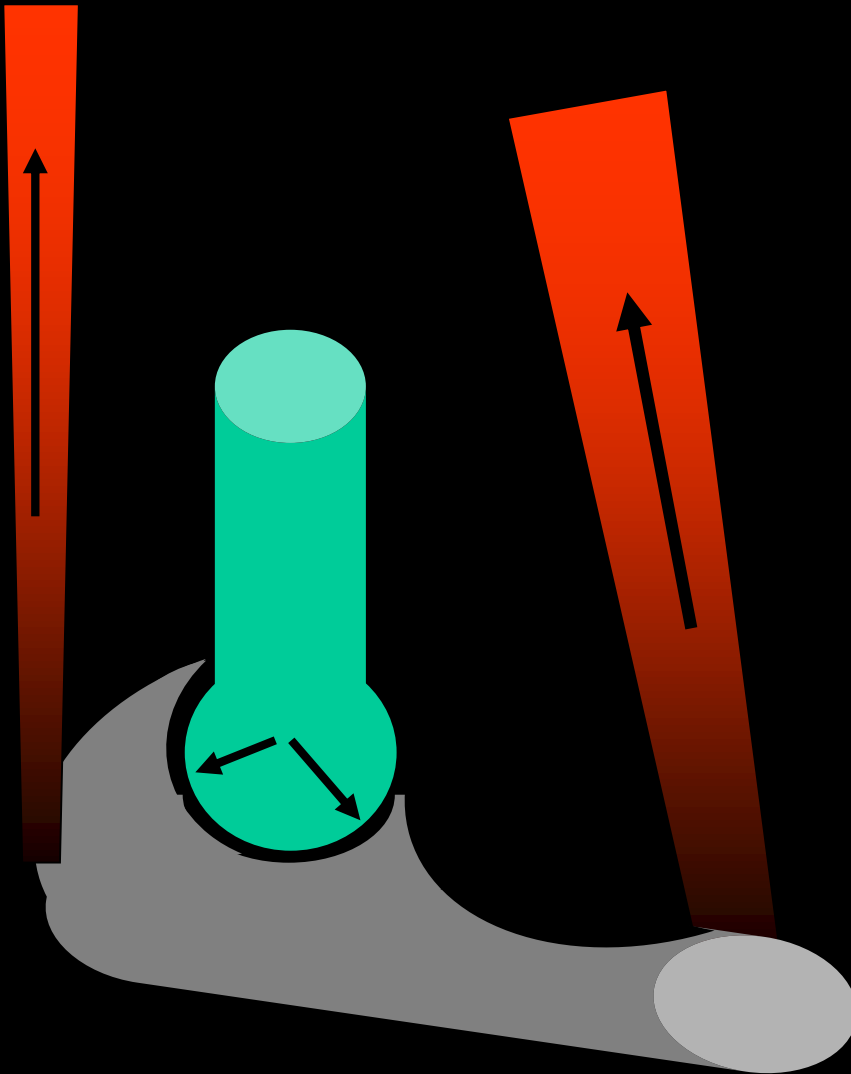
raideur du site fracturaire induite par le matériel varie au cours du temps.

- * Déverrouillage de clous centromédullaires
- * Dynamisation des fixateurs externes
- * Vis dynamiques (Dynamic hip screw)

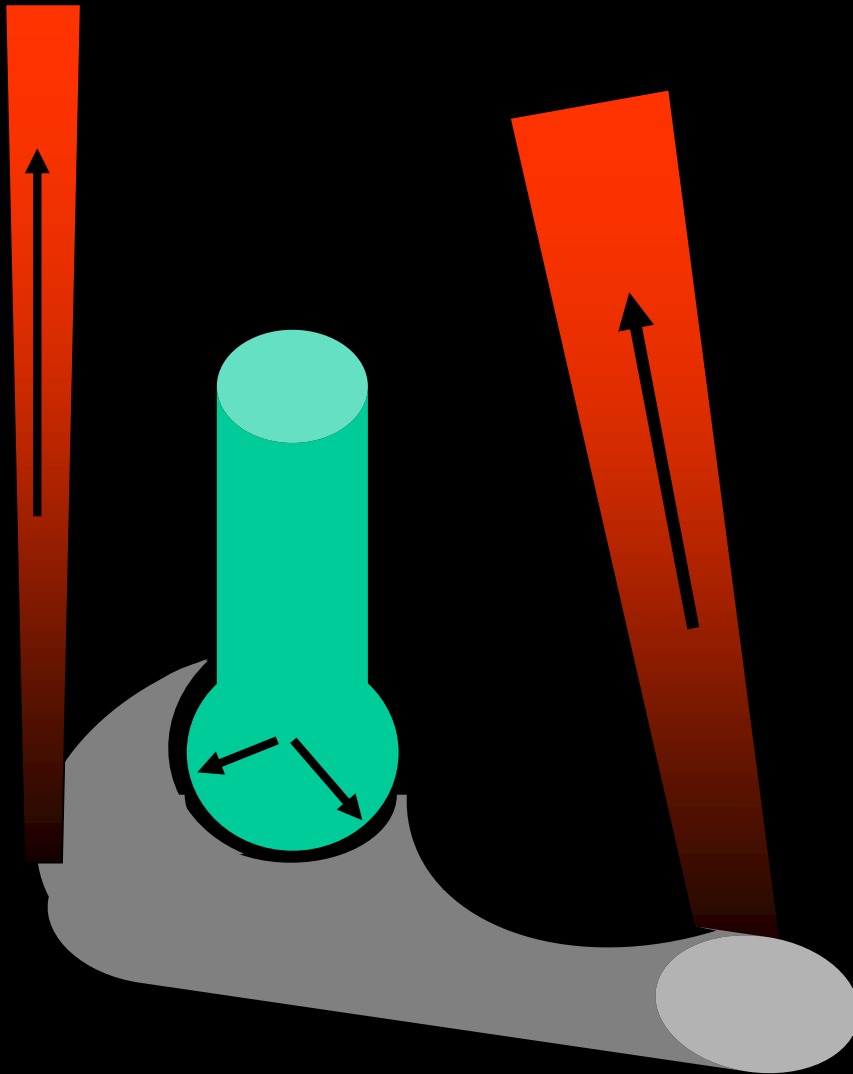
Fractures de l'olécrane



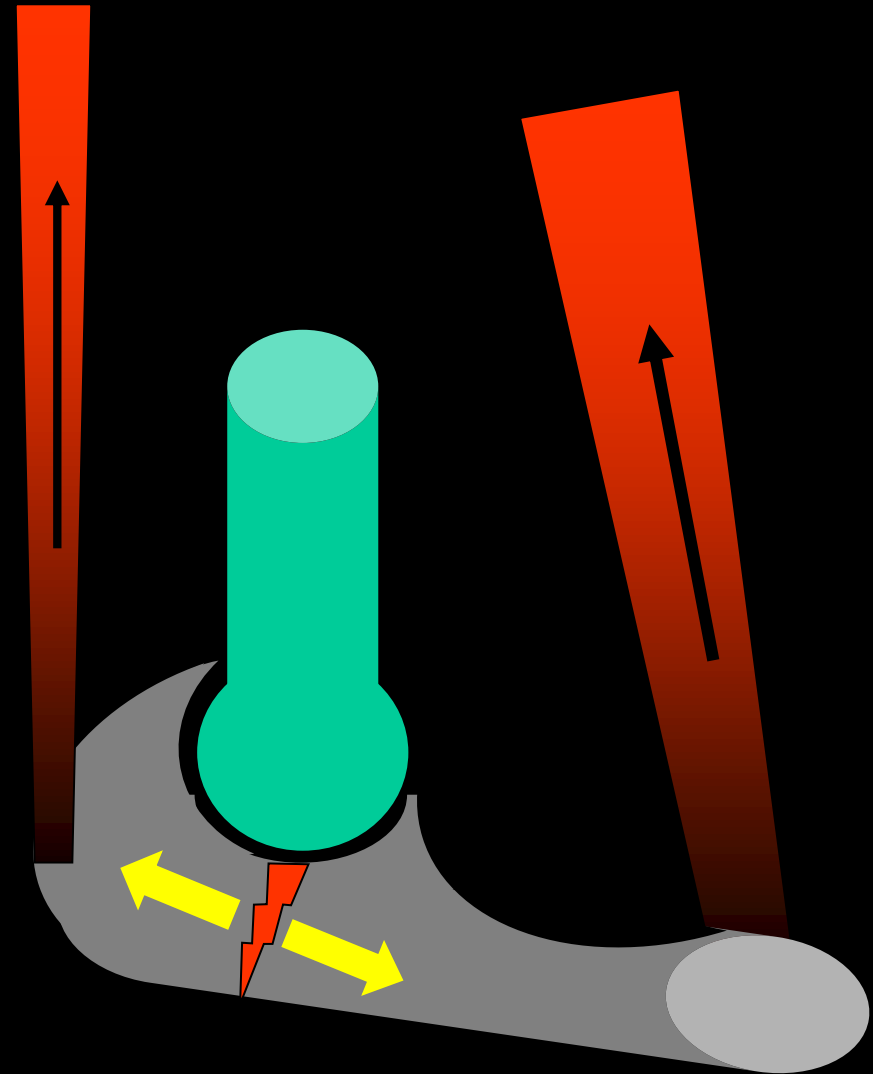
Biomécanique normale



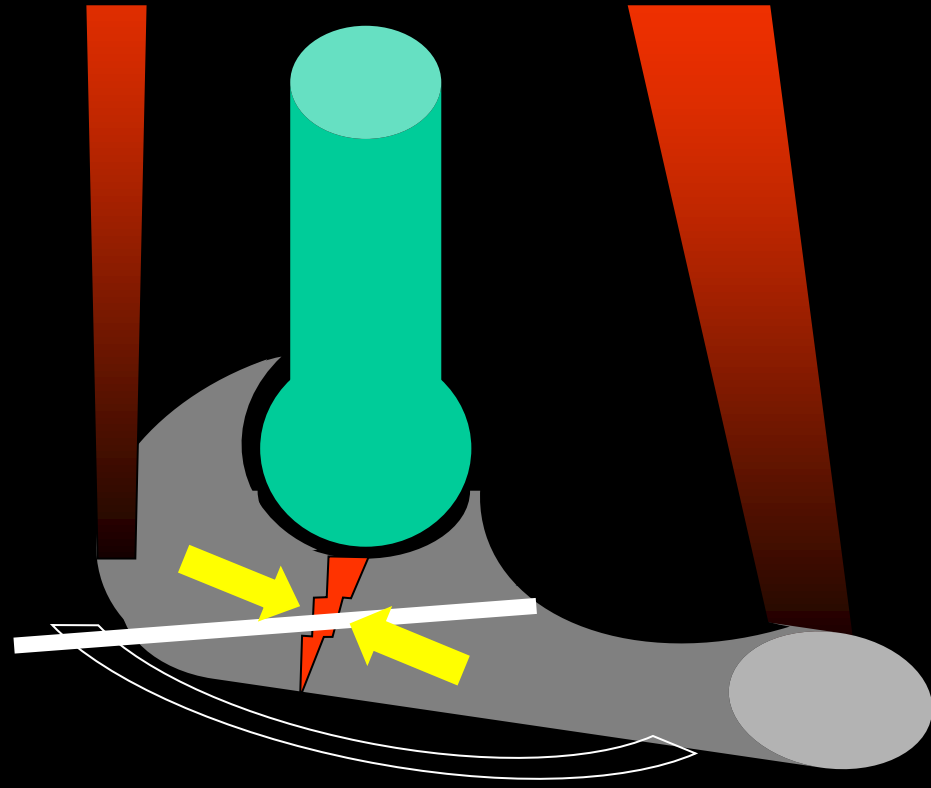
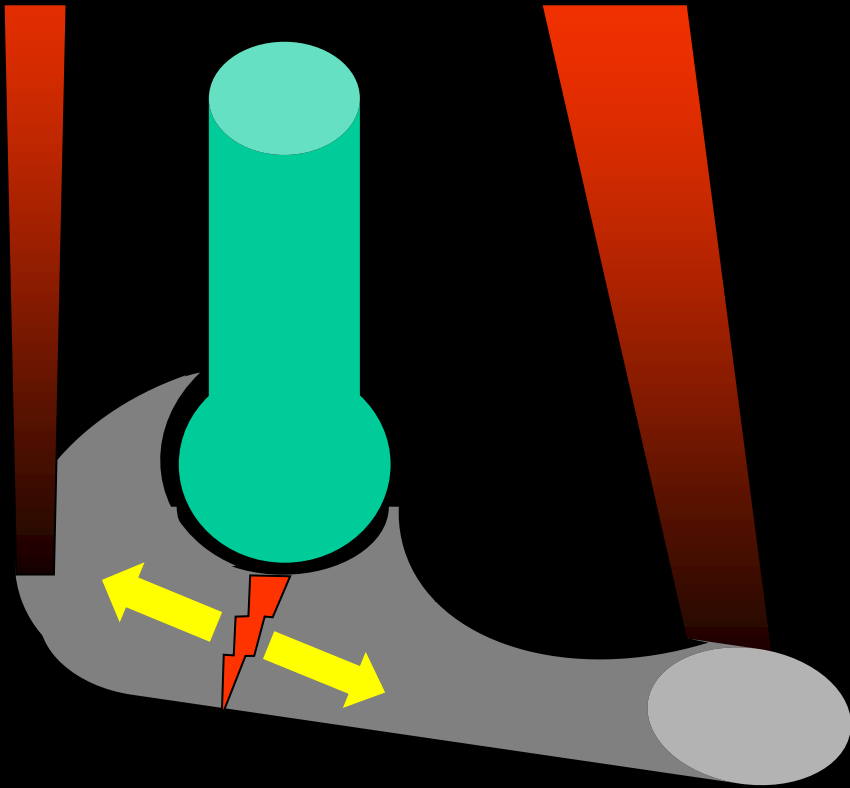
Biomécanique normale



Fracture de l'olécrane



Fixation par haubanage:
Inverse direction de contraintes
Permet d'utiliser contraintes physiologiques

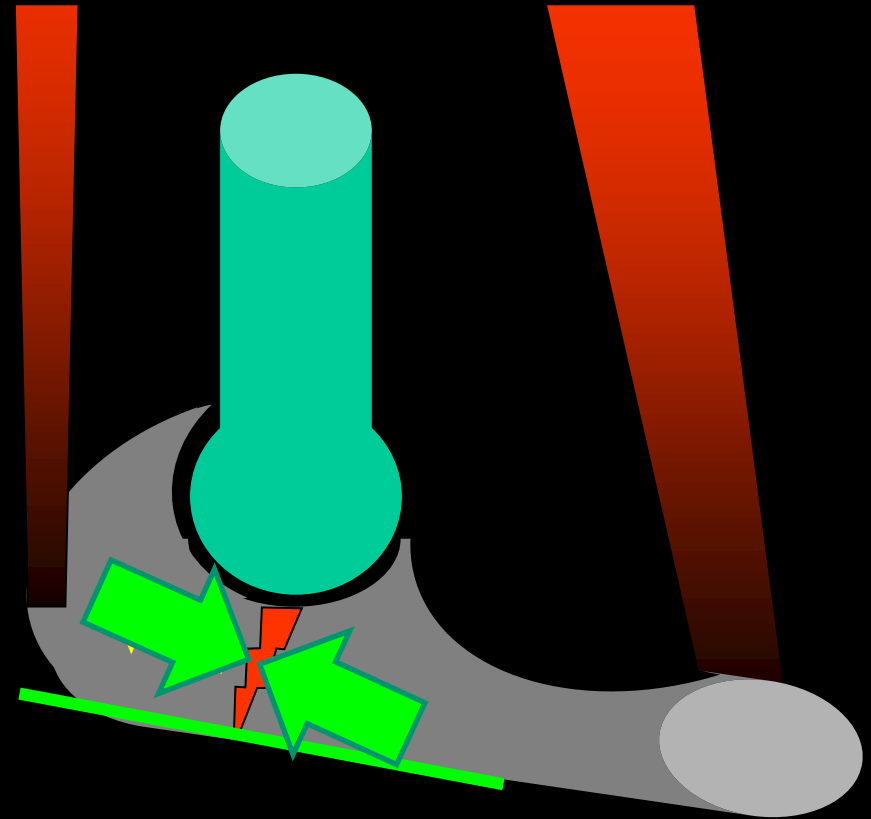
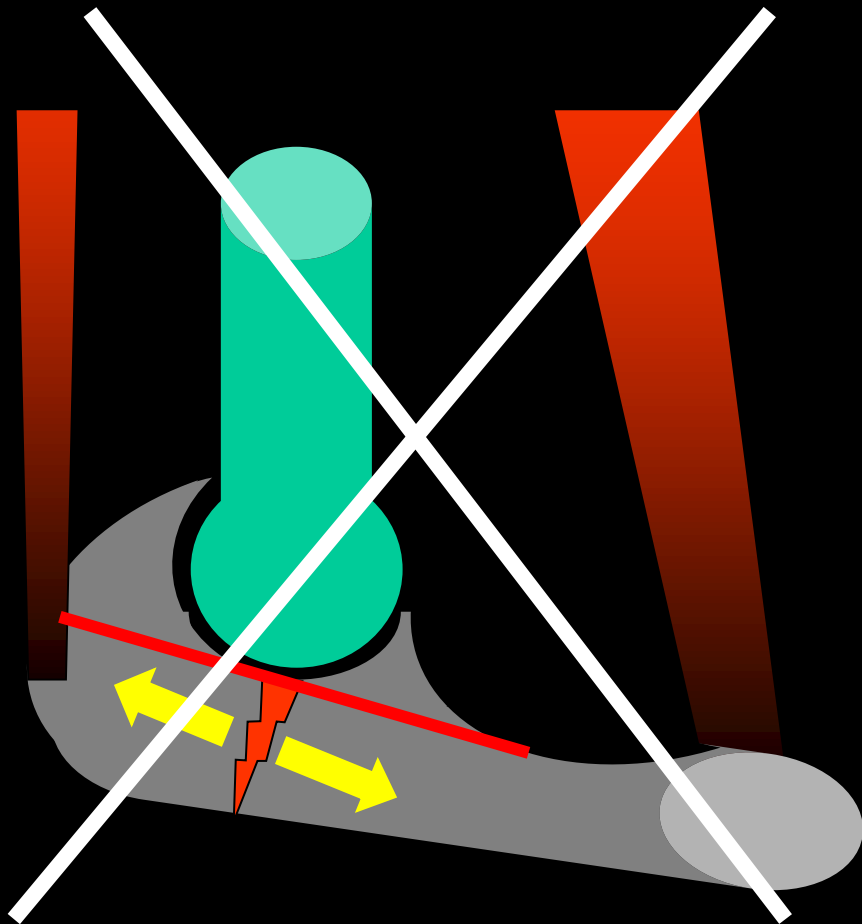


Fixation par haubanage:

Déplacement du centre de rotation

Inverse direction de contraintes

Permet d'utiliser contraintes physiologiques

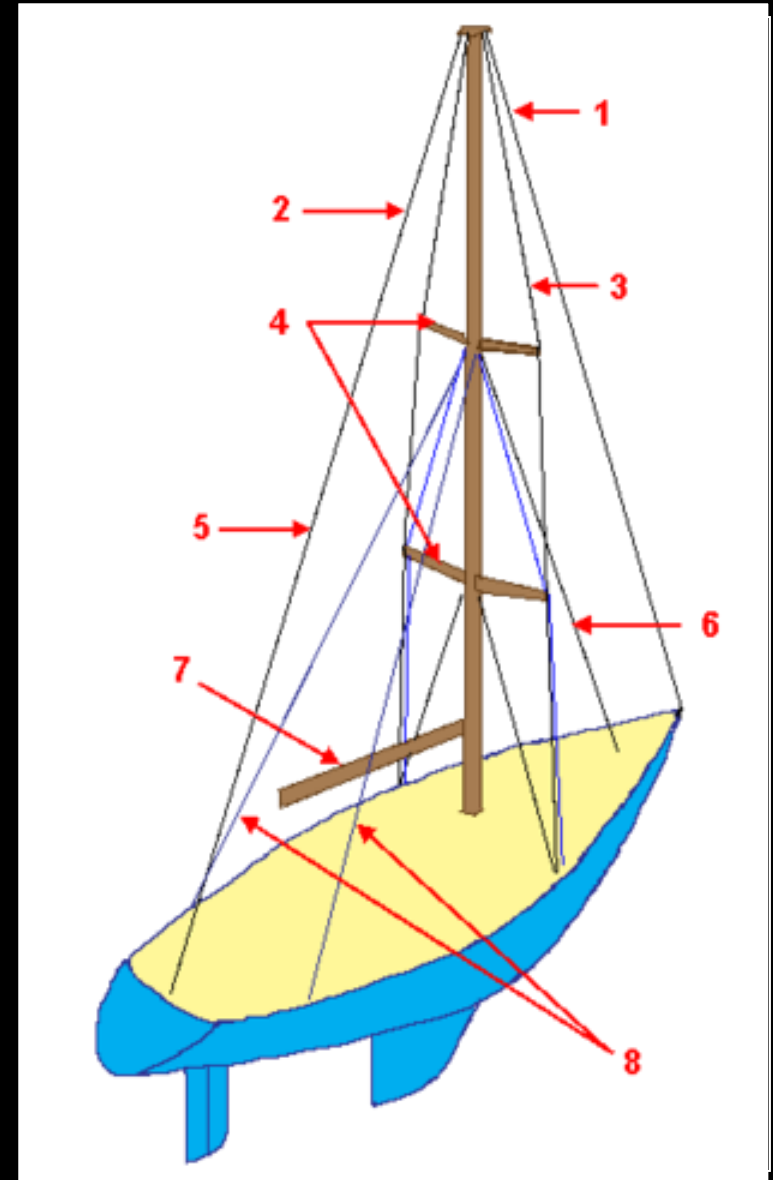


Haubans:

Cables reliant le mat au pont stabilisent le mat contre les forces transversales du vent dans les voiles.

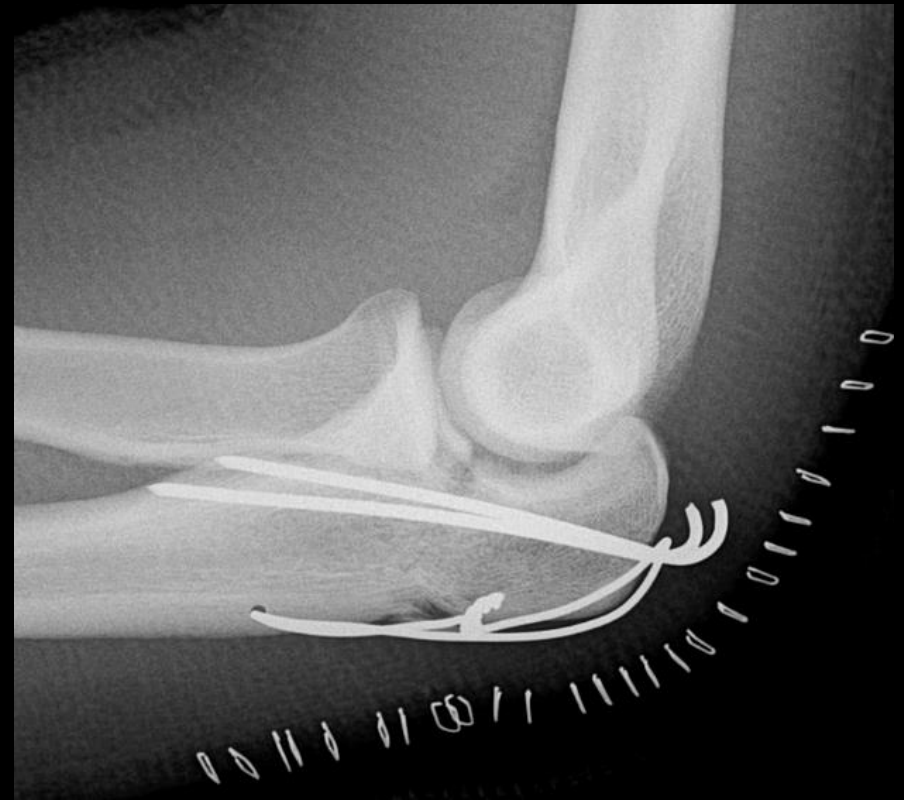
Fixateur dynamique:

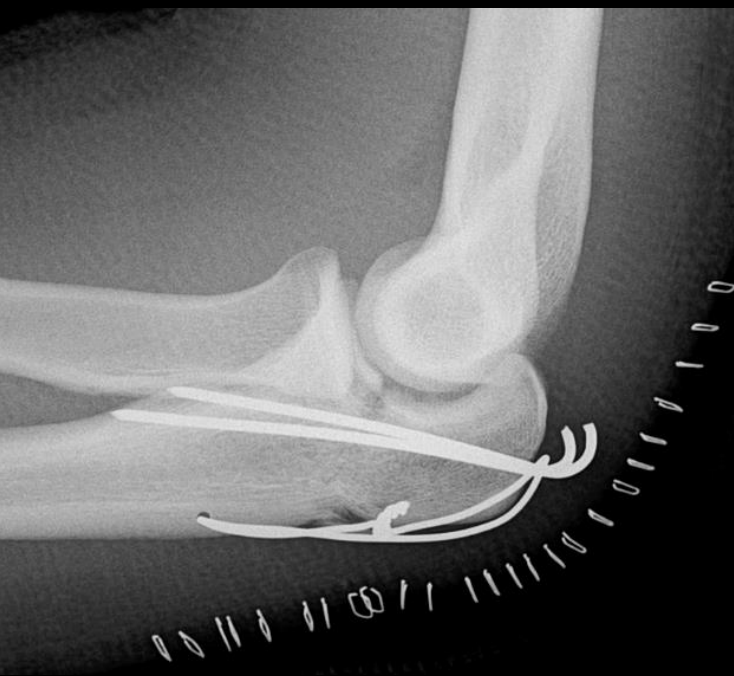
Plus le vent souffle, plus le mat plie, plus la tension du hauban augmente.



Le haubanage externe: forme ultime de la fixation dynamique

- * Inverse les contraintes biomécaniques
(traction devient compression)
- * Permet l'utilisation des contraintes biomécaniques normales





J4



J30



J150

Sélection précise des fracture à traiter par haubanage
Fracture simple sans fragment additionnel
Fracture centrée en regard de l'humérus



Fracture comminutive
Trait trop distal



Complication

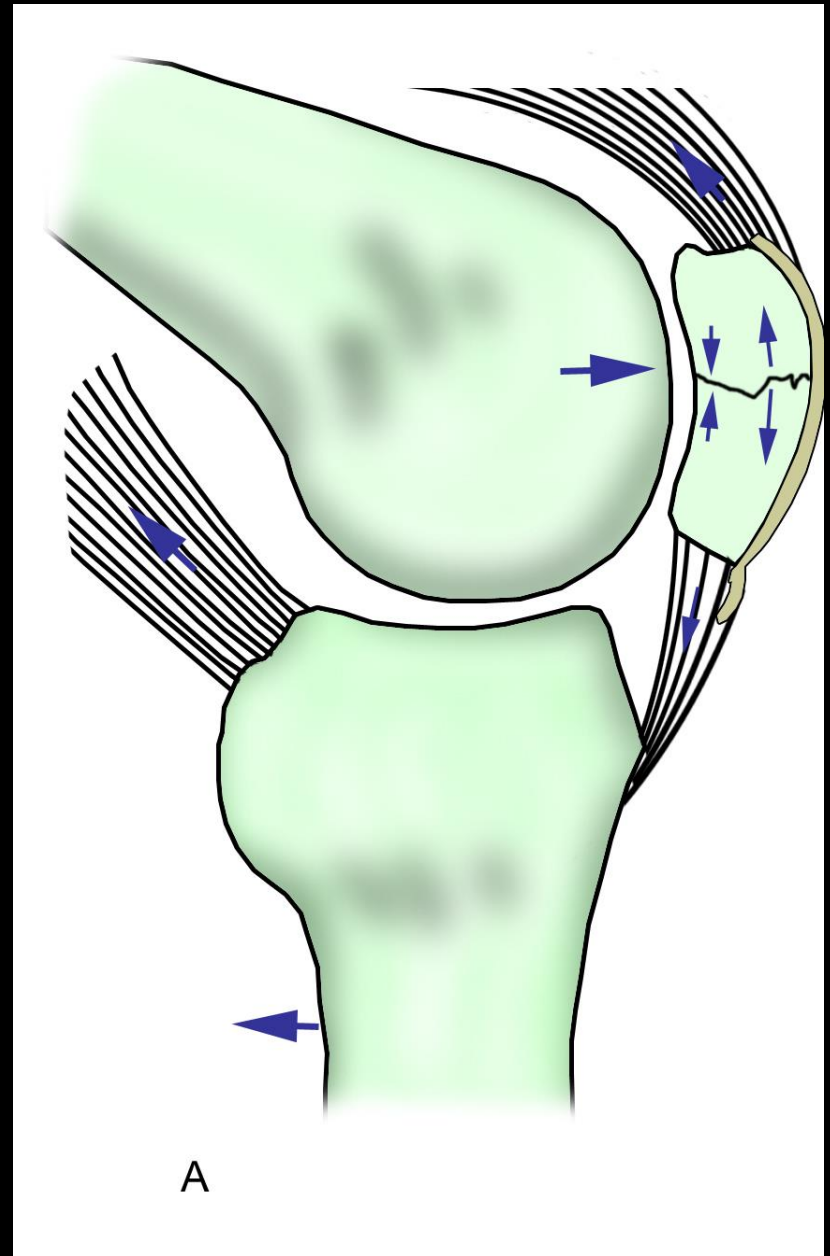
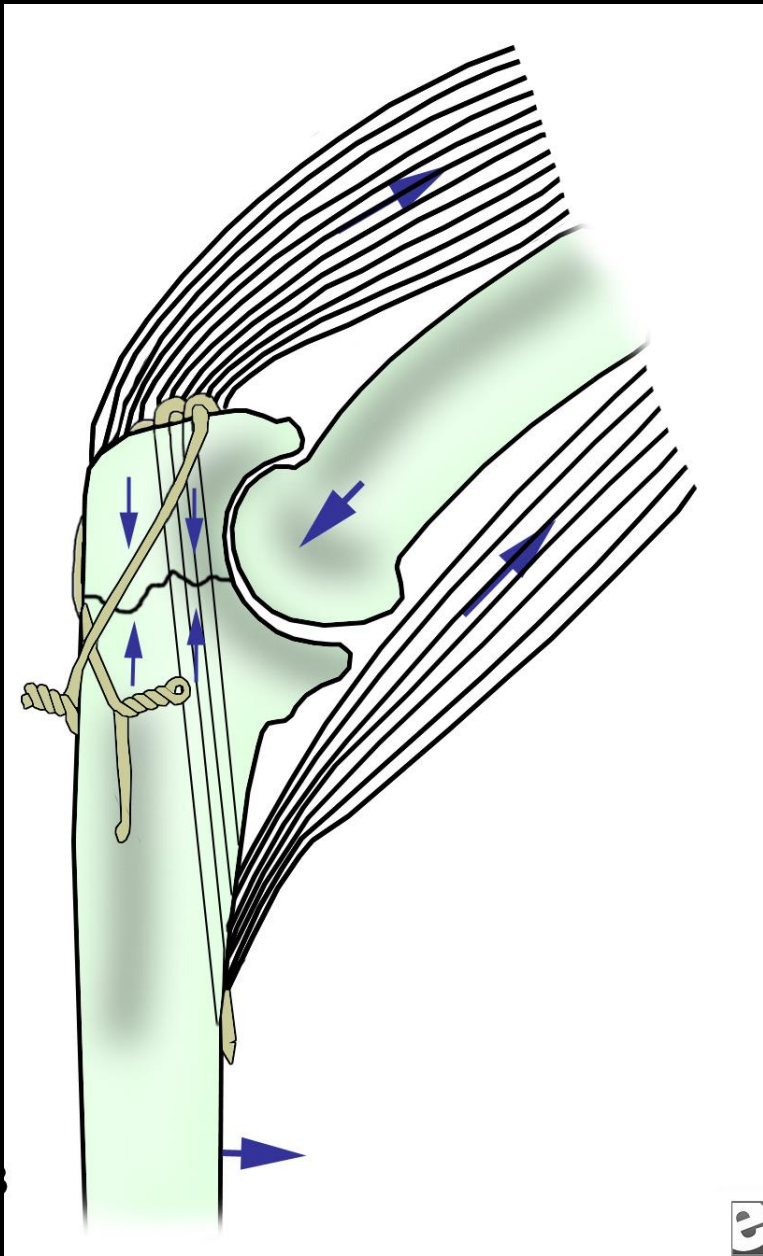
Femme de 93 ans

01 (FRONT) >



Complication du haubanage démontage





From General principles of internal fixation R Lakatos



En conclusion

Type de consolidation	Directe	Indirecte
Type de fixation	Statique	Dynamique
Materiel chirurgical	Vis Plaque	Clou CM, Clou gamma, DHS, hauban
Imagerie	Pas de cal Pas de mobilité Pas de diastasis	Cal +++ Micromobilité Micro-diastasis

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Complications des fractures

- Déformations résiduelles
- Troubles de la consolidation
 - retard (< 6mois)
 - Pseudarthrose (> 6 mois)
- Infection (fractures ouvertes)
- Nécrose (osseuse, musculaire, cutanée)
- Capsulite, Syndrome douloureux régional complexe (SDRC)
- Arthrose

Consolidation des fractures:

Biomécanique osseuse



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Case 1



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

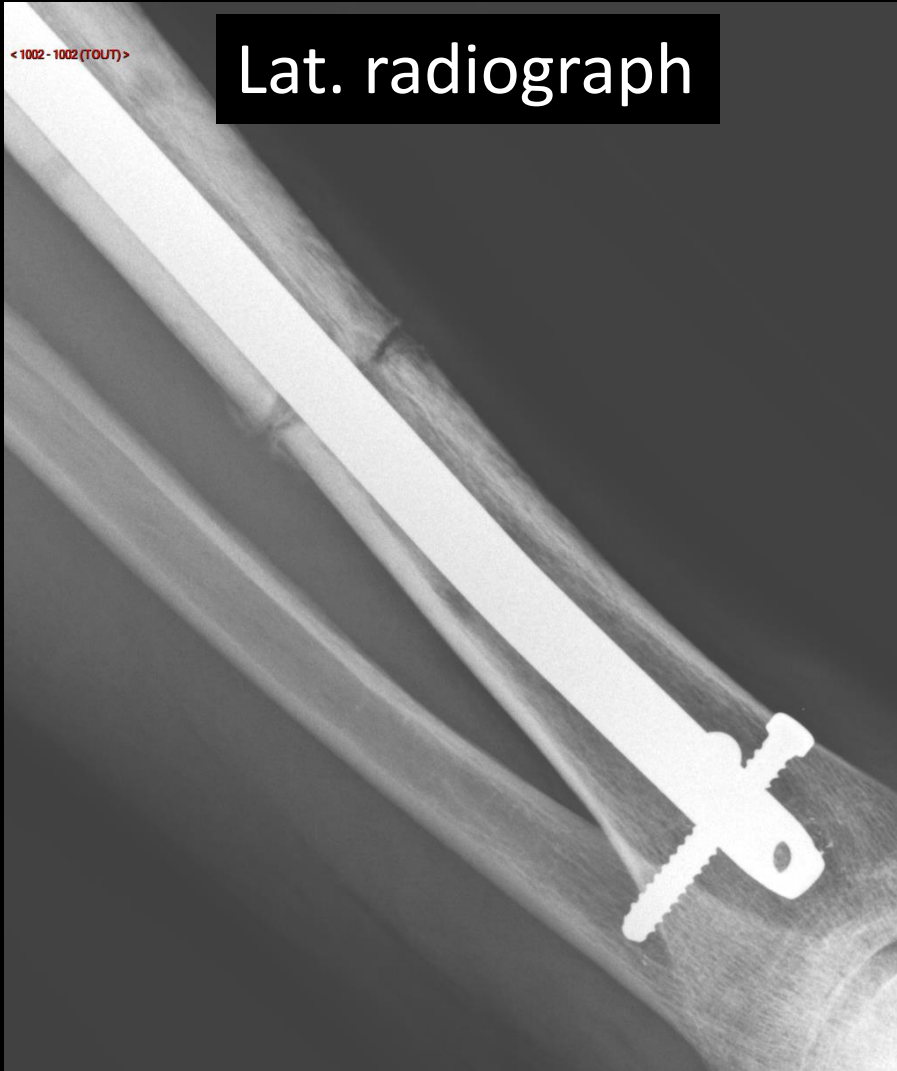
Case 1



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1

Lat. radiograph

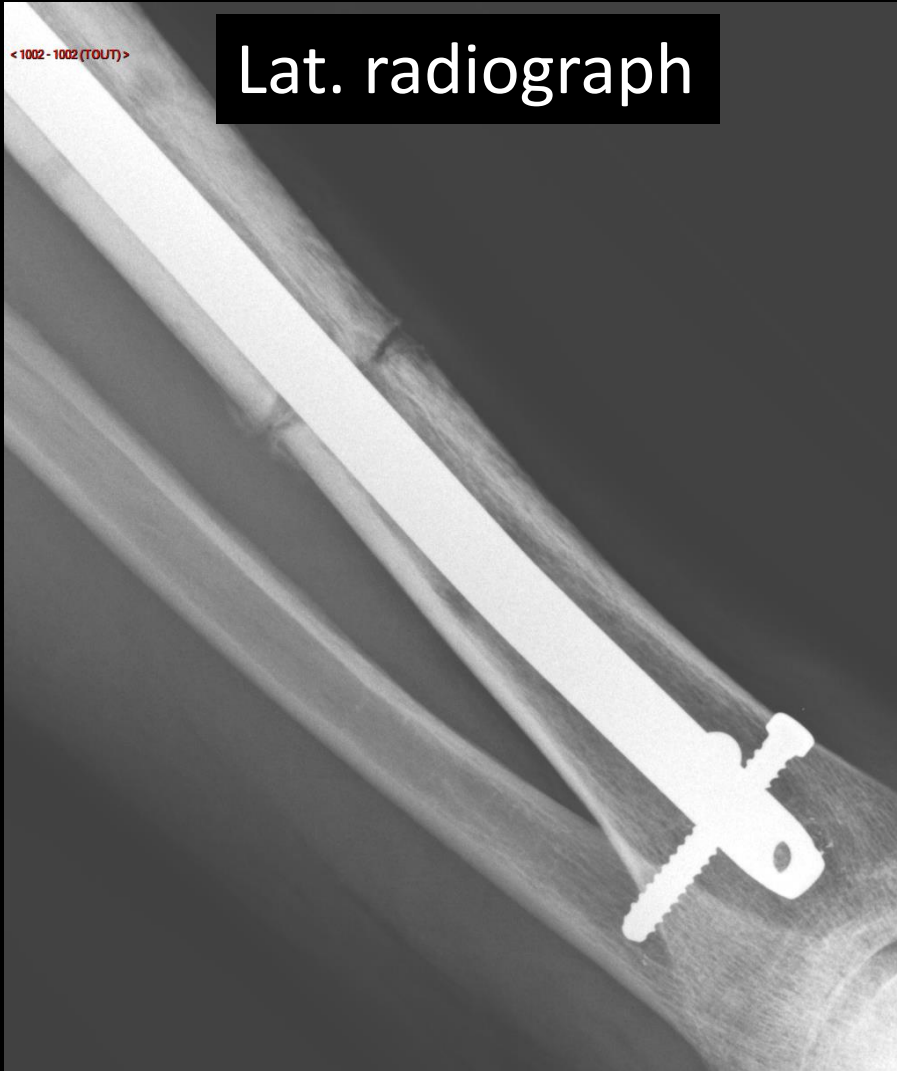


:

1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

Case 1

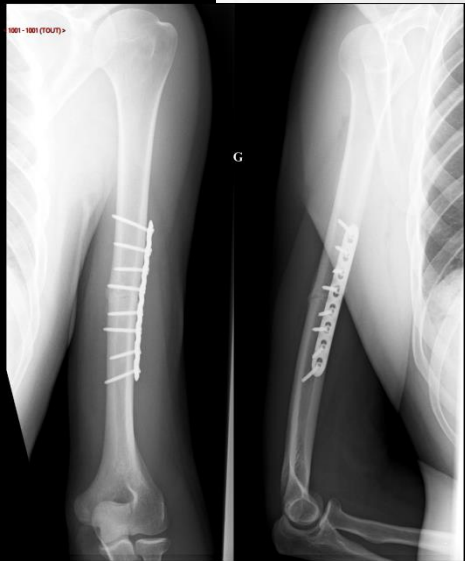
Lat. radiograph



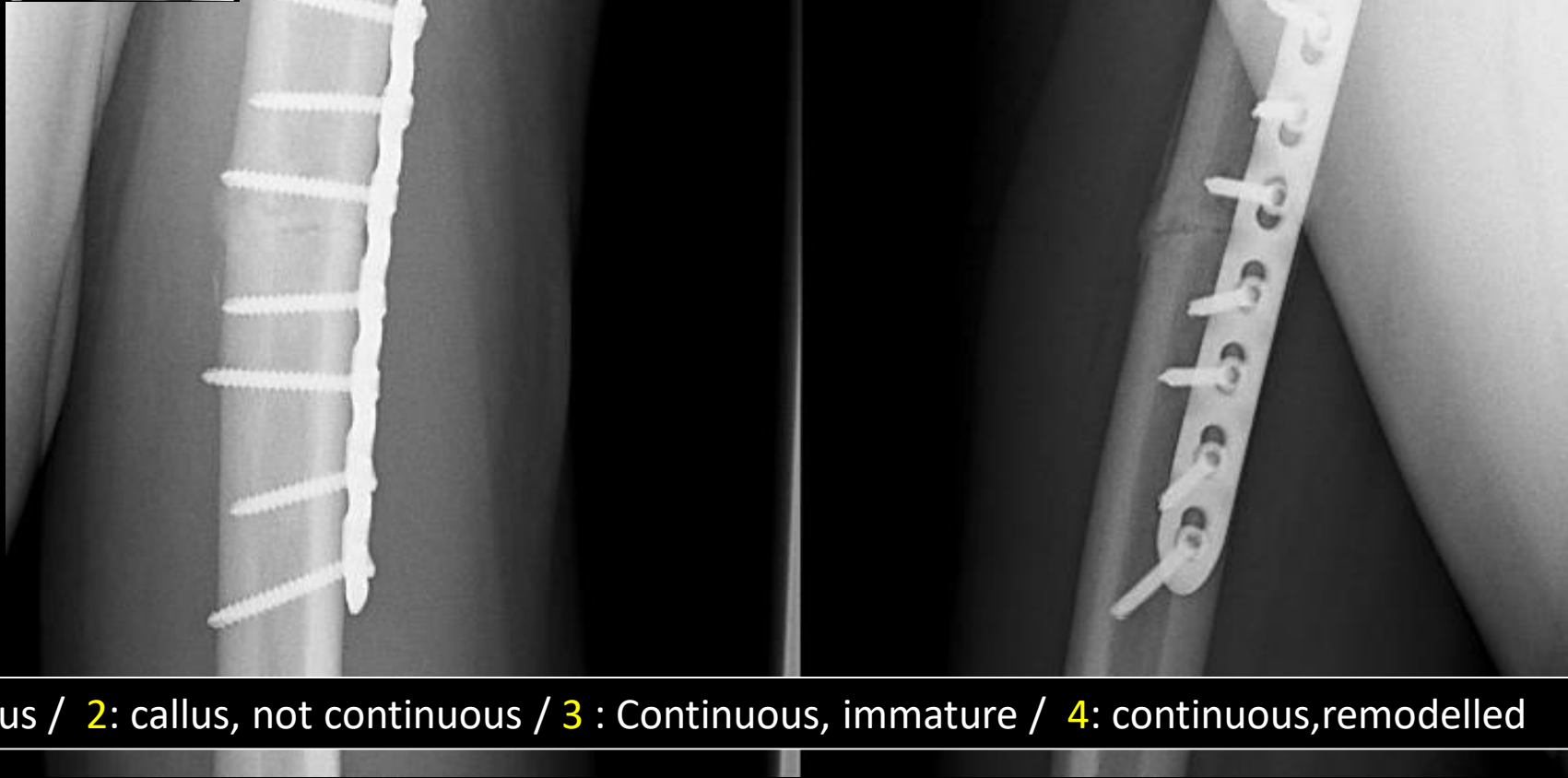
Sagittal CT reformat



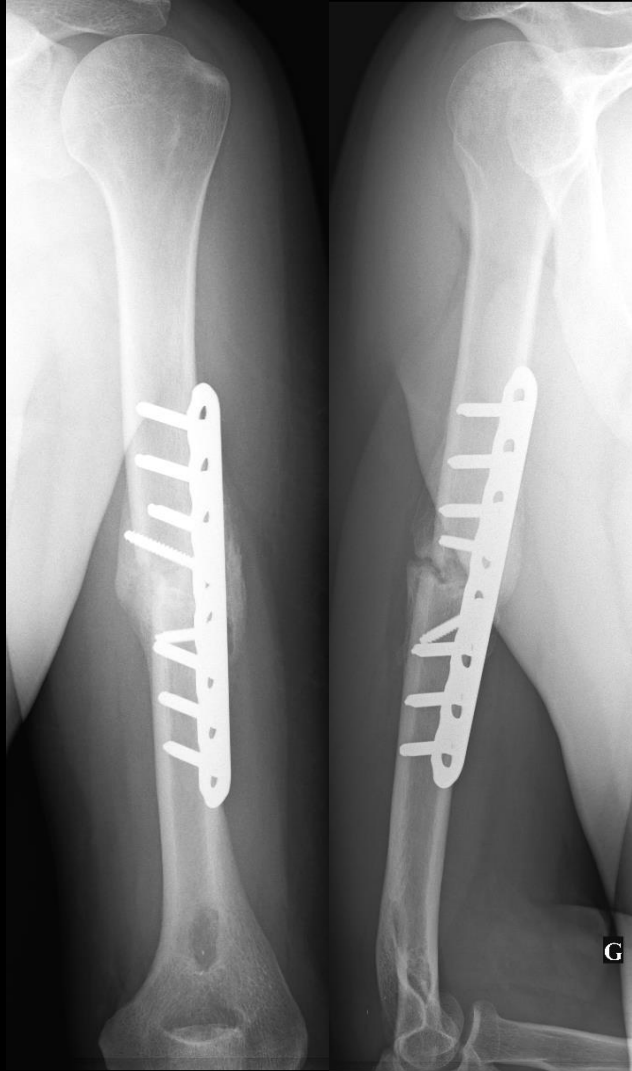
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled



G



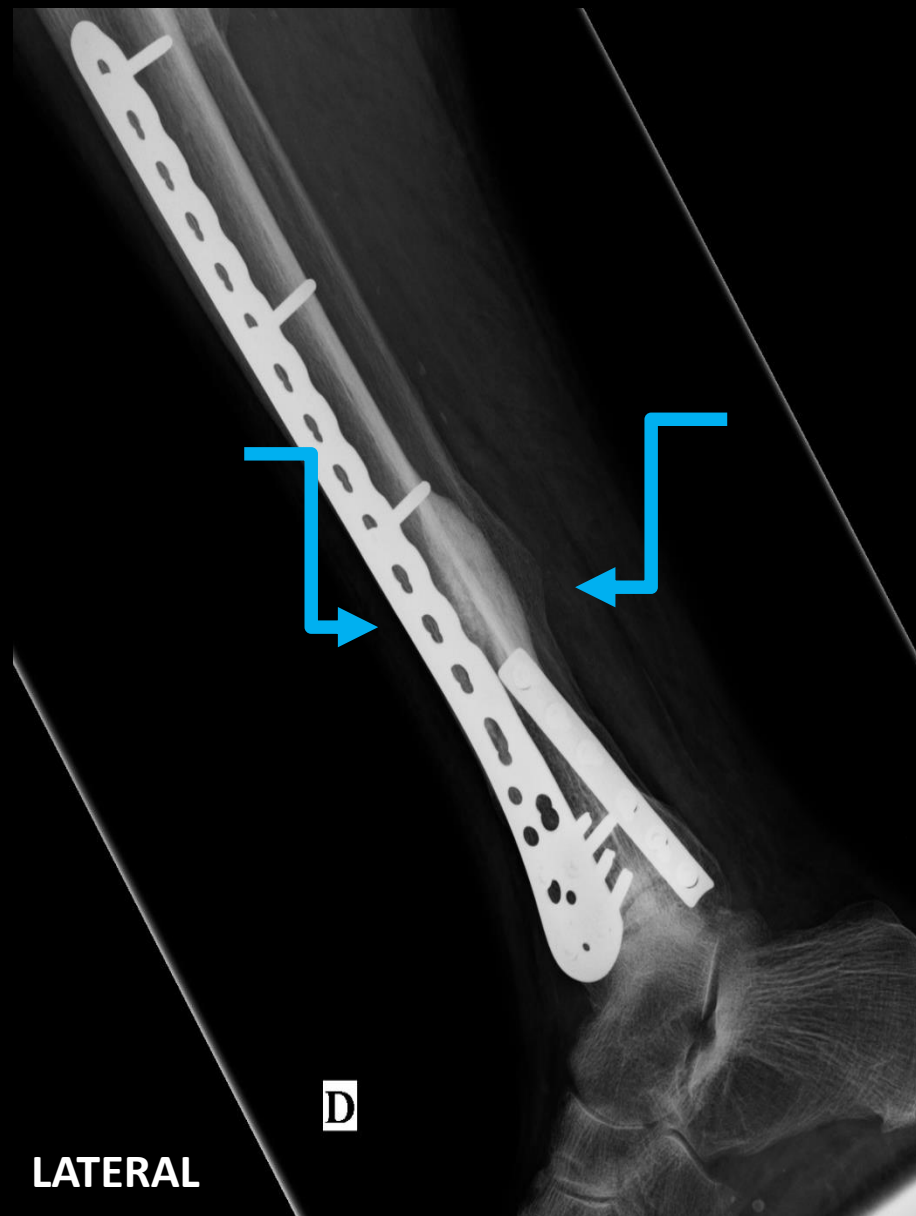
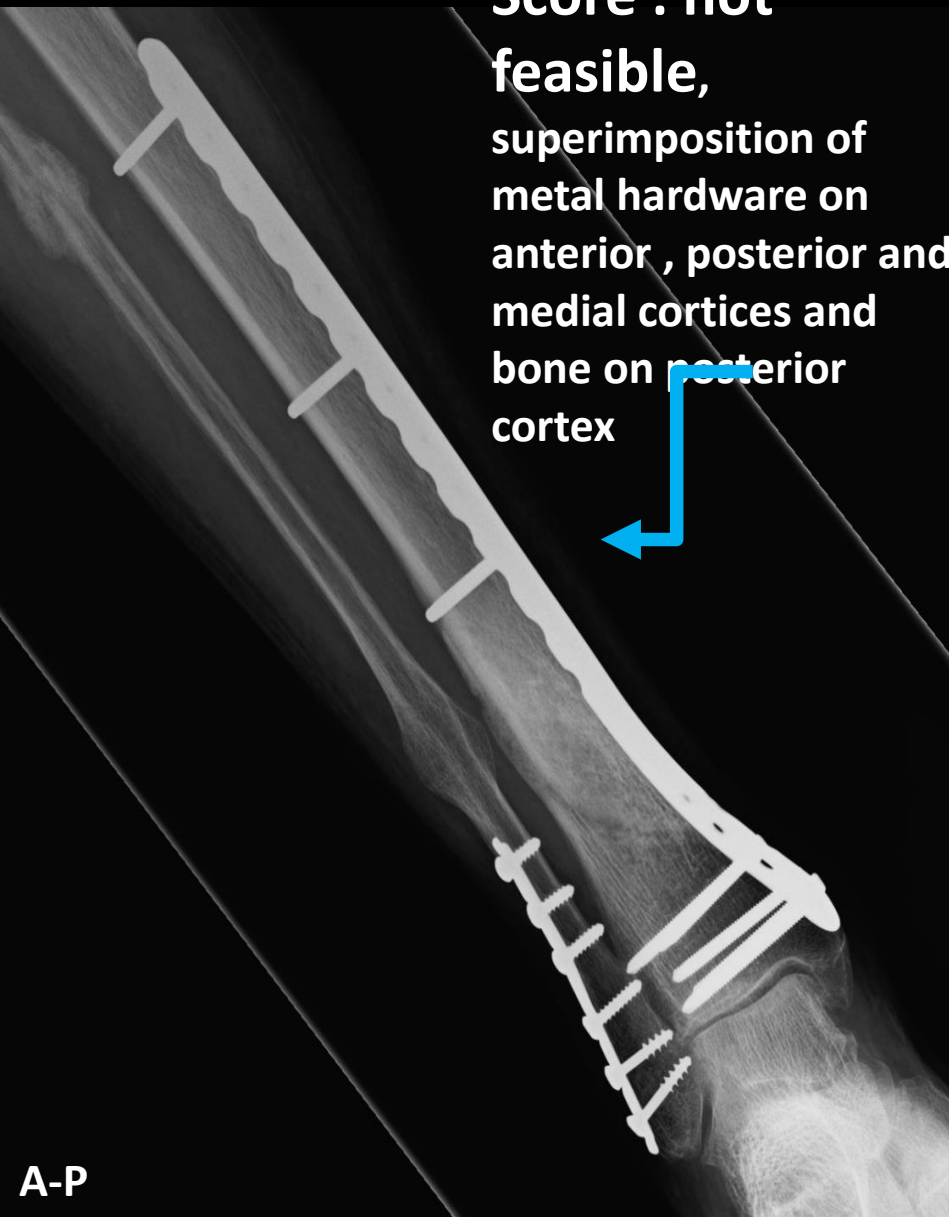
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

**Score : not
feasible,
superimposition of
metal hardware on
anterior , posterior and
medial cortices and
bone on posterior
cortex**

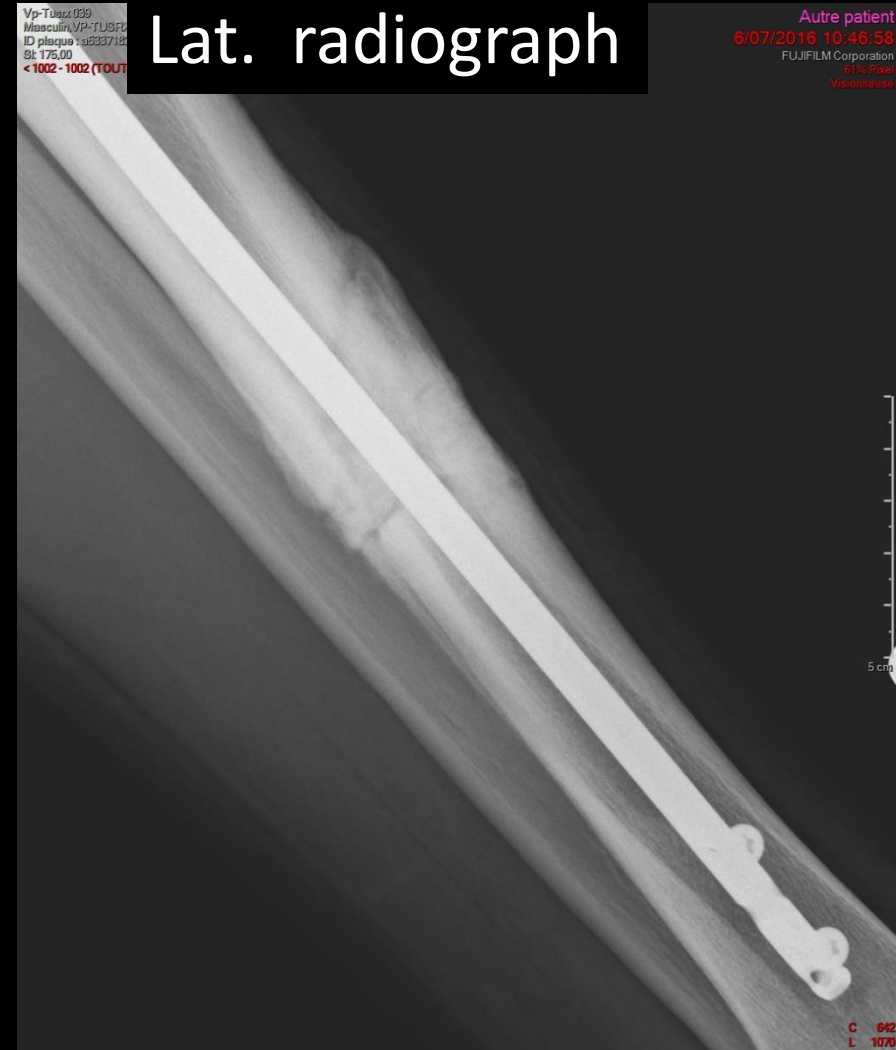


Case 2

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

Case 2

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 2

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 2

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 2

Lat. radiograph

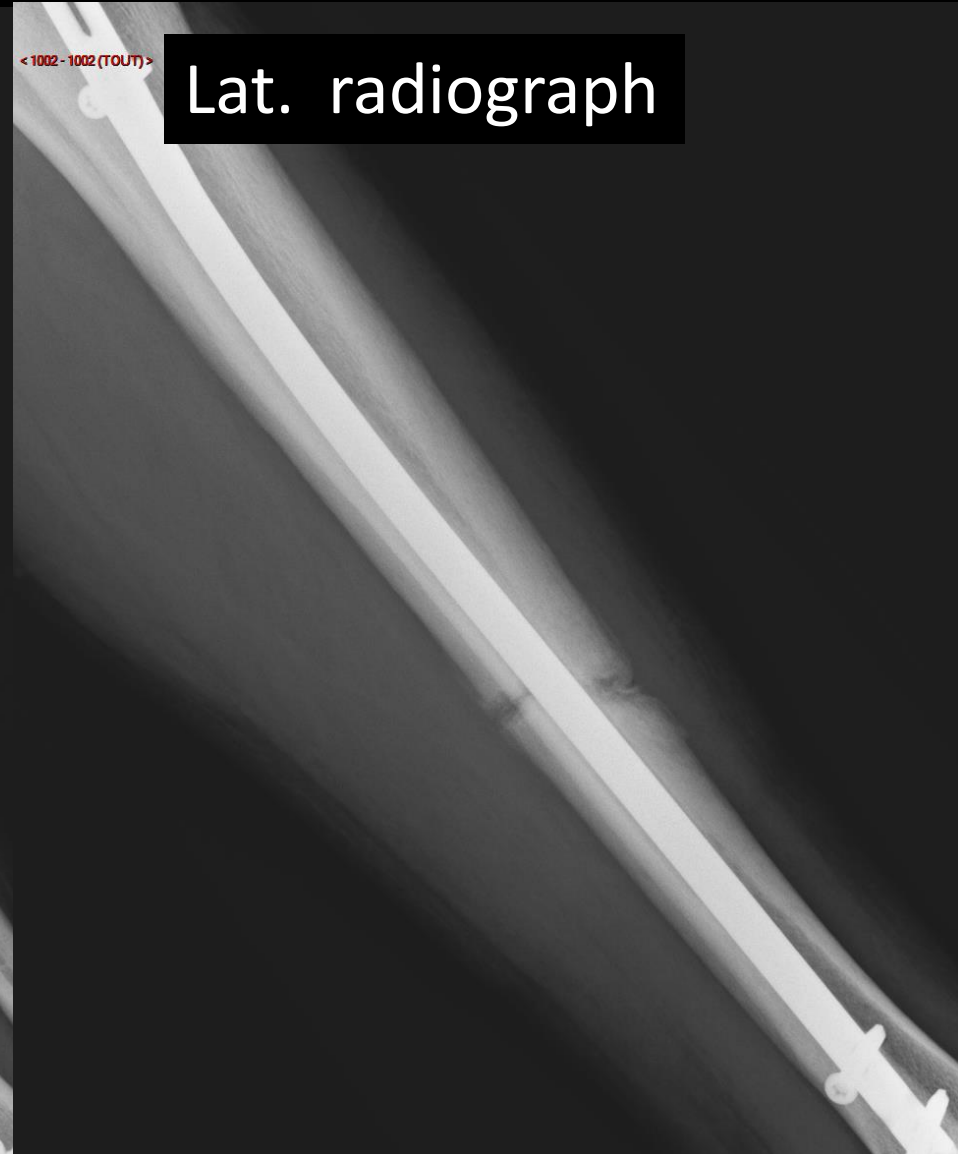
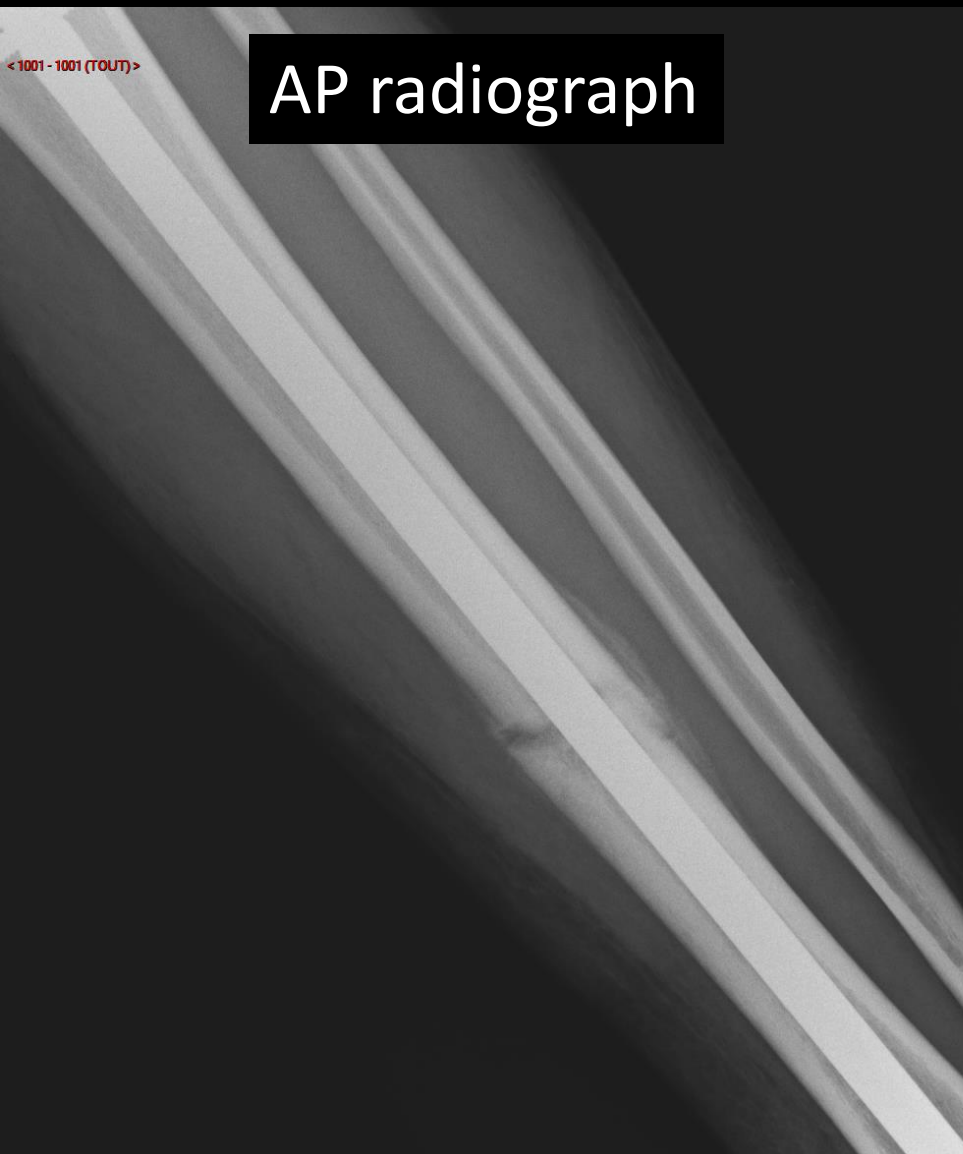


Sagittal CT reformat



1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

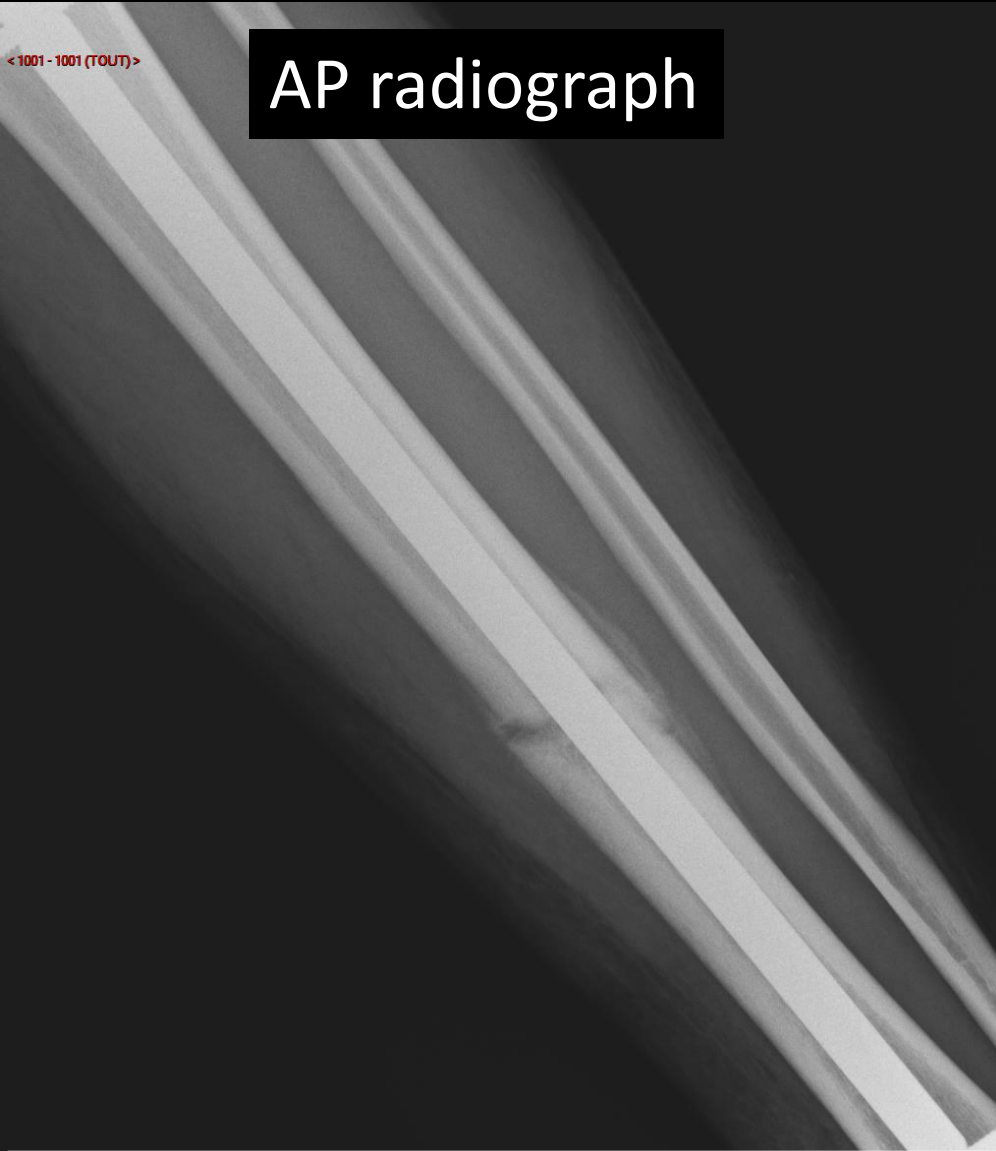
Case 3



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

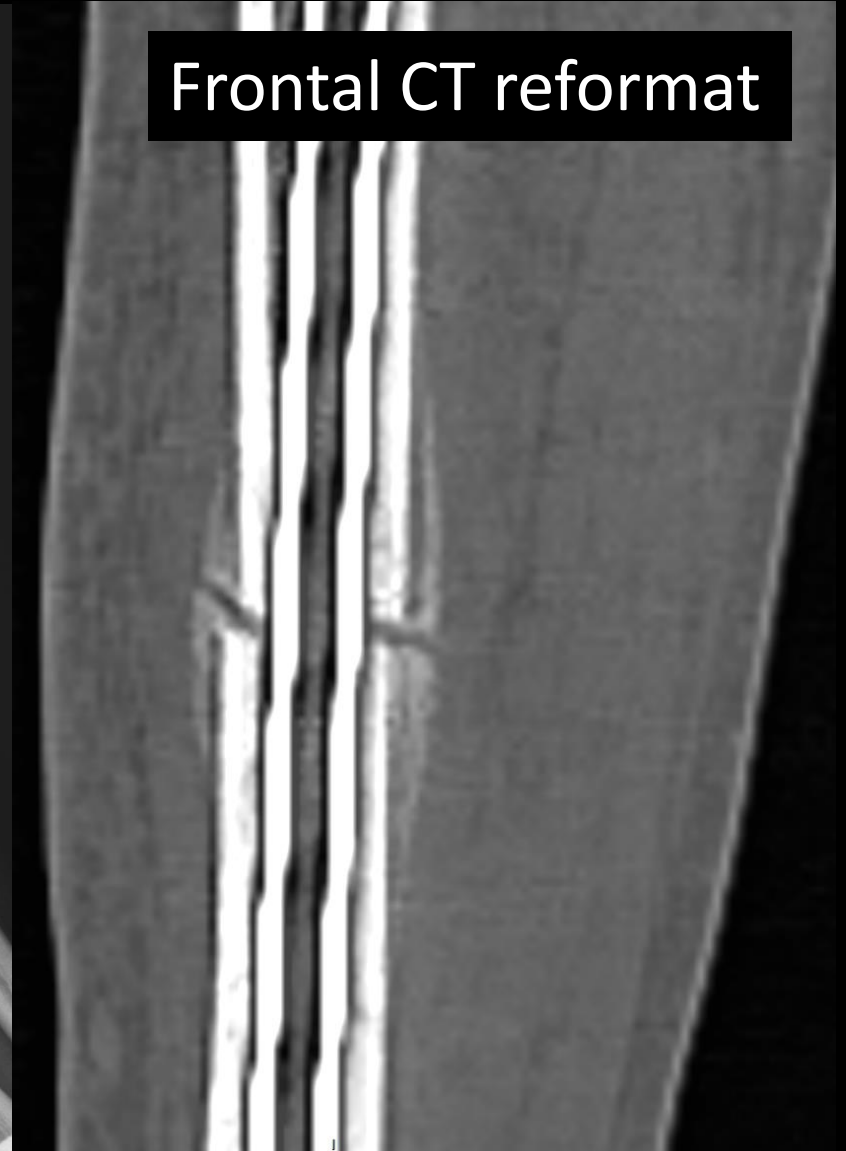
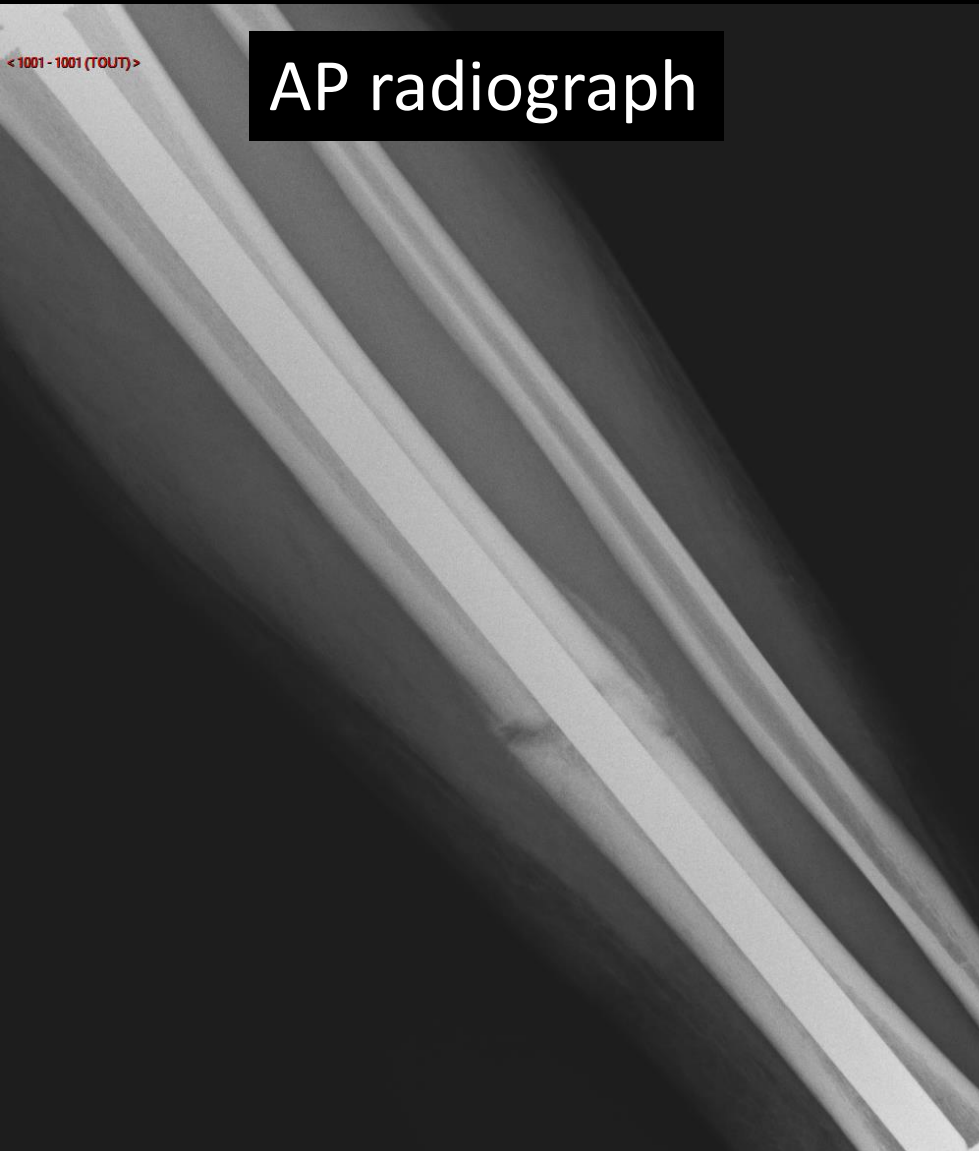
Case 3

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 3

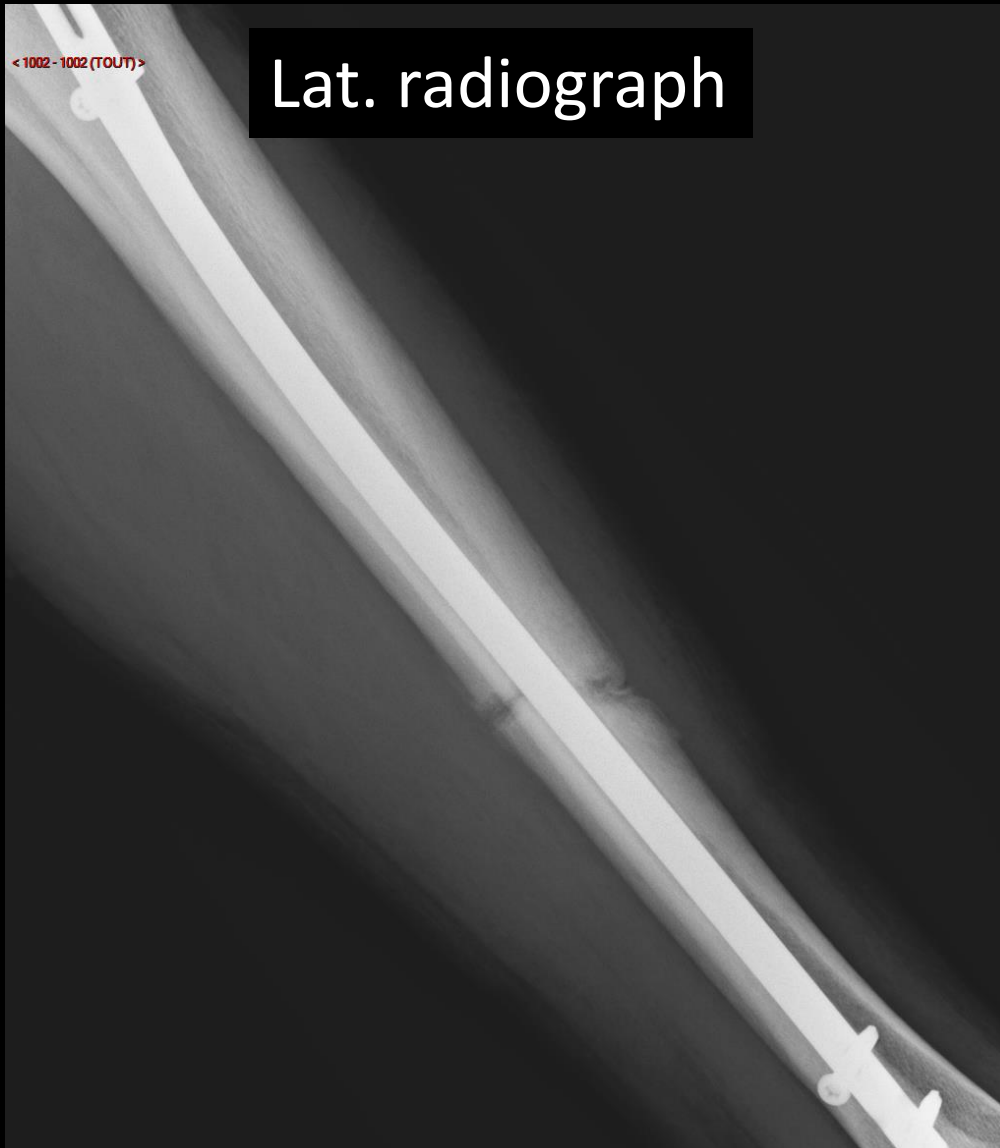


:

1: No callus / **2:** callus, not continuous / **3 :** Continuous, immature / **4:** continuous, remodelled

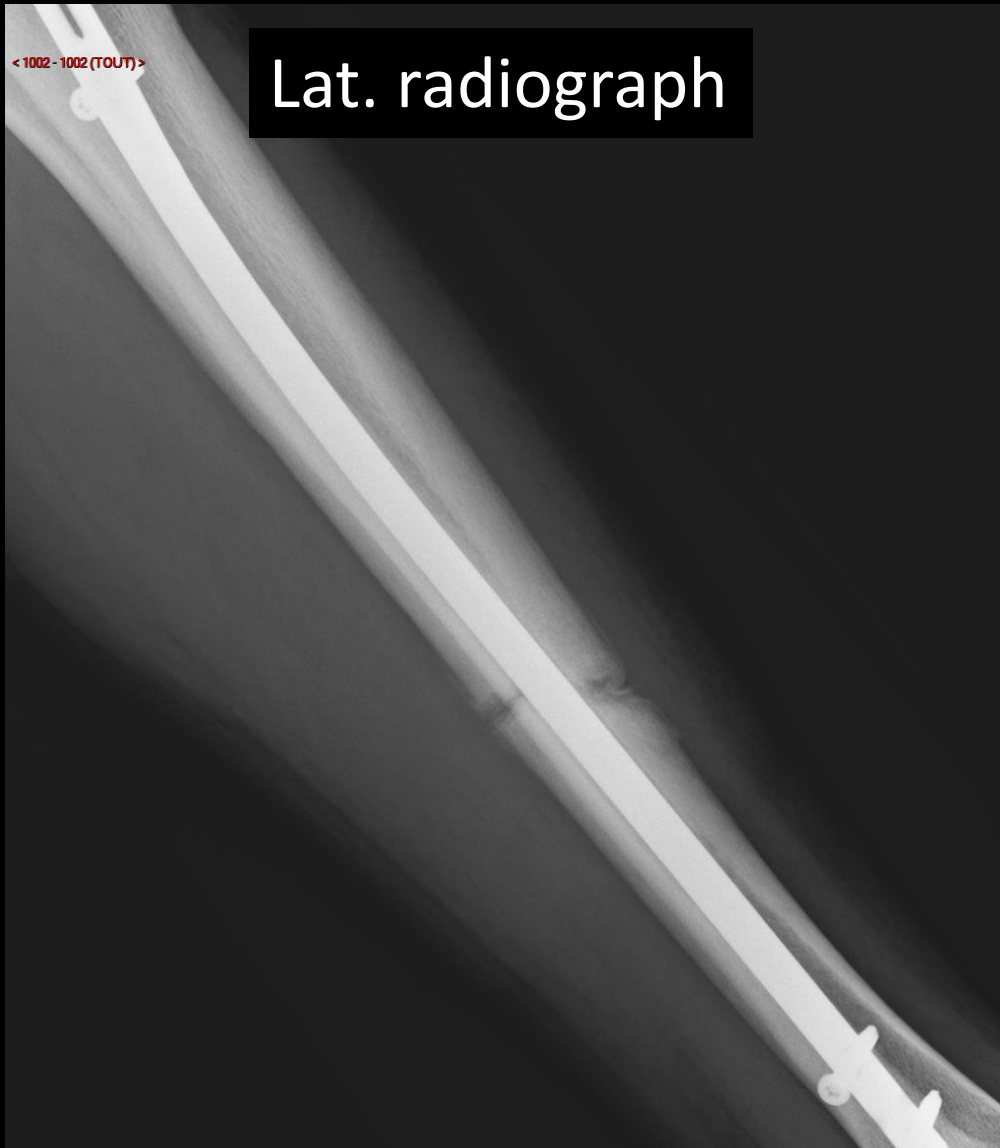
Case 3

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 3



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



Lat. radiograph



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



Frontal CT reformat



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

Lat. radiograph



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

Lat. radiograph



Sagittal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



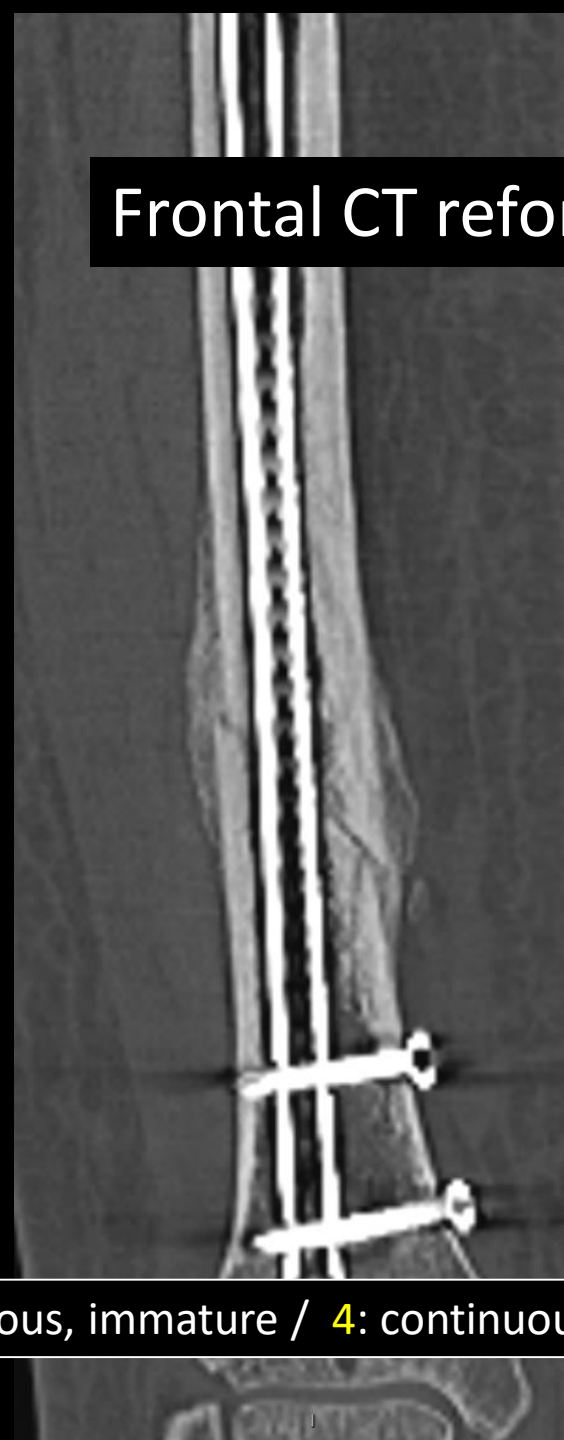
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 5



:

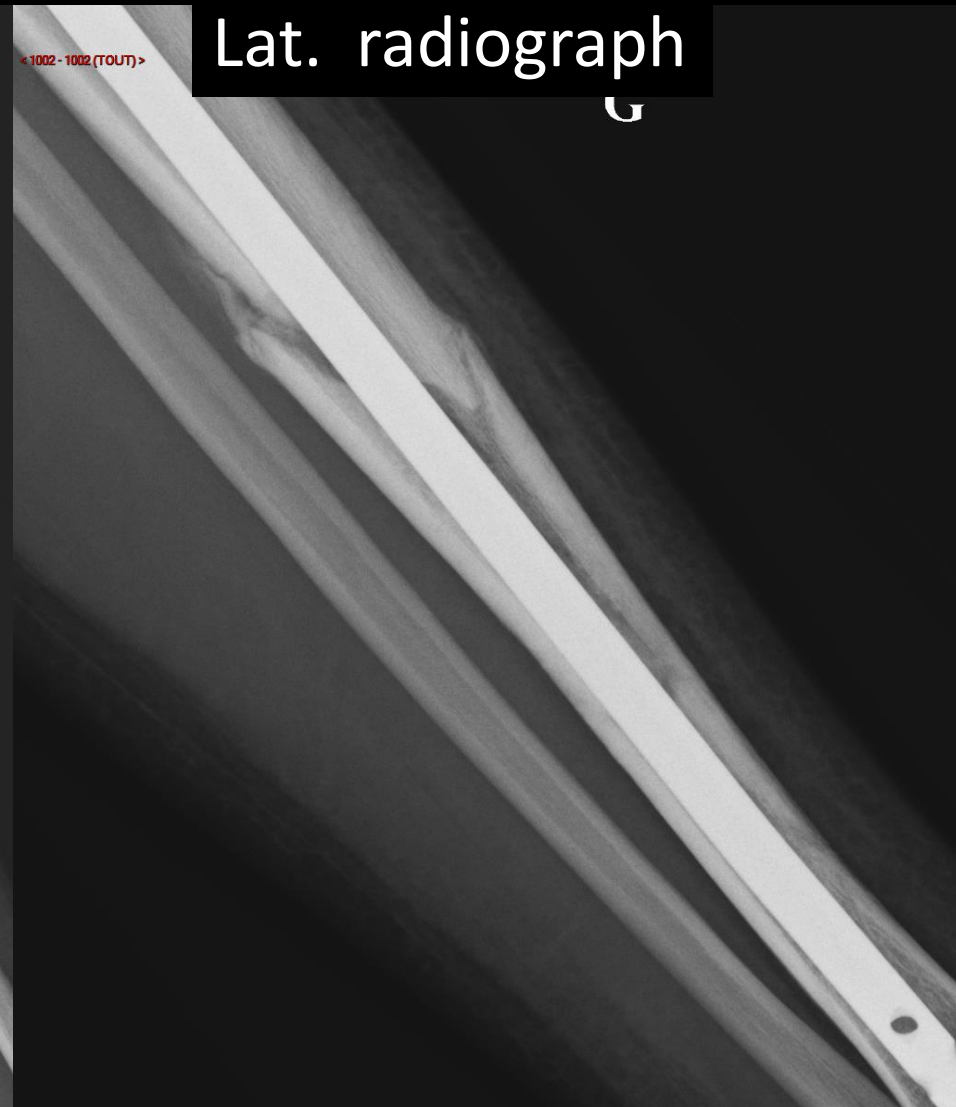
1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

Case 7

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 7

AP radiograph

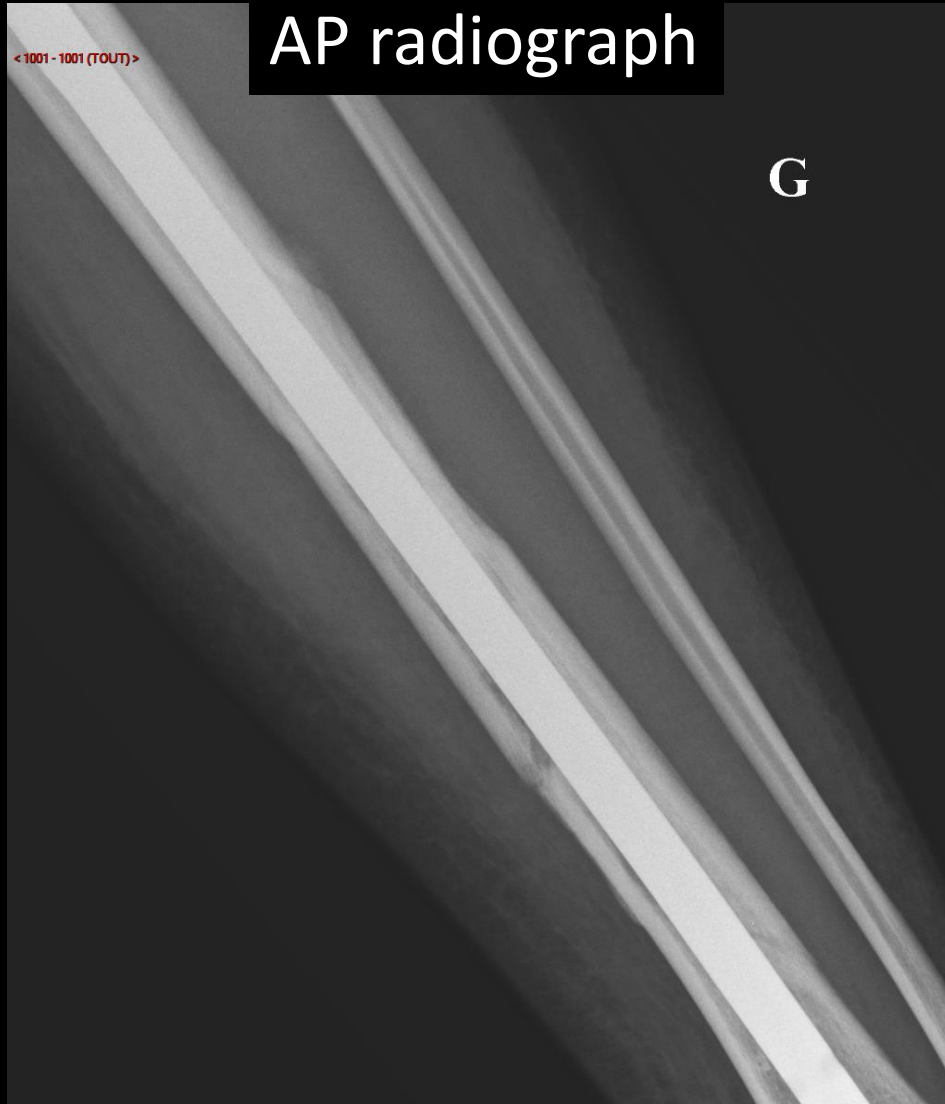
G

< 1001 - 1001 (TOU) >

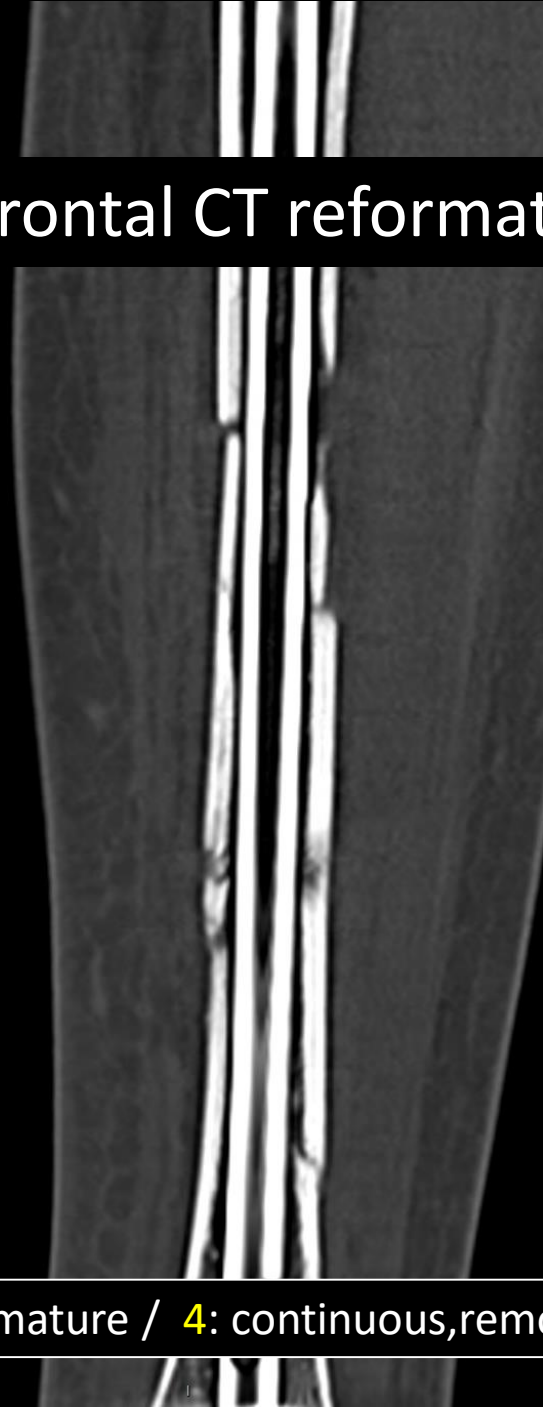
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 7

AP radiograph



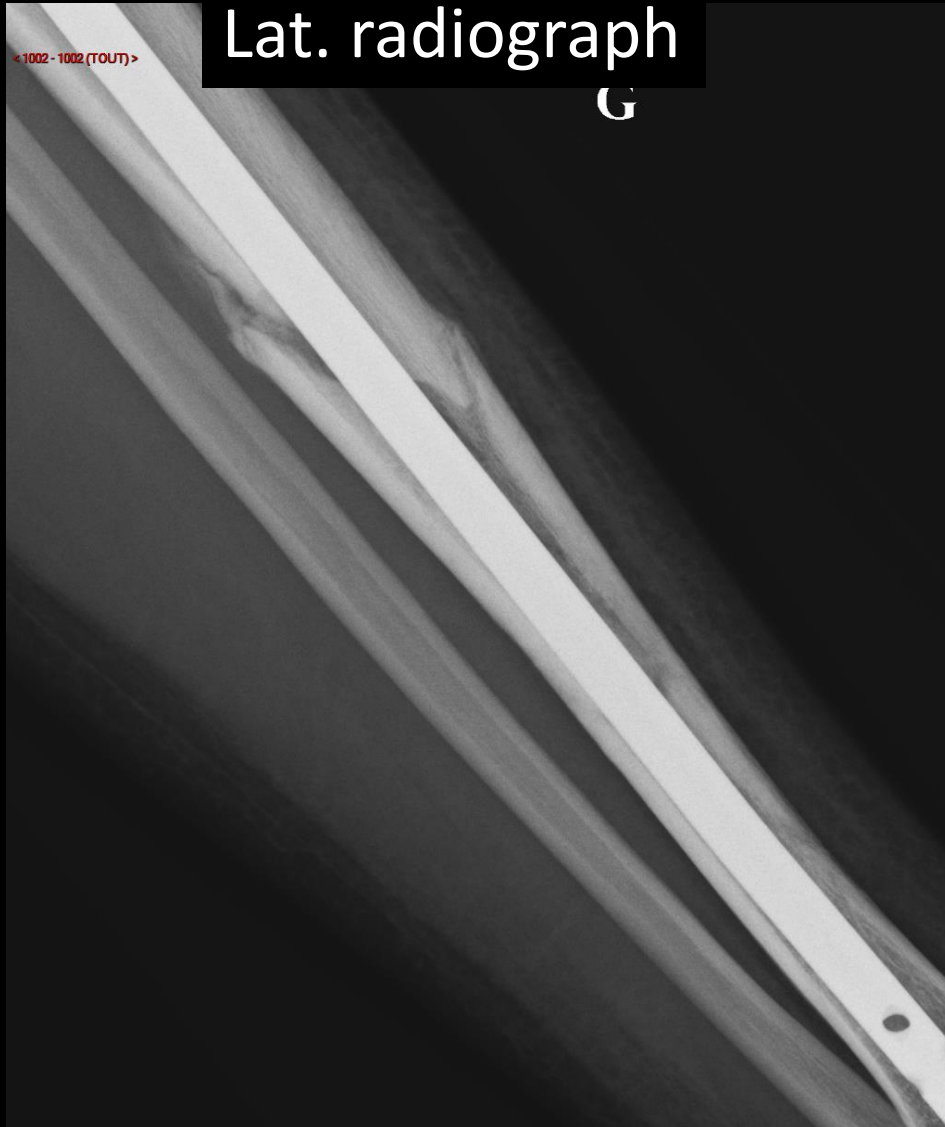
Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

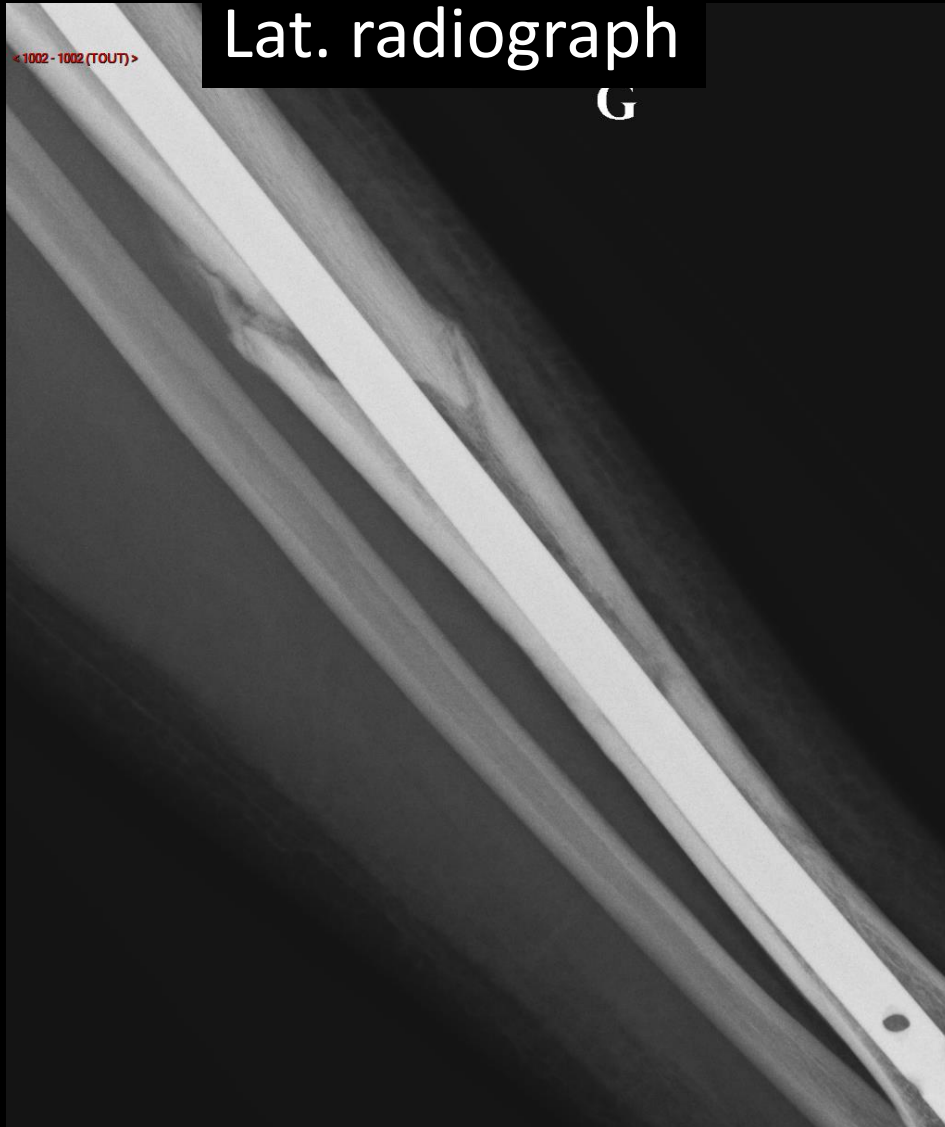
Case 7

Lat. radiograph



Case 7

Lat. radiograph



Sagittal CT reformat



Case 8

AP radiograph



Lat. radiograph



Case 8

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 8

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 8

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 8

Lat. radiograph



Sagittal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9

AP radiograph



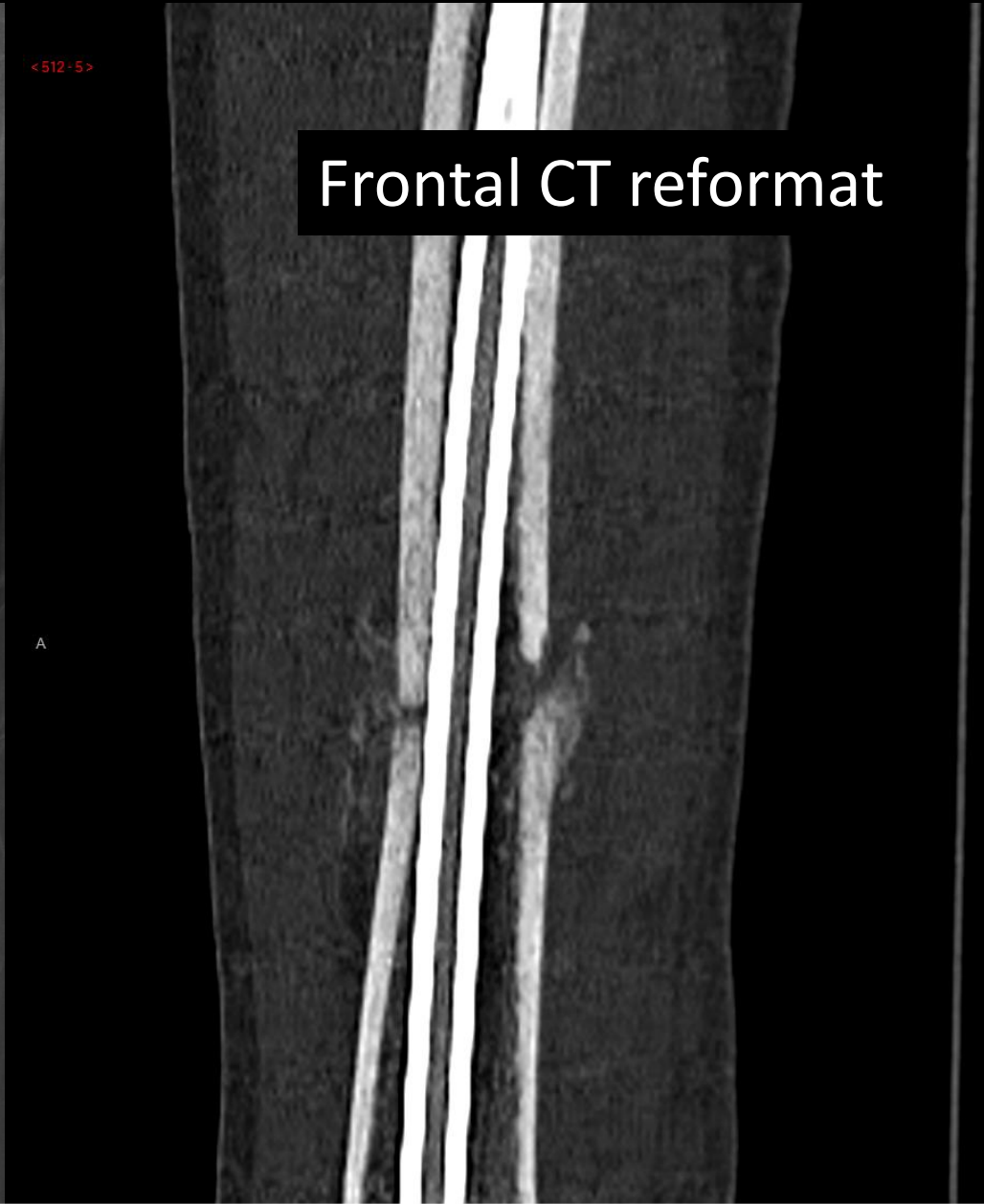
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9

AP radiograph



Frontal CT reformat



:

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9

Lat. radiograph



Sagittal CT reformat



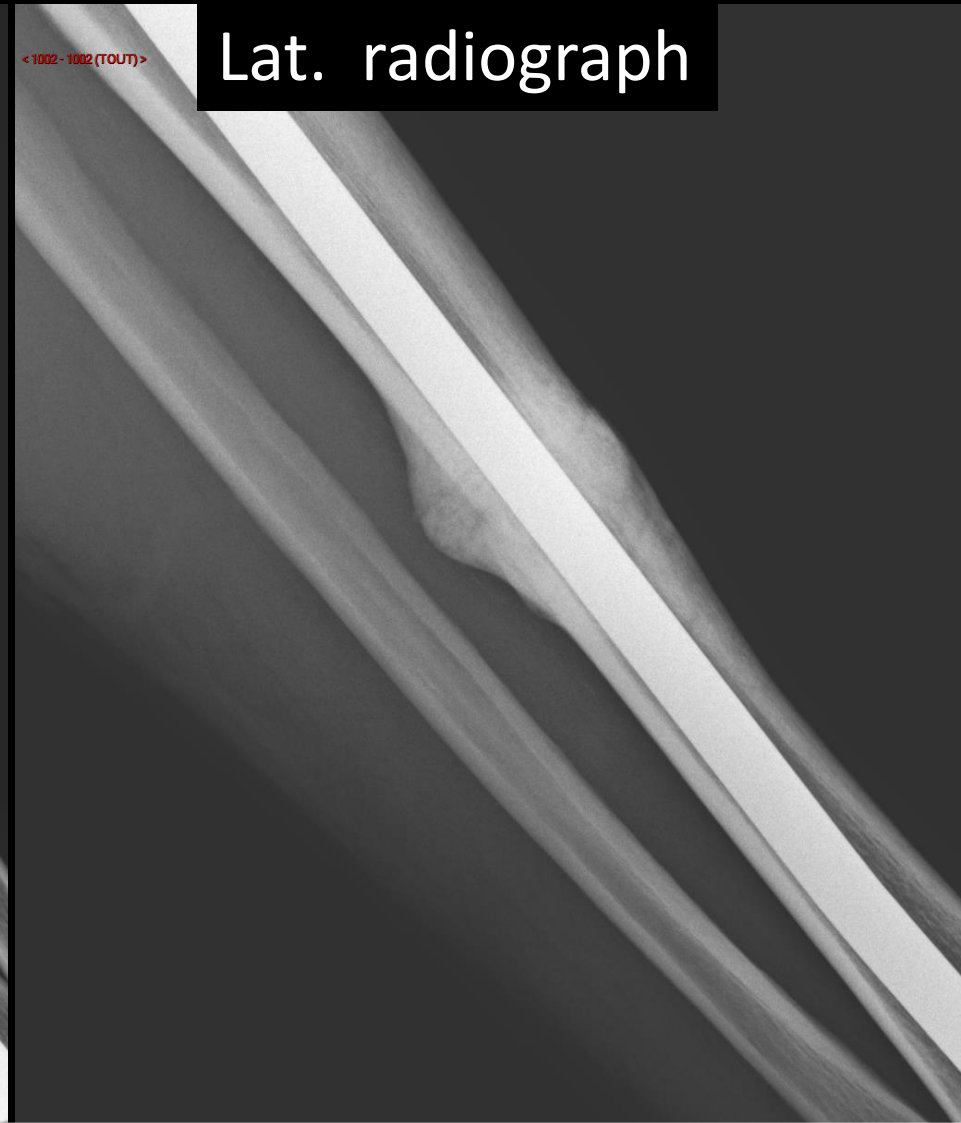
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9 bis

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9 bis

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9 bis

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9 bis

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 9 bis



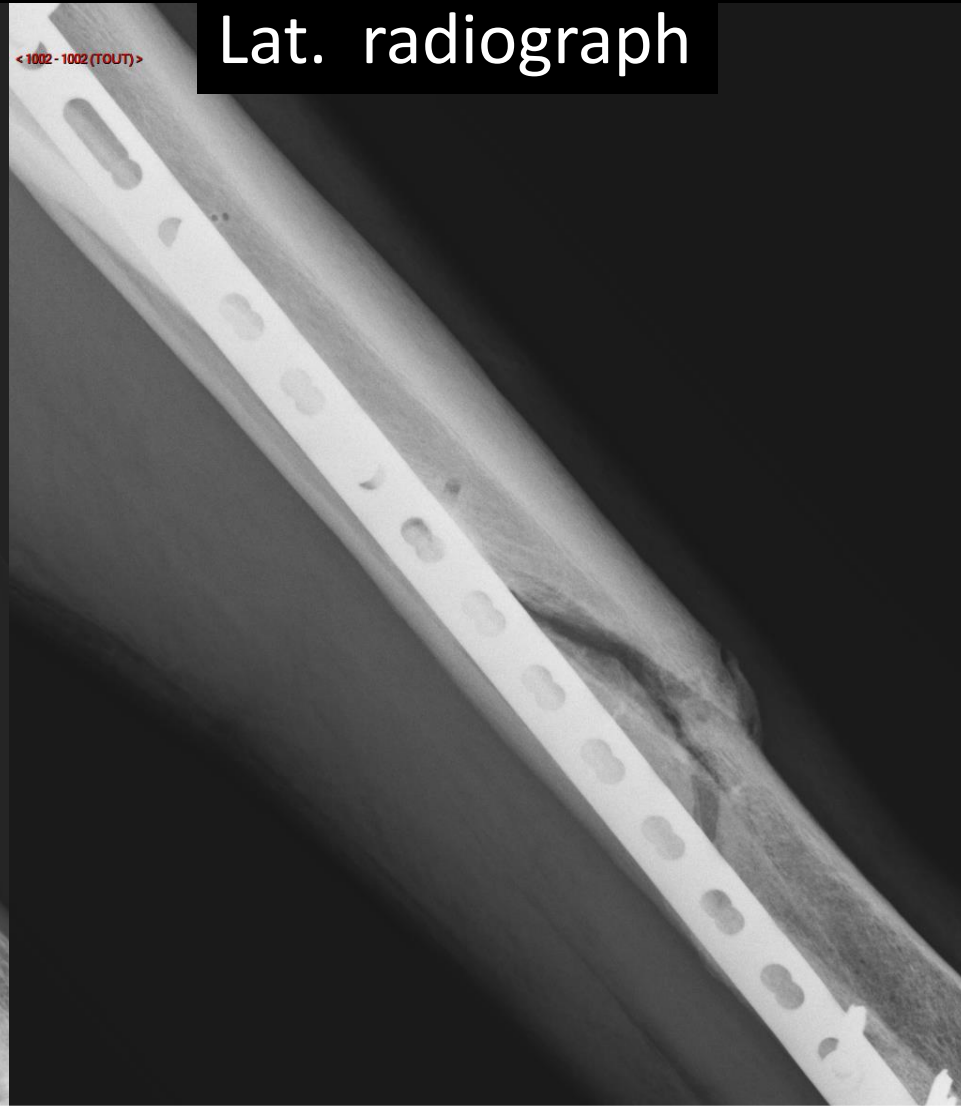
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 10

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 10

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 10

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 10

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 10

Lat. radiograph



Sagittal CT reformat



:

1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

Case 11

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 11

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 11

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 11

Lat. radiograph



Case 11

Lat. radiograph



Sagittal CT reformat



Case 13

AP radiograph



Lat. radiograph



Case 13

AP radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 13

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 13

Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 13

Lat. radiograph



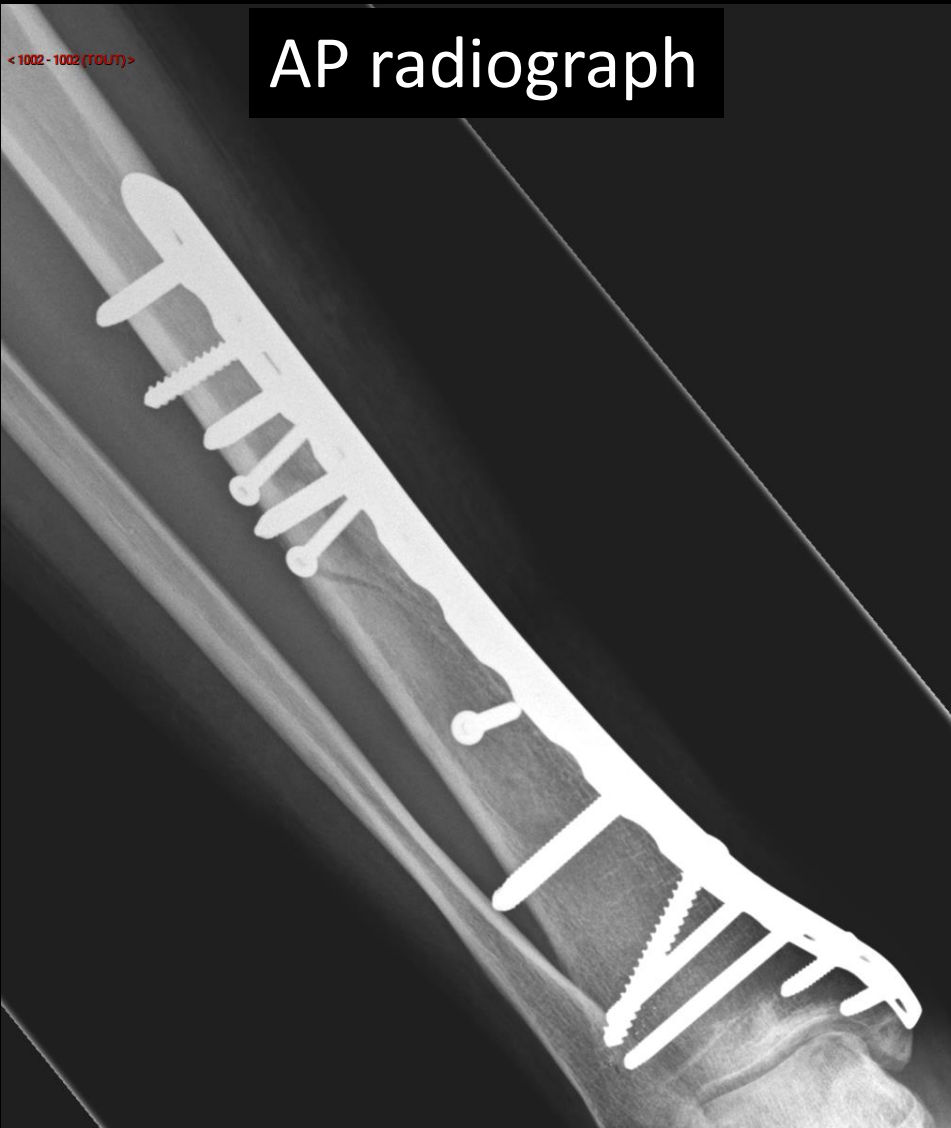
Sagittal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 14

AP radiograph



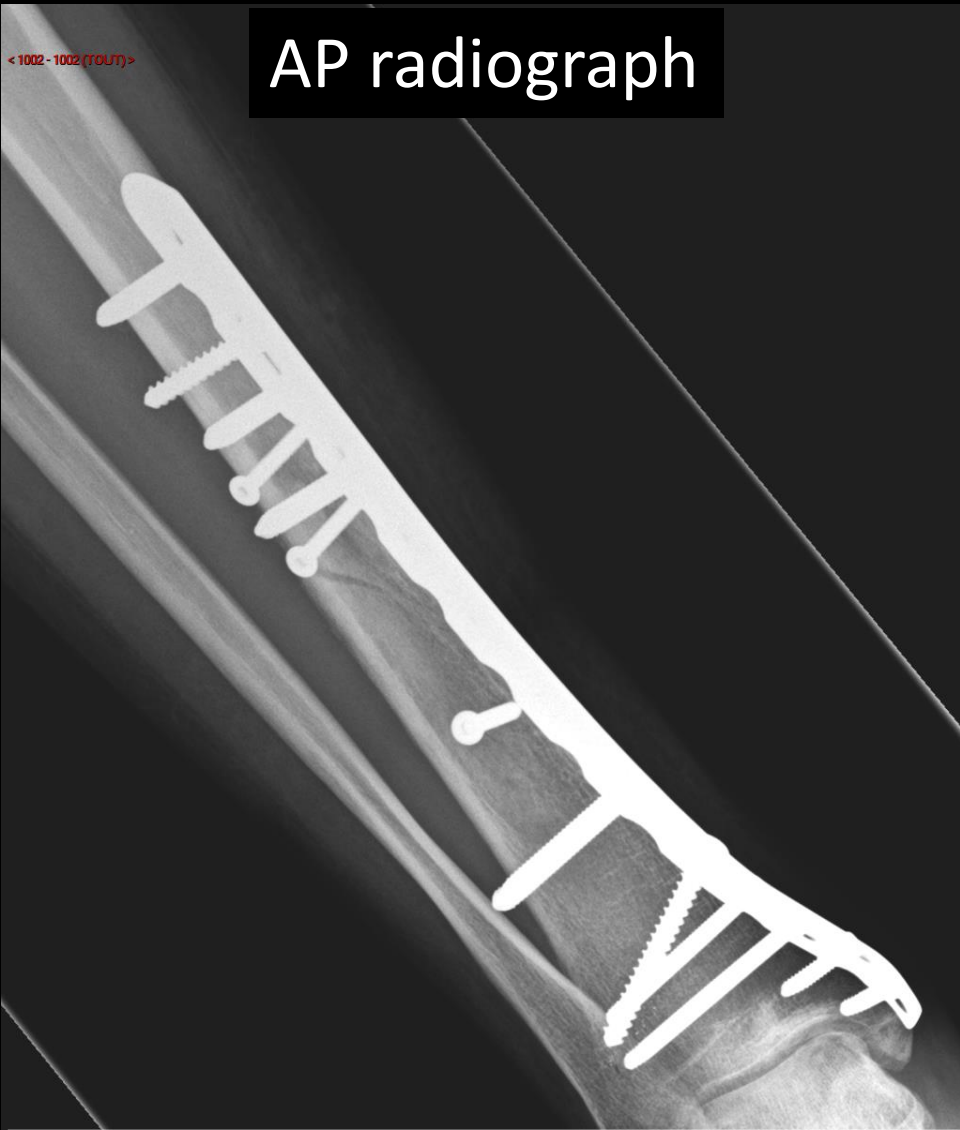
Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 14

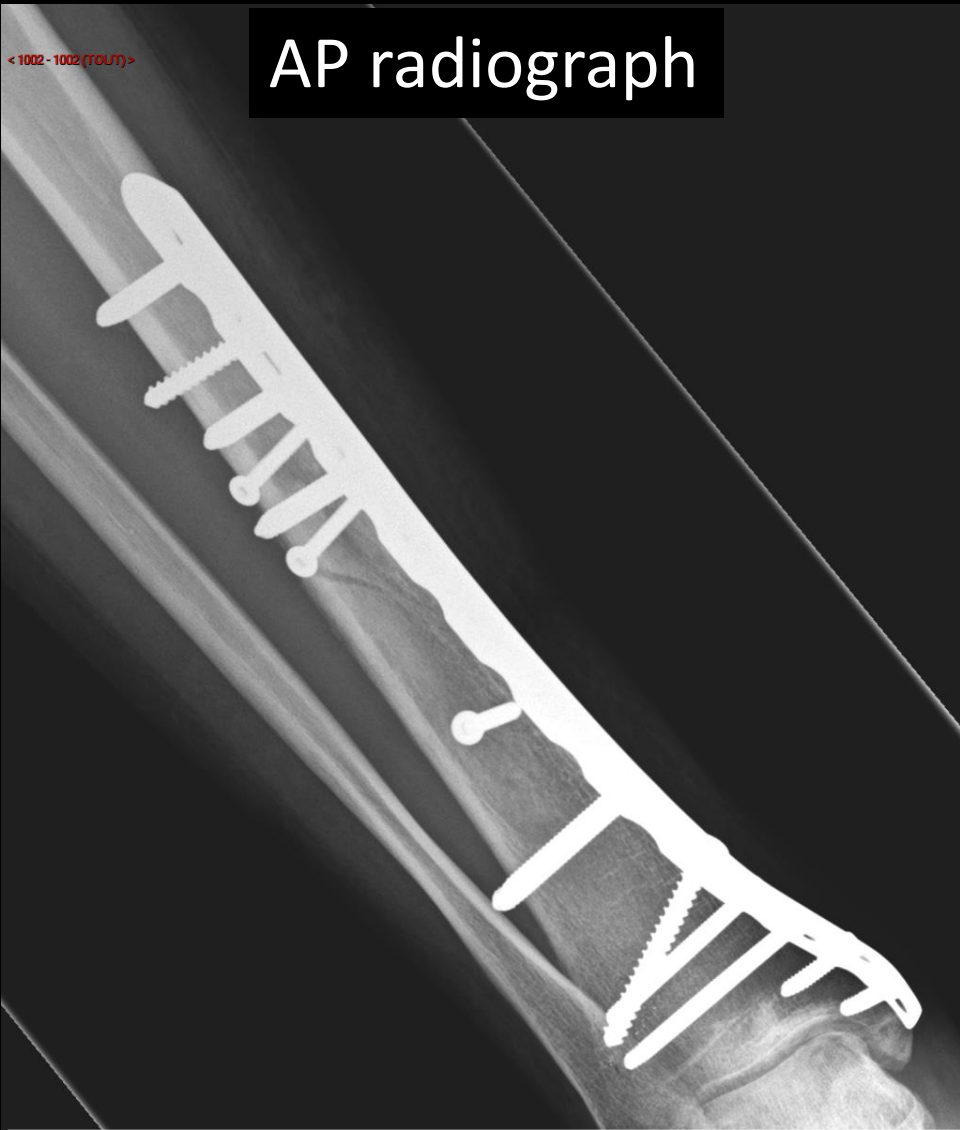
AP radiograph



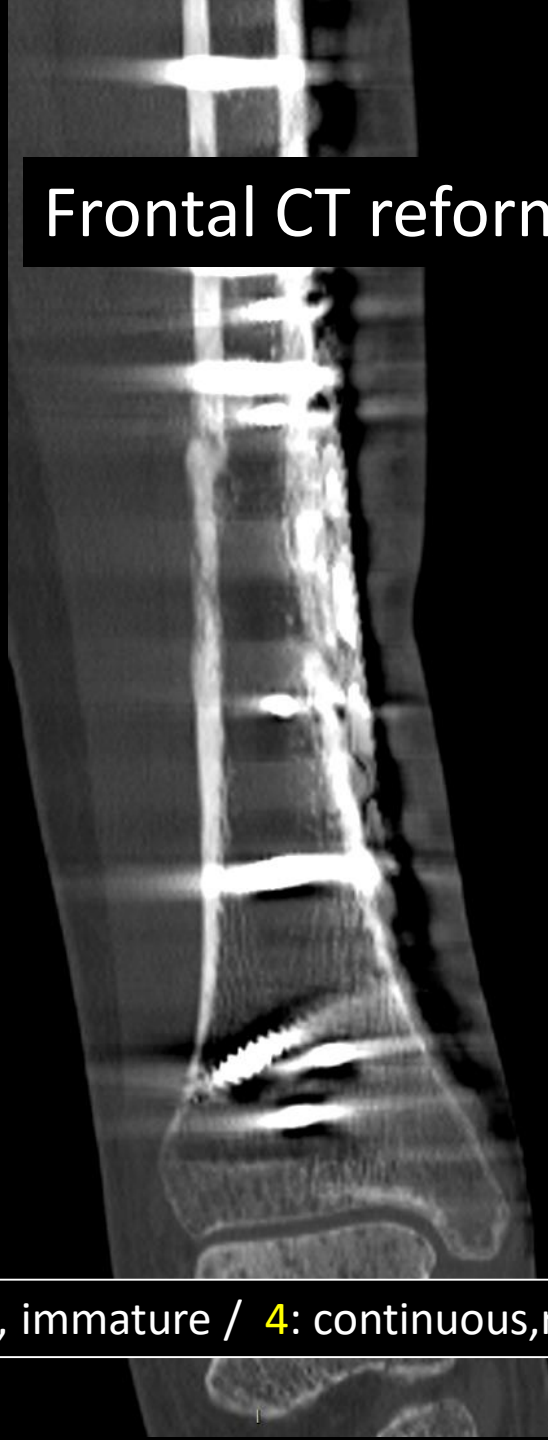
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 14

AP radiograph



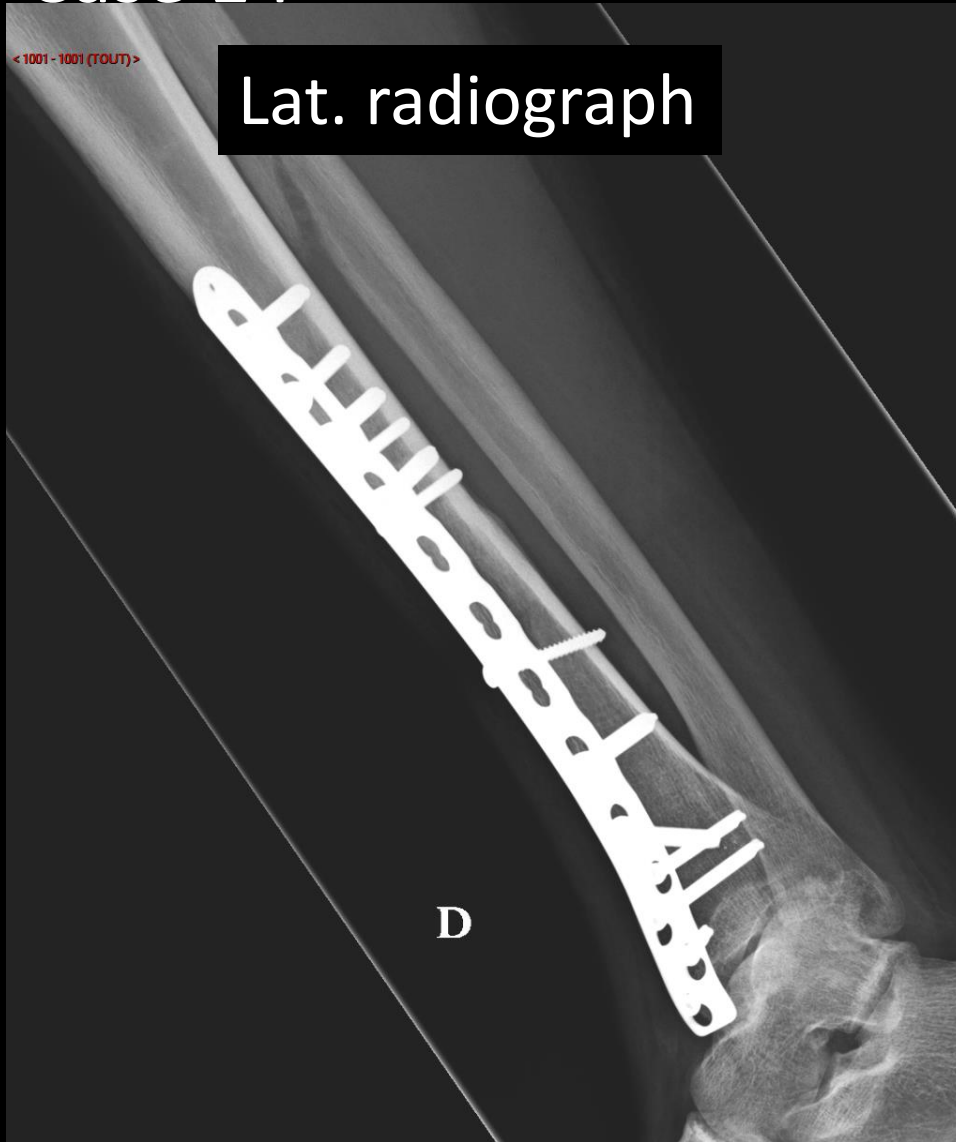
Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 14

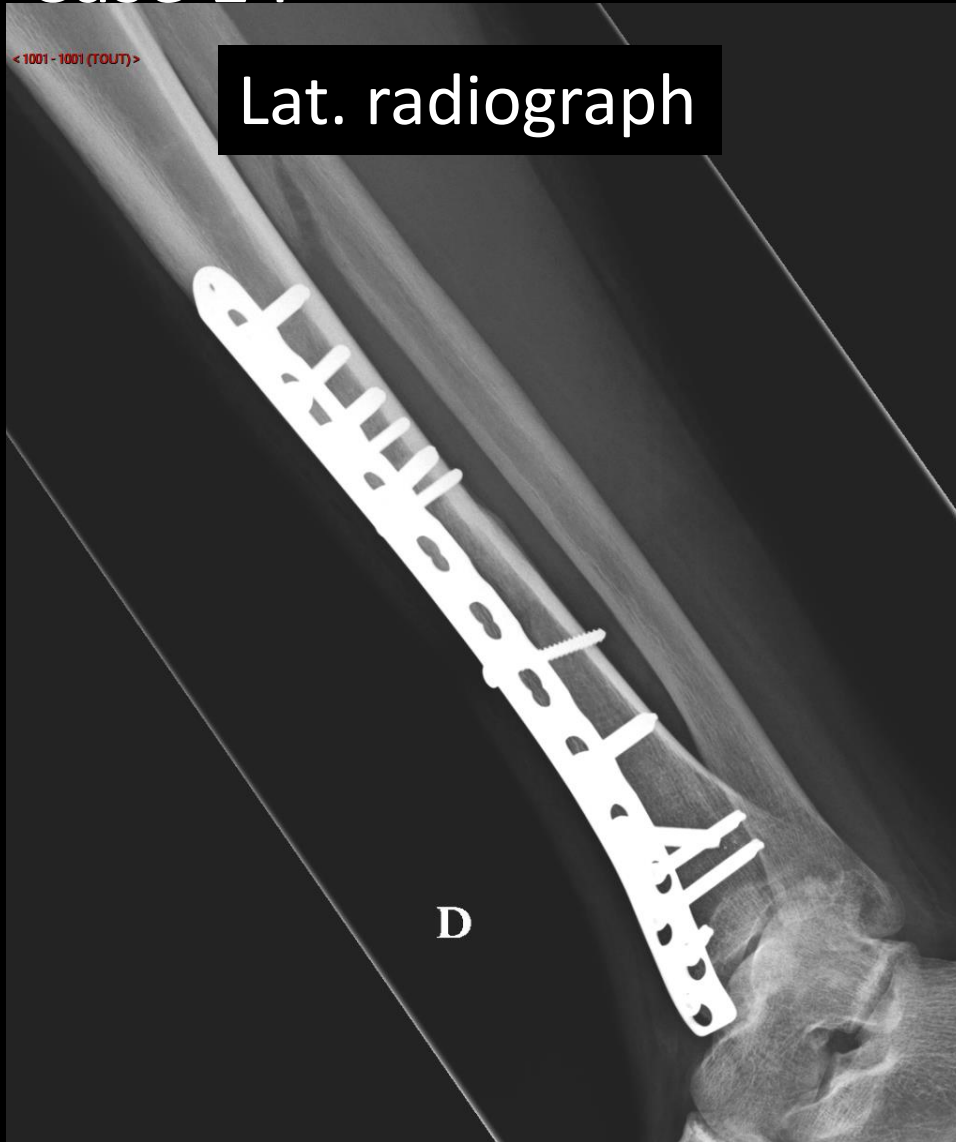
Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 14

Lat. radiograph



Sagittal CT reformat



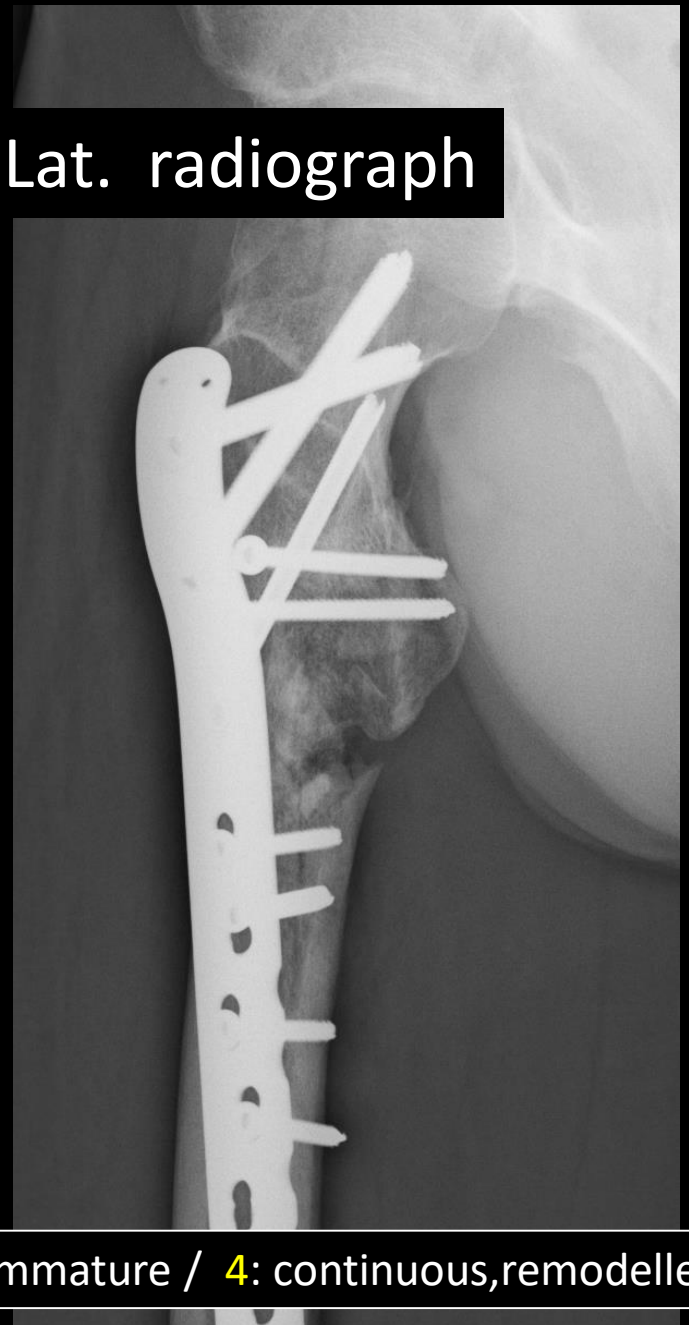
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 15

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 16

AP radiograph



Vp-Tusx 044
Fémur in, VP-TUSFX 044
ID plaque : a52661648c
St: 303,00
<1003 - 1003>

Lat. radiograph



1: No callus / 2: callus, not continuous / 3: Continuous, immature / 4: continuous, remodelled

Case 17

AP radiograph



Frontal CT reformat



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 18

AP radiograph



Lat. radiograph



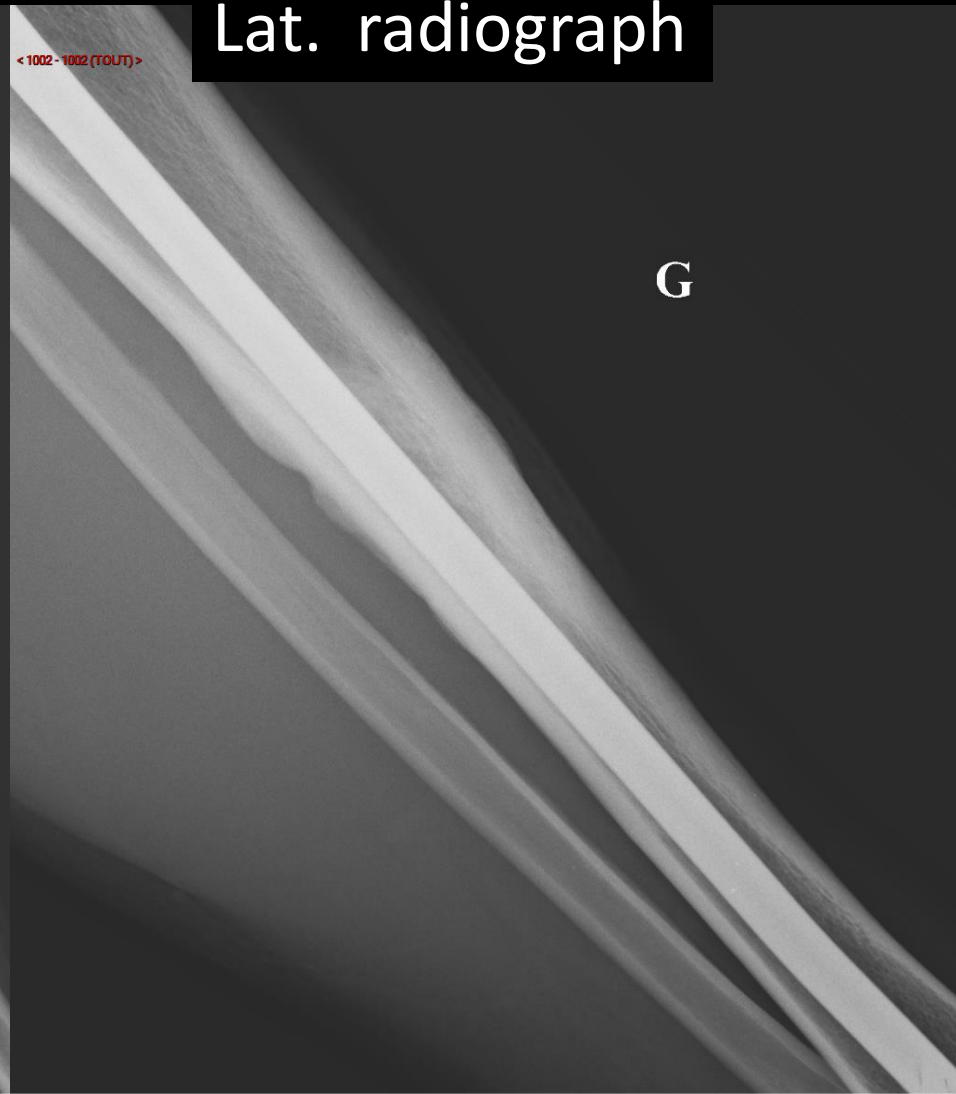
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 19

AP radiograph



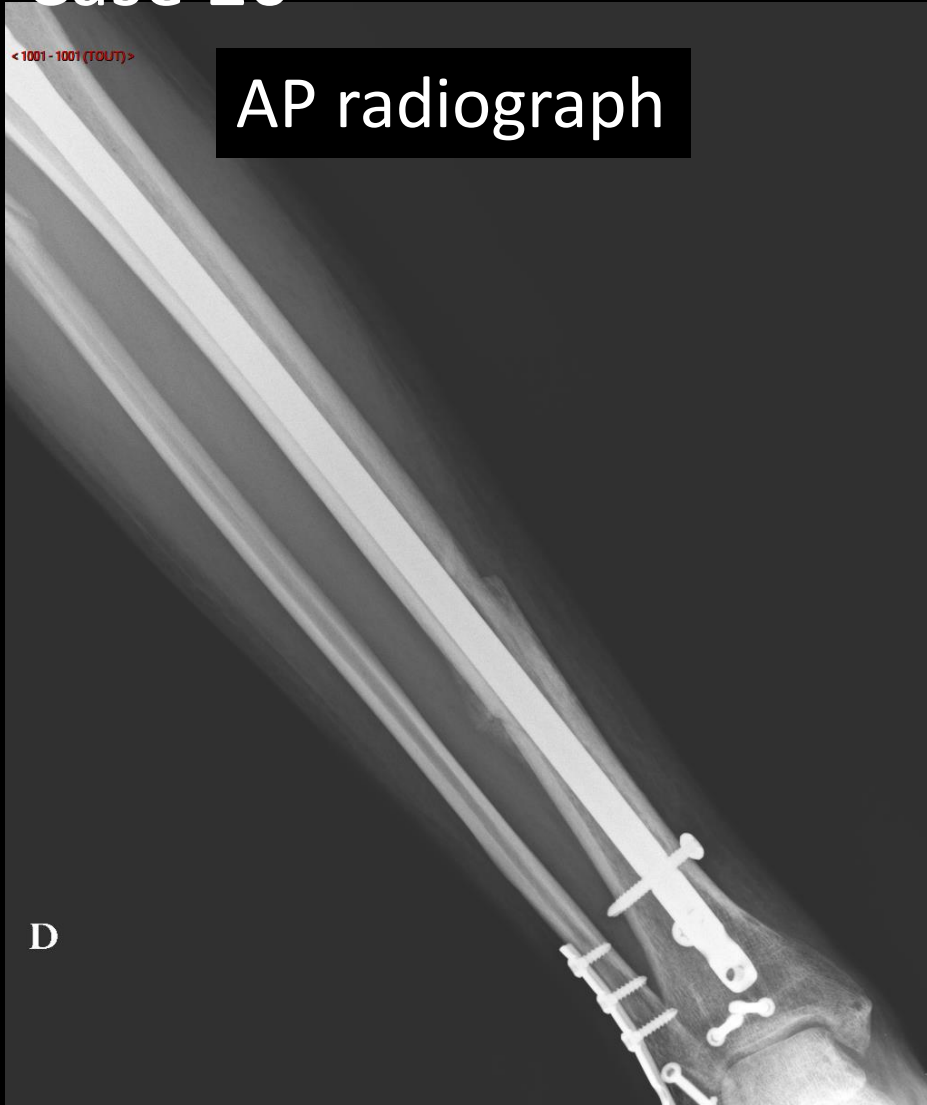
Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 20

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 21

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 22

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 23

AP radiograph



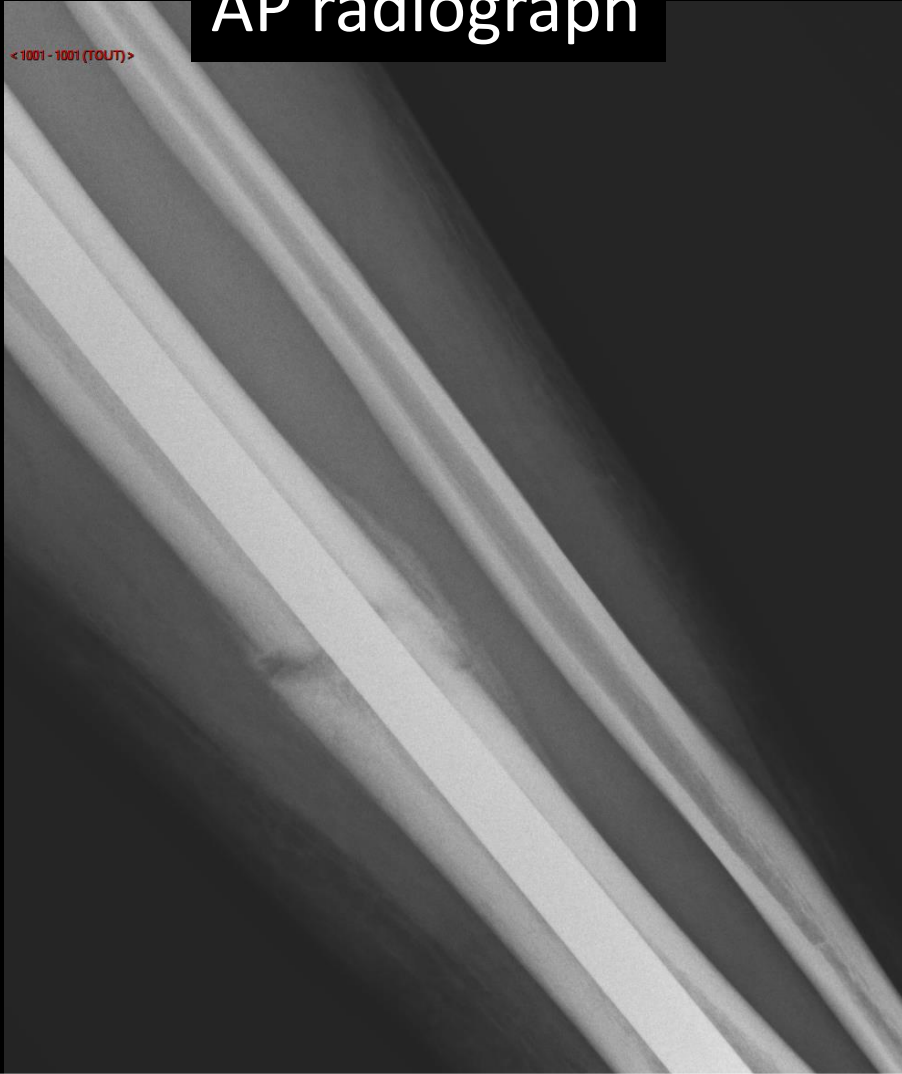
Lat. radiograph



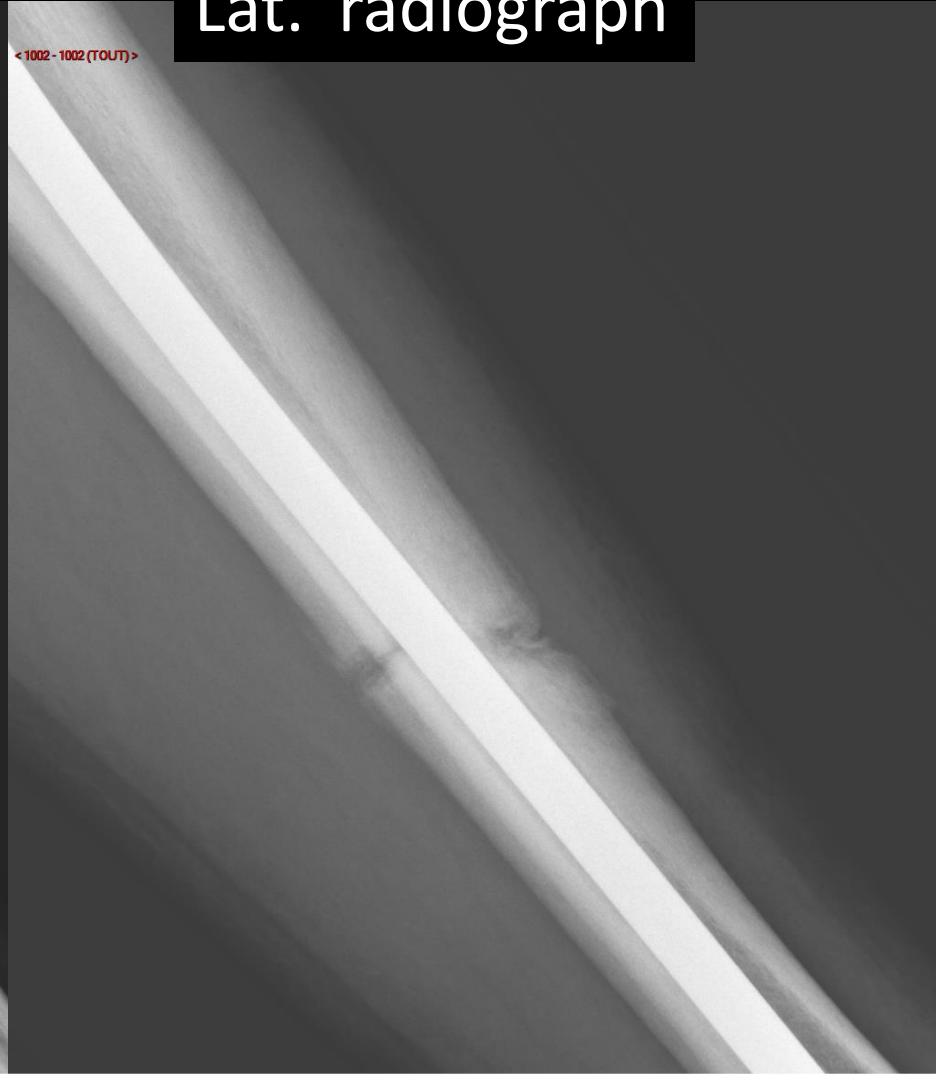
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 24

AP radiograph



Lat. radiograph



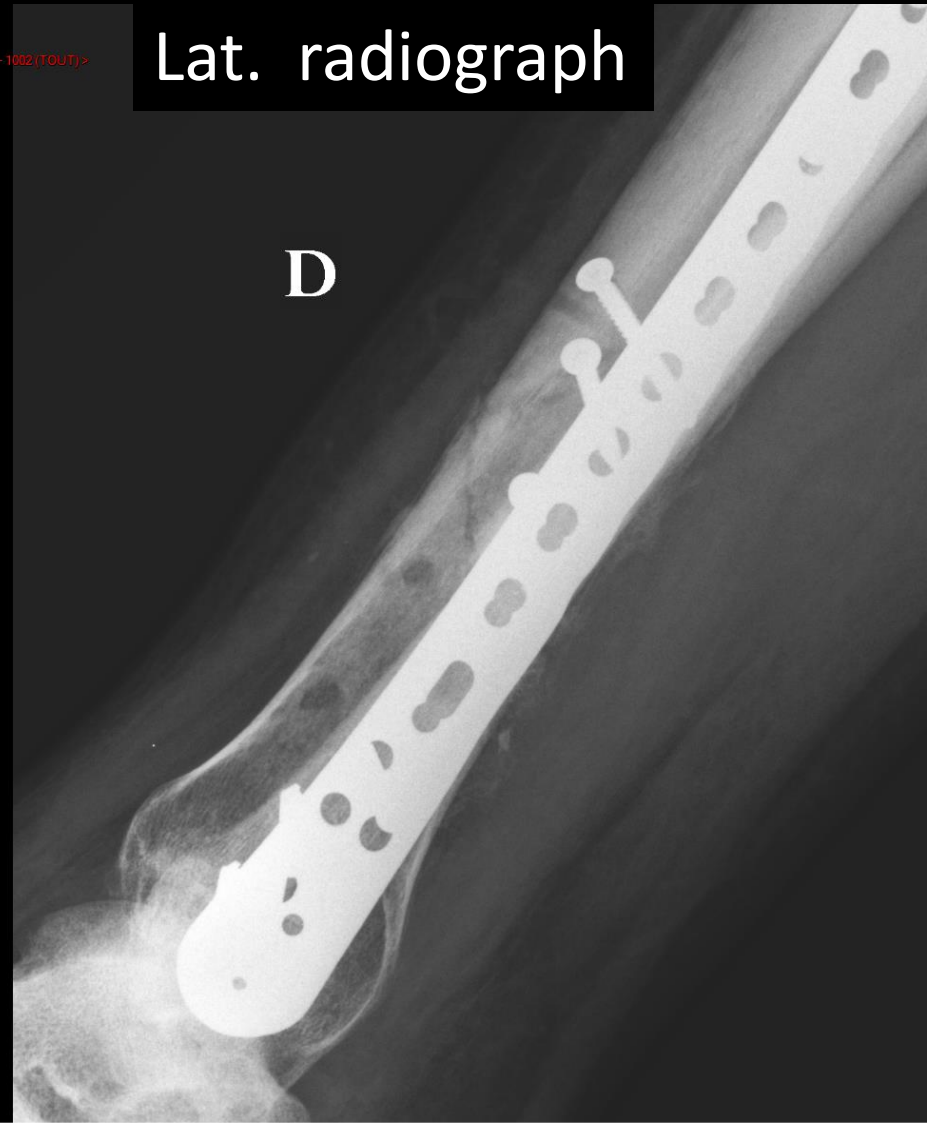
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 25

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 26

AP radiograph



Lat. radiograph



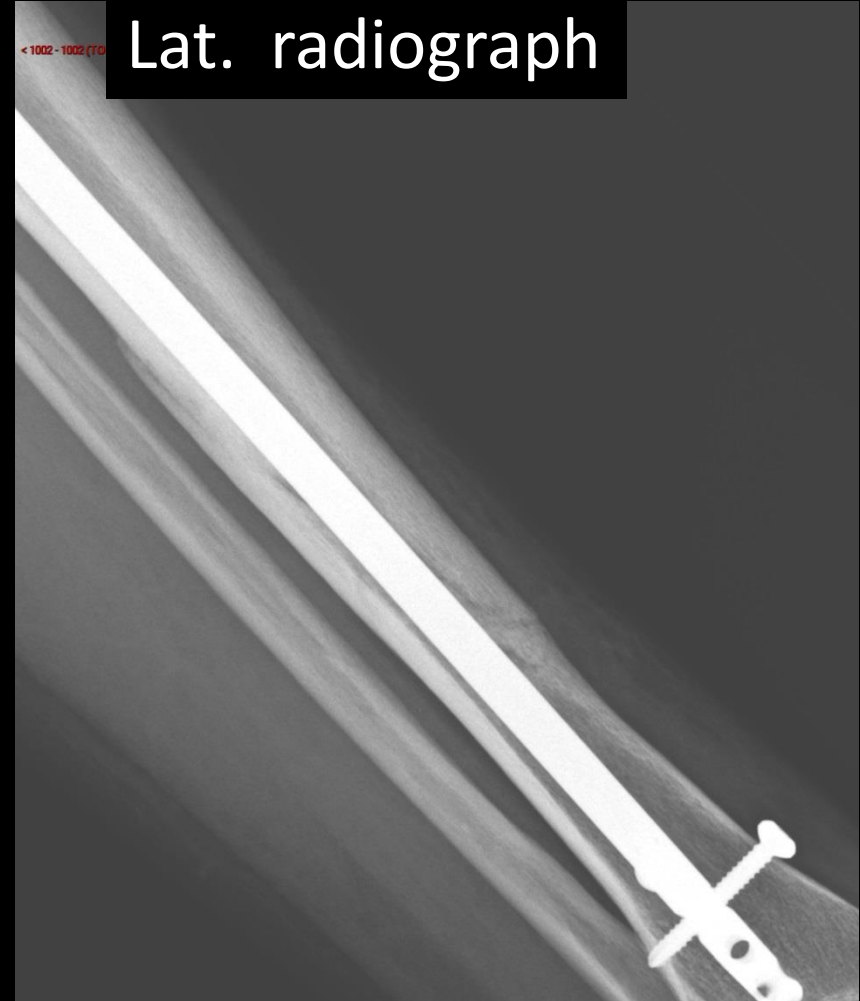
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 27

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 28

AP radiograph G



Lat. radiograph G

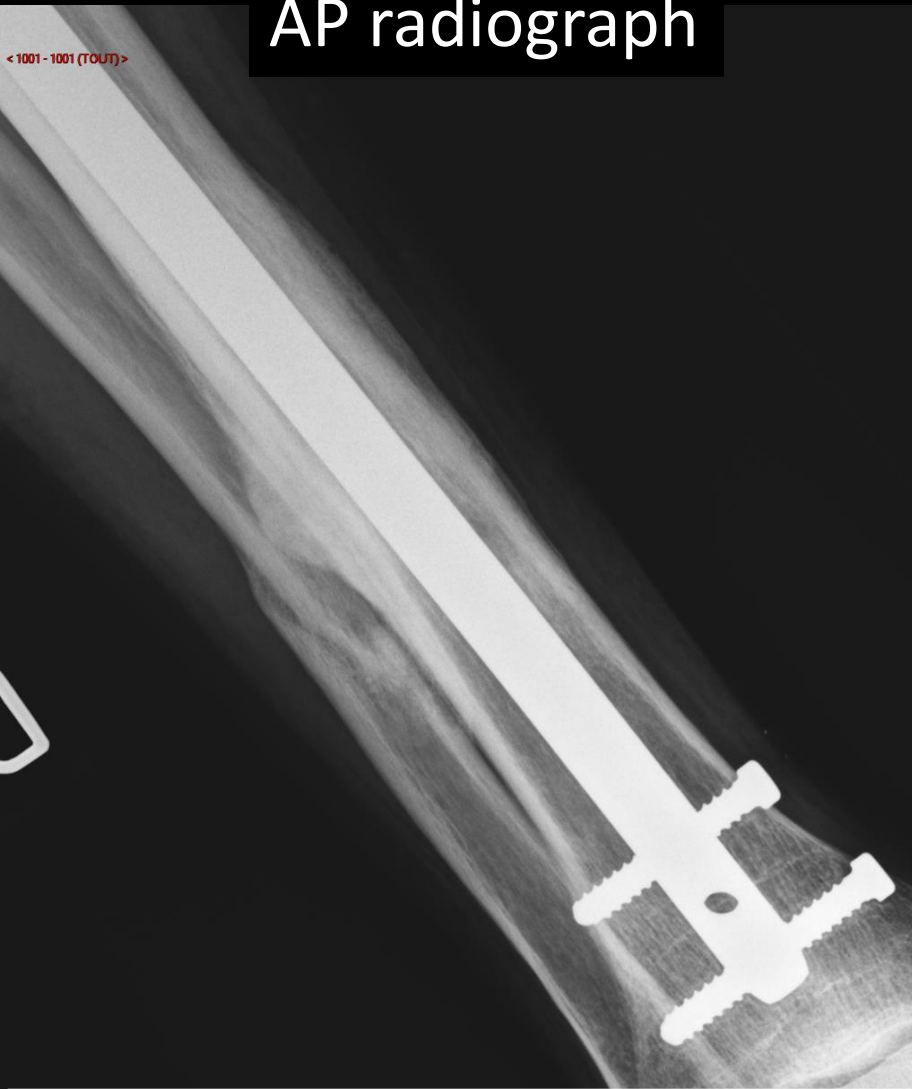


G

:
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 29

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 30

AP radiograph



Lat. radiograph



1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 31

AP radiograph

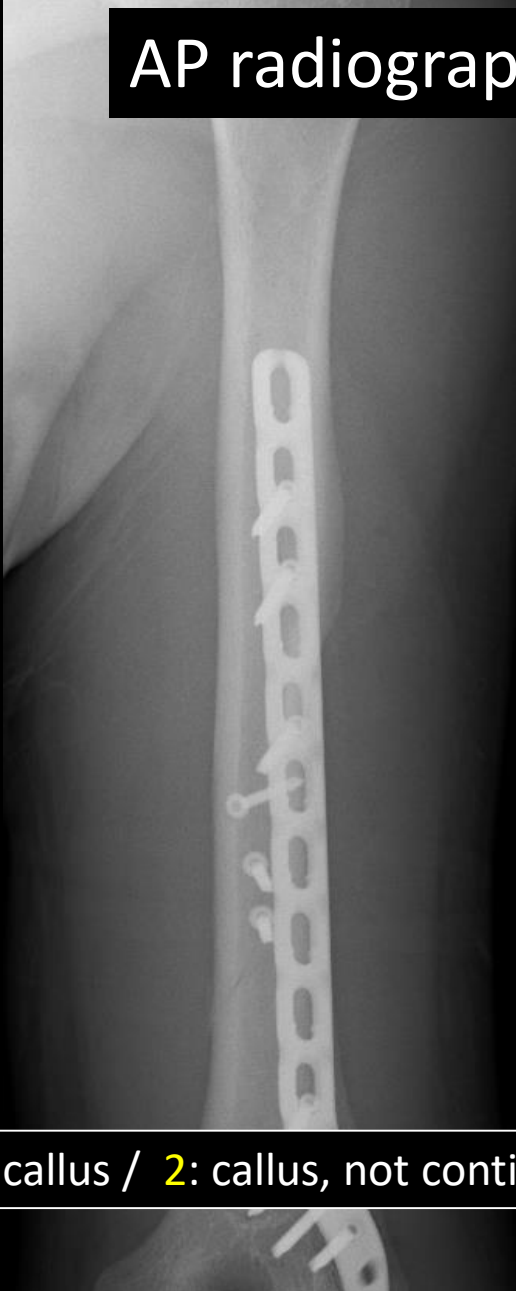
Lat. radiograph

G

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 32

AP radiograph



Lat. radiograph



G

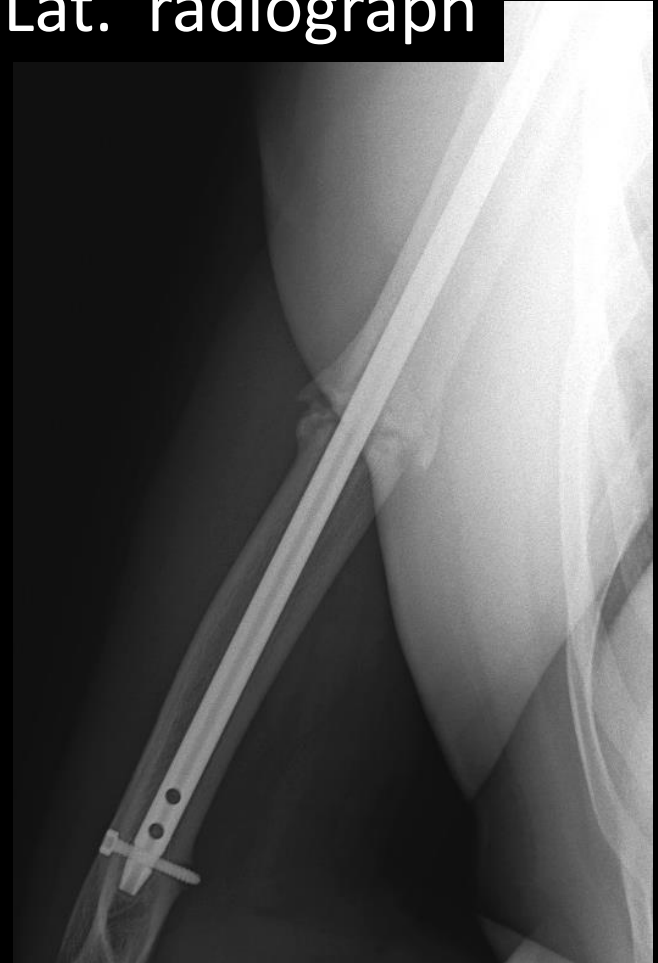
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 33

AP radiograph



Lat. radiograph



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 34

AP radiograph



Lat. radiograph



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Fracture tibia distal





mois 0



mois 2

Fracture tibia distal



mois 2



mois 4



mois 7

7° mois retard de consolidation (pseudarthrose hypertrophique)



7° mois retard de consolidation (pseudarthrose hypertrophique)



Fracture tibia distal, reprise de la stabilisation à M7



mois 7,5



mois 9,5



mois 12

Femme 77 ans
Pseudarthrose atrophique



Fracture

Retard consolidat

2 mois



Fracture
J0



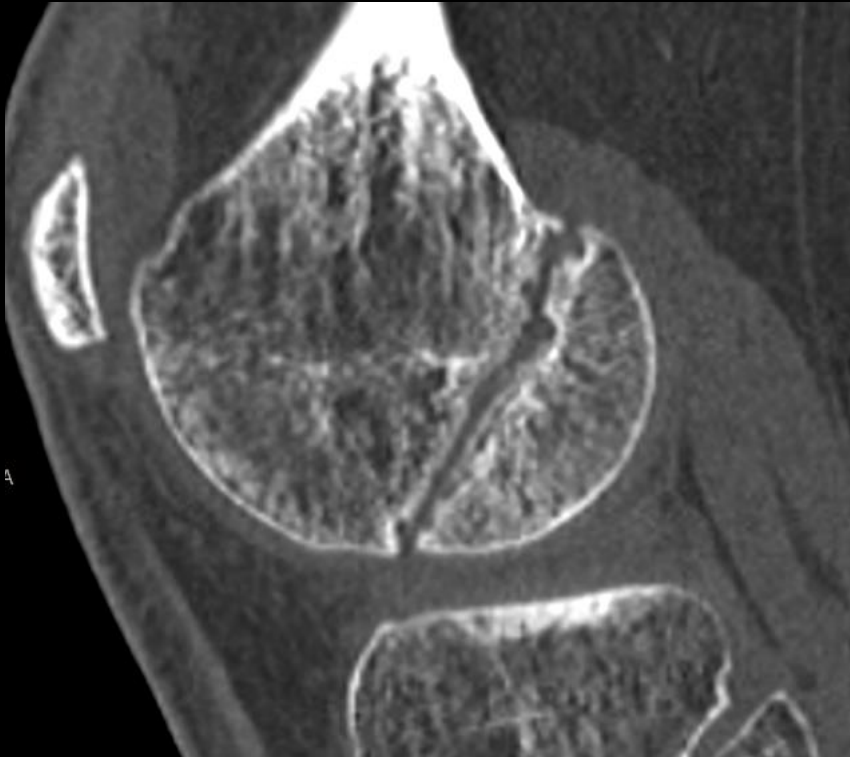
Retard
M2



guérison
M 1



Fracture condyle latéral
à 8 mois
Retard de consolidation
Nécrose ?



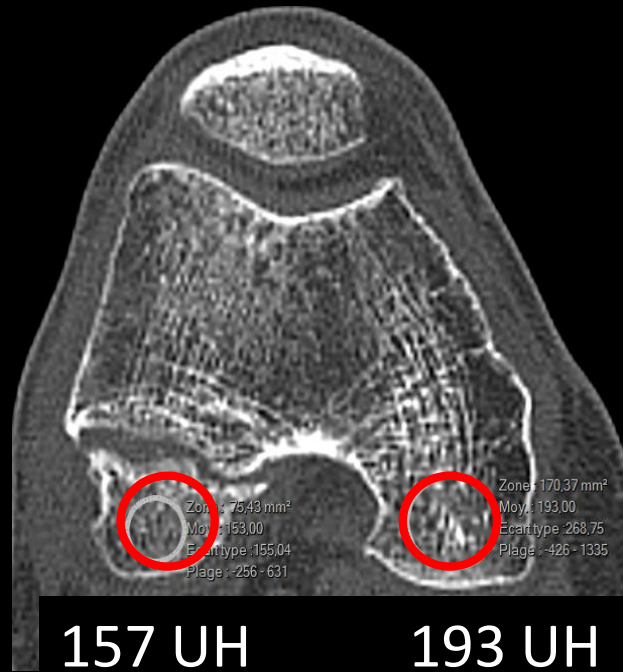
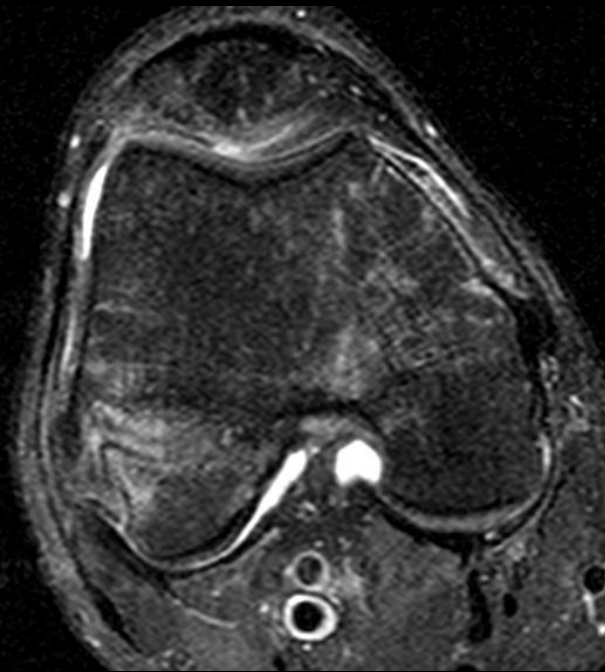
DP fs



SE T2

Fracture condyle latéral à 8 mois

Retard de consolidation , nécrose ?



Œdème médullaire

raréfaction osseuse

Retard de consolidation



Retard de consolidation Pseudarthrose du scaphoïde



Pseudarthrose du scaphoïde

Perfusion respectée



SE T1



SE T1 fs + Gd

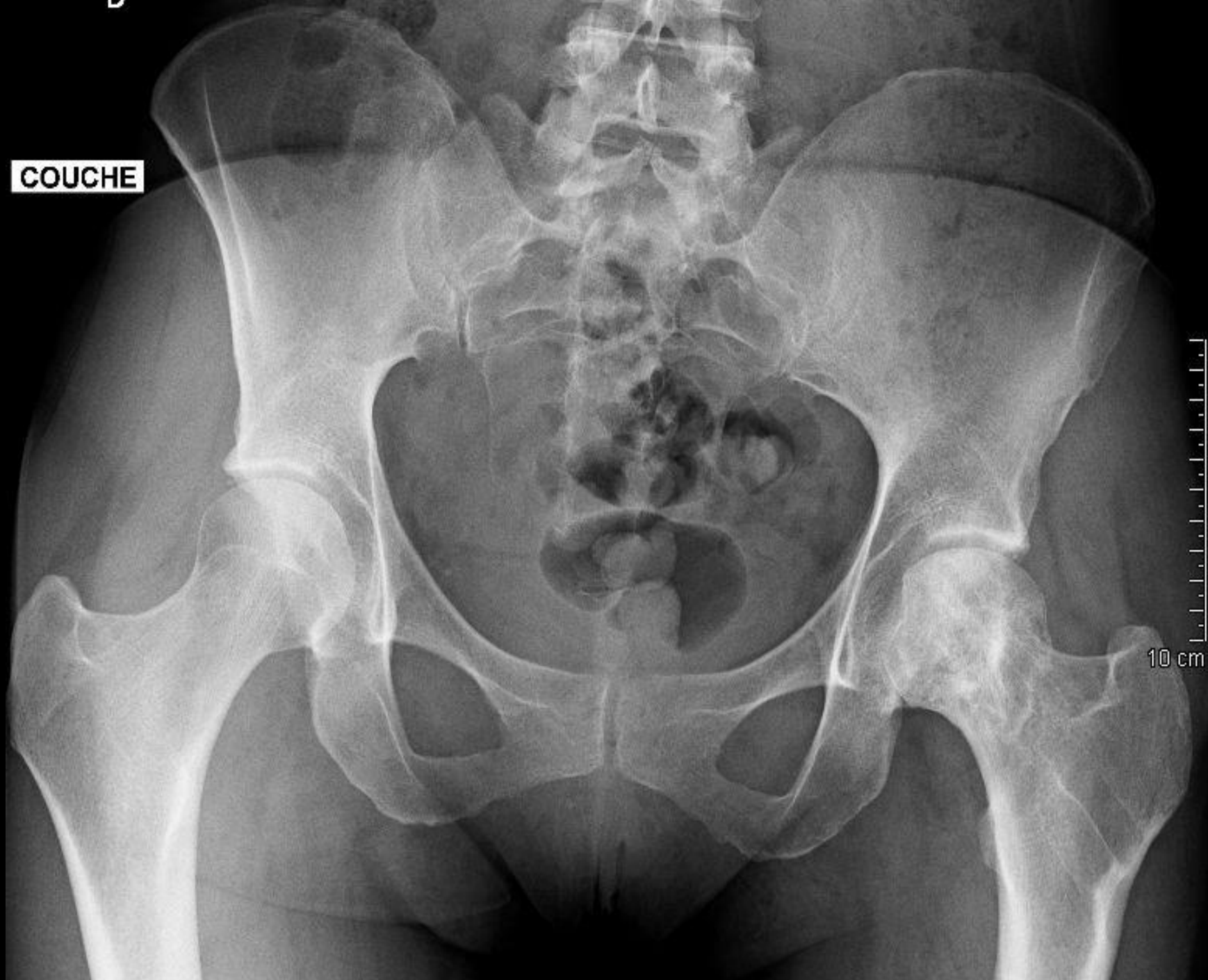
Complications des fractures

- Déformations résiduelles
- Troubles de la consolidation
 - retard (< 6mois)
 - Pseudarthrose (> 6 mois)
- Infection (fractures ouvertes)
- Nécrose (osseuse, musculaire, cutanée)
- Capsulite, Syndrome douloureux régional complexe (SDRC)
- Arthrose

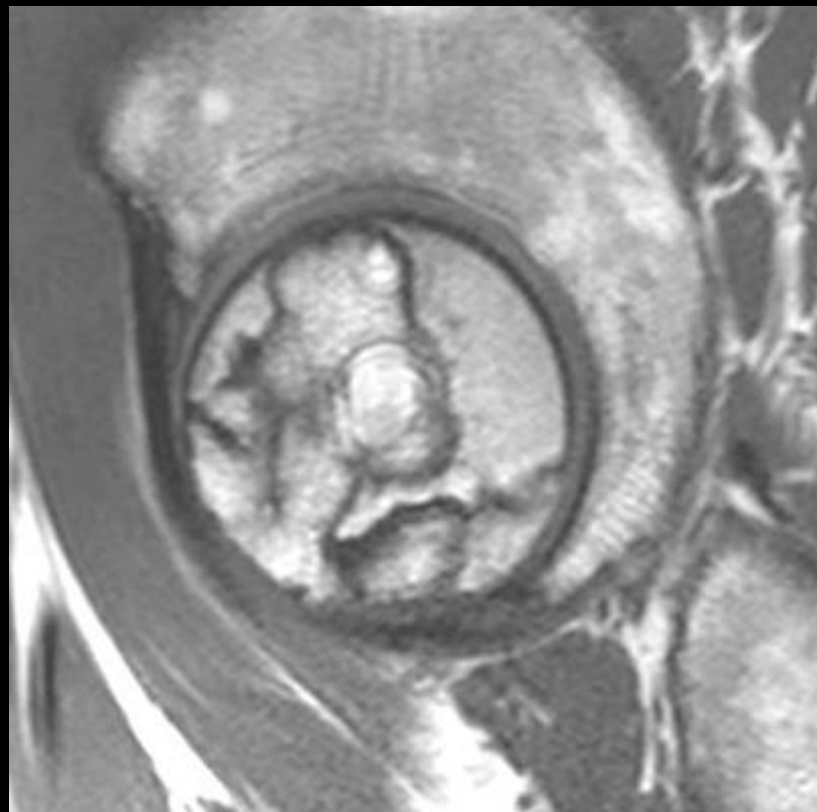




COUCHE







Fracture sous capitale



suivi 14 mois effondrement (nécrose)



Nécrose épiphysaire post-traumatique



Nécrose épiphysaire post-traumatique



Ct initial



CT à 3 mois

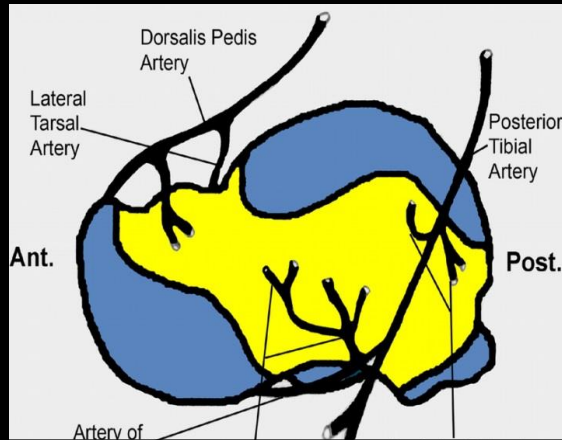
Phénomène d'échappement osseux (CT):

absence de raréfaction osseuse
dans un environnement raréfié

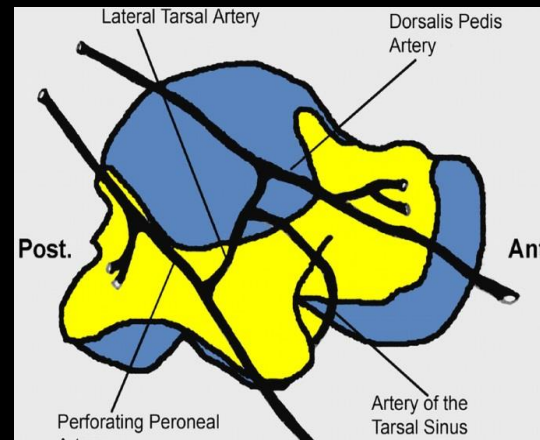
Nécrose post-traumatique

- Interruption vasculaire traumatique
- Territoires osseux distaux ou hypoperfusés
 - Pole proximal du scaphoïde
 - Dôme talien
 - Épiphyses fémorales, humérales proximales
 -

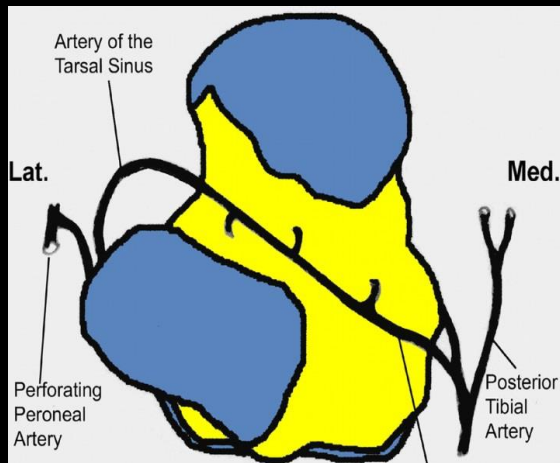
Risque de nécrose : Anatomie vasculaire de l'os fracturé



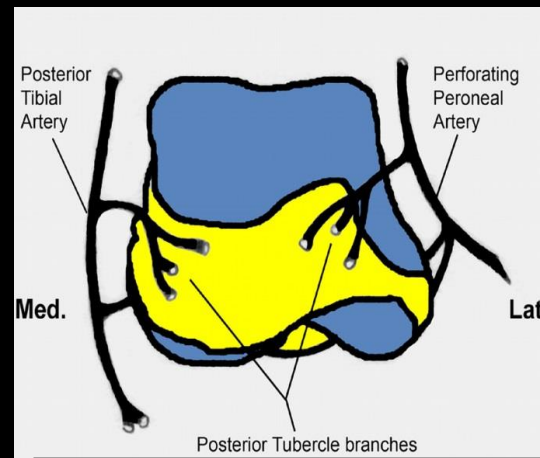
Hawkins type 1: fracture non déplacée du col talien sans subluxation (risque très faible de nécrose)



(b) Hawkins type 2: fracture du col talien avec subluxatio/luxation des articulations sous-taliennes;

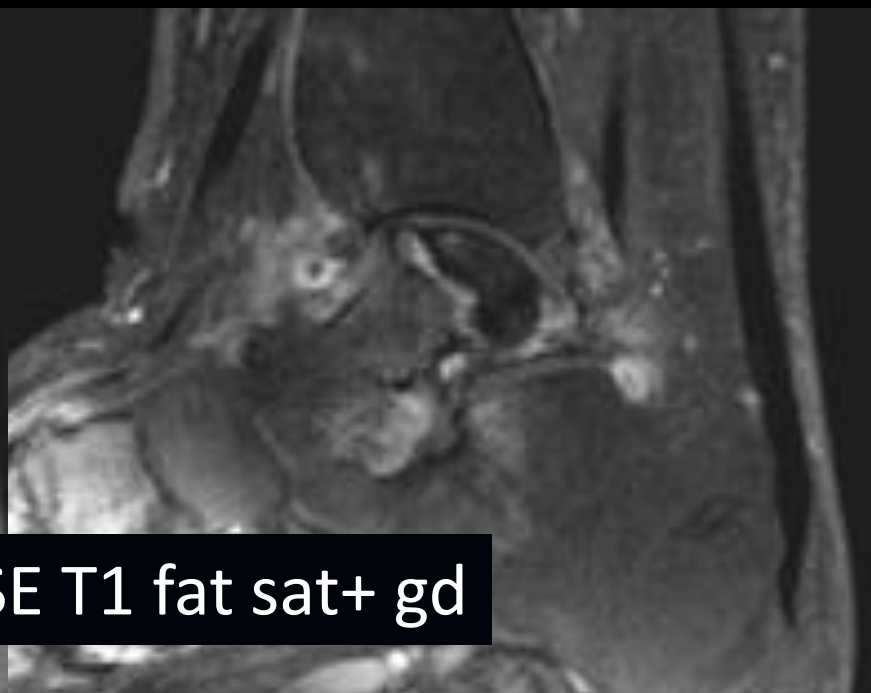
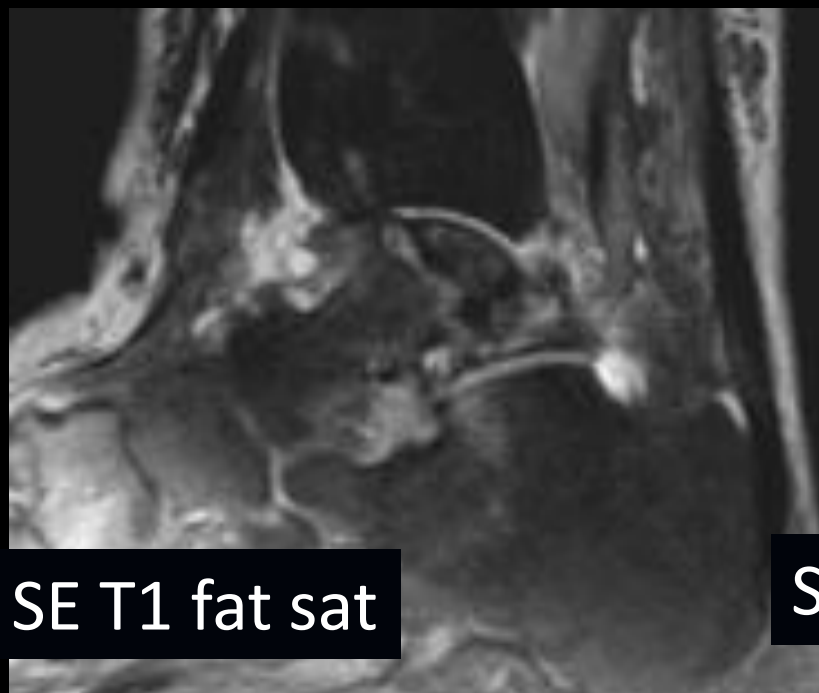
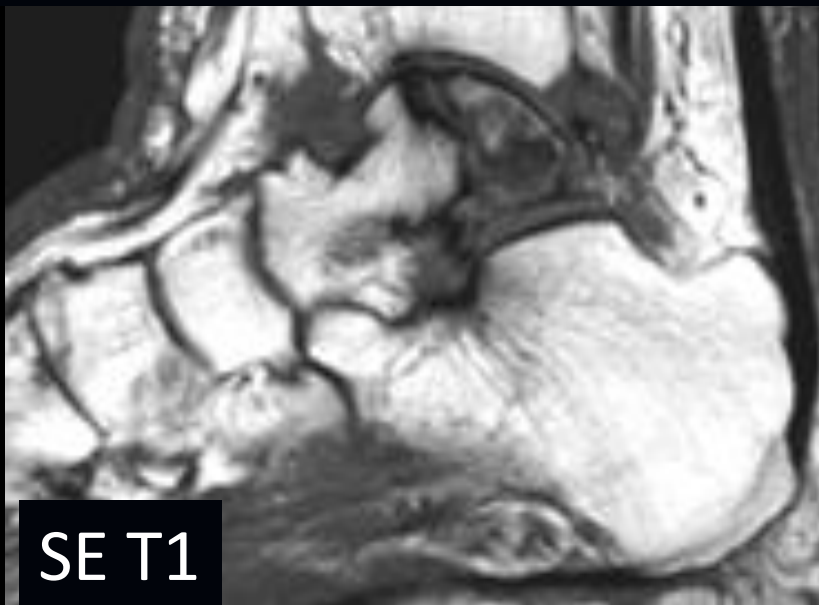


(c) Hawkins type 3: fracture du col talien avec (sub)luxation des articulations talo-crurale et sous-talienne.



(d) fracture type 4: fracture du col avec déplacement du dome talien et (sub)luxation articulaire (risque très élevé de nécrose).

Intérêt IRM et contraste iv



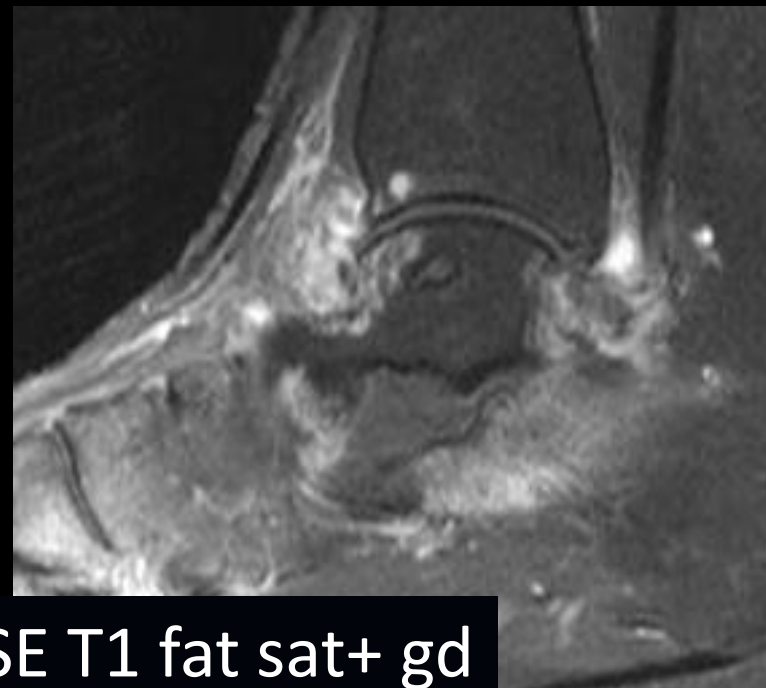
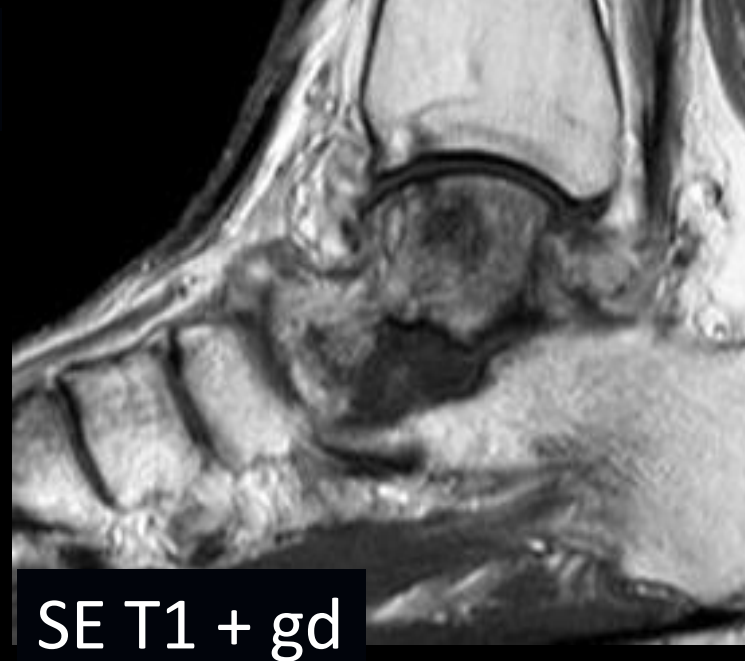
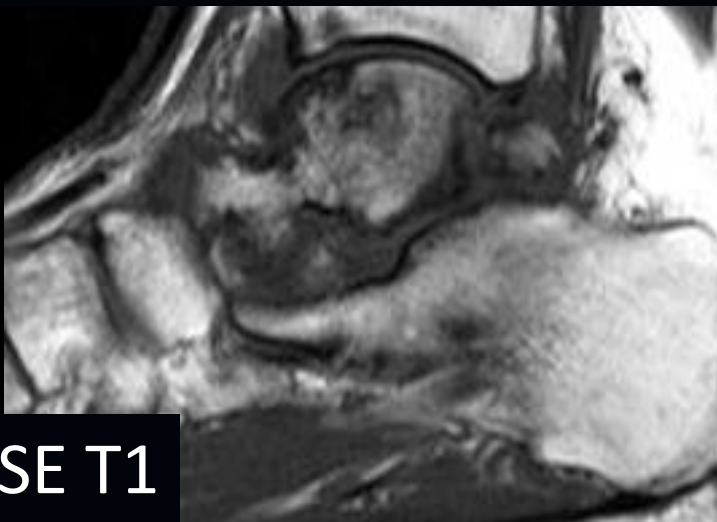
Ischémie



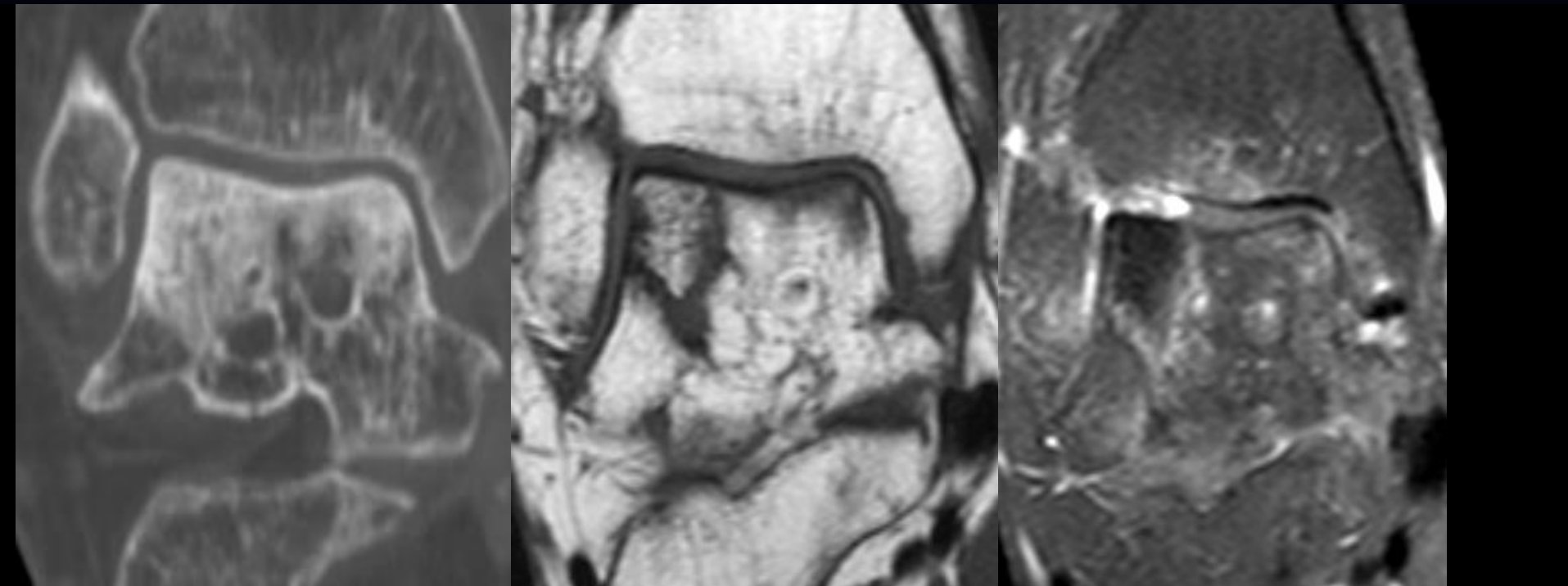
Vascularisation persistante



Intérêt IRM et contraste iv



Intérêt IRM vs TDM



SE T1

SE T1 fat sat+ gd

Initial



Suivi à 2 mois



Suivi à 4 mois

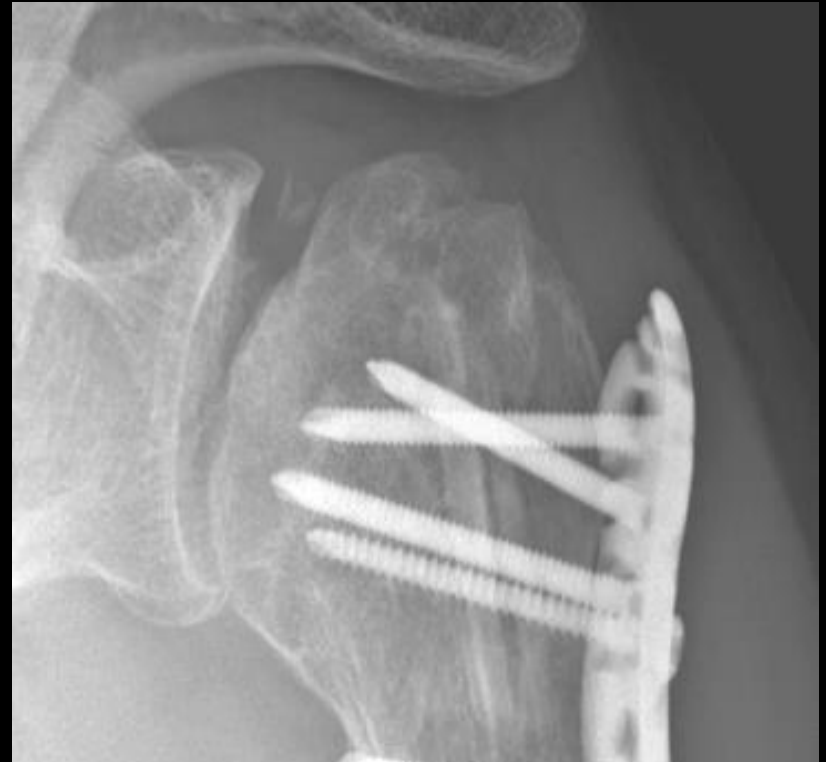
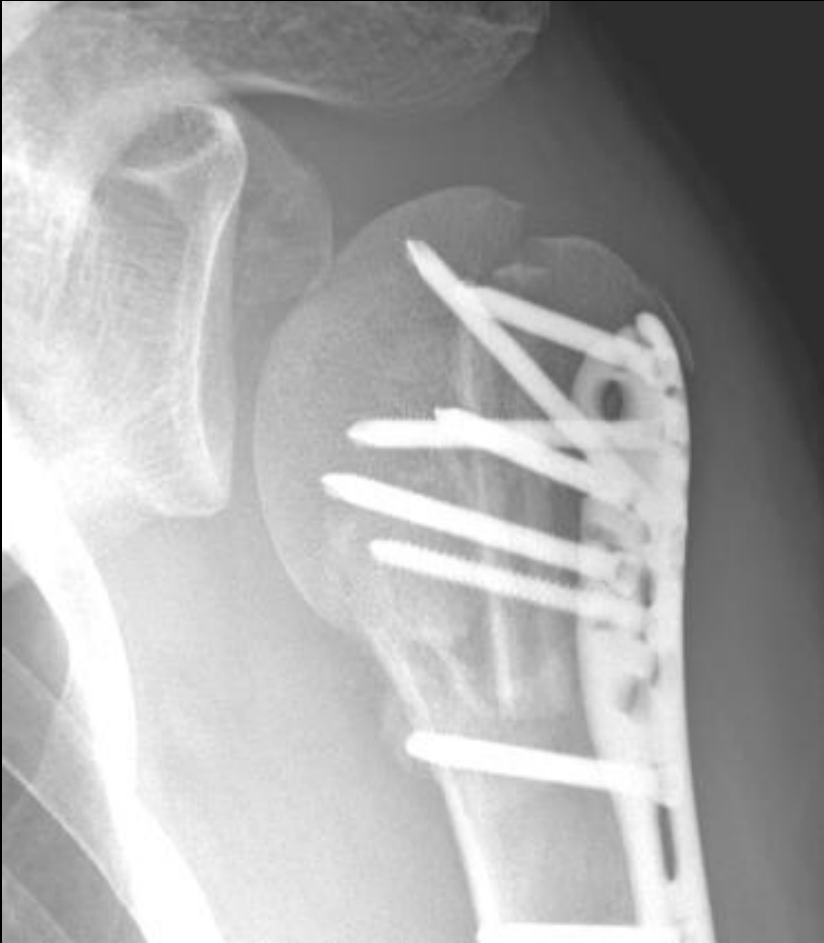


Limites de la radiologie pour la détection de la nécrose

Même jour, conditions techniques différentes



Nécrose épiphysaire post-traumatique



Suivi à 12 mois

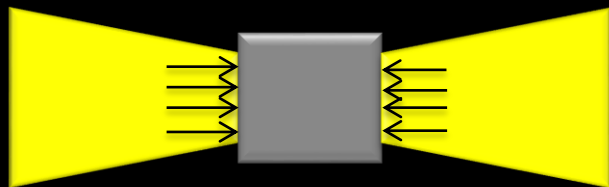
Collapsus épiphysaire spontané

Objectifs

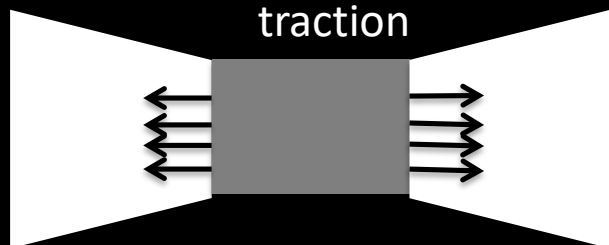
- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures

Types de contraintes biomécaniques - direction

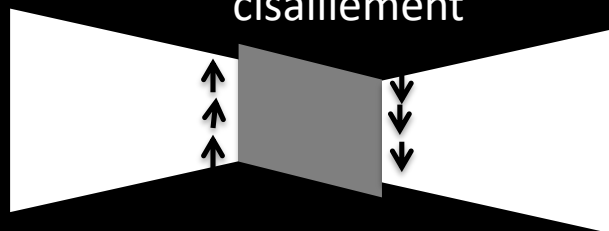
compression



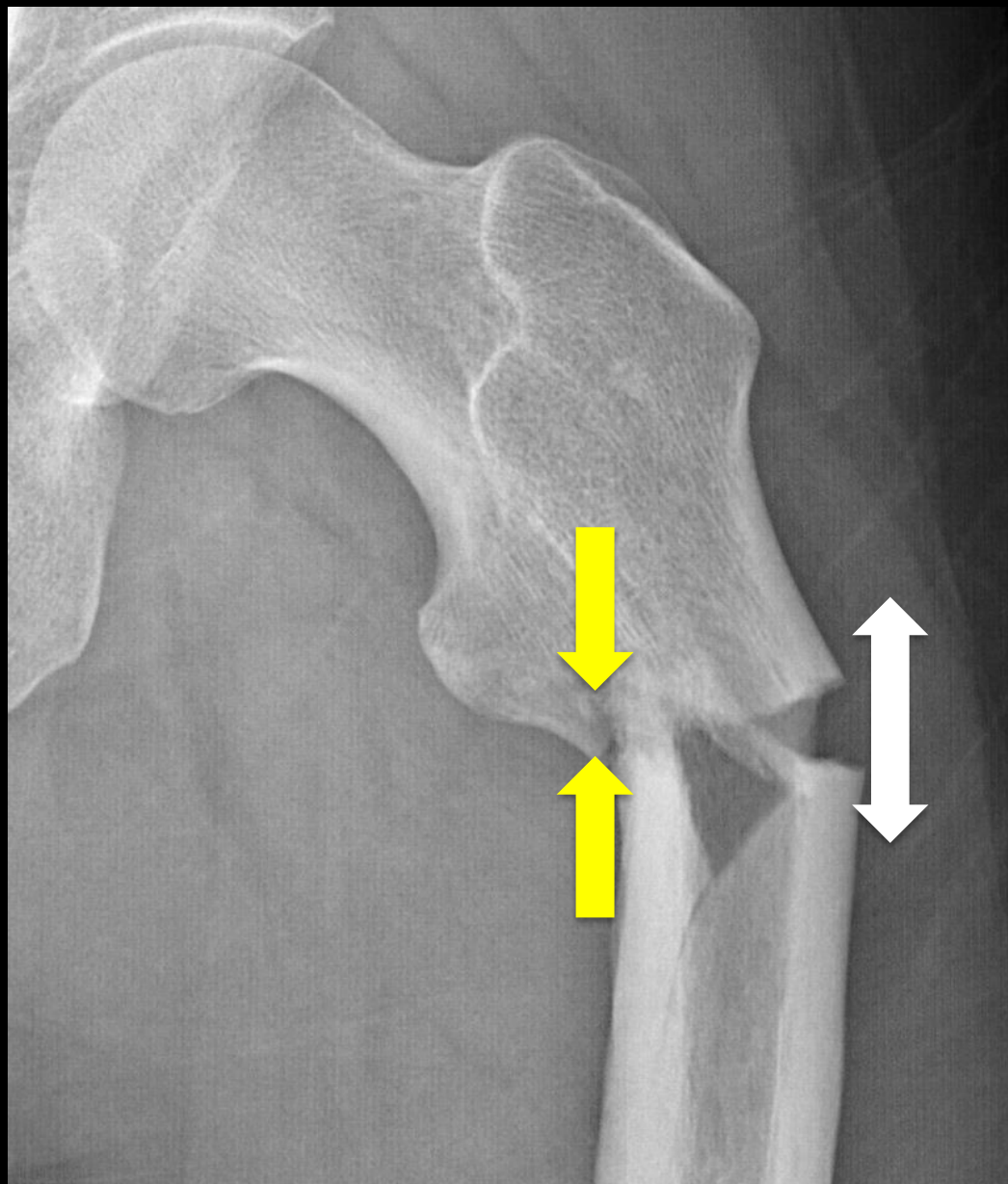
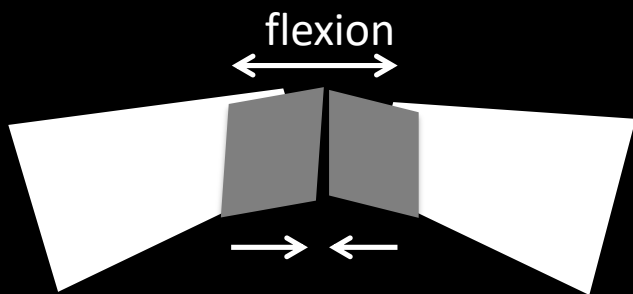
traction



cisaillement

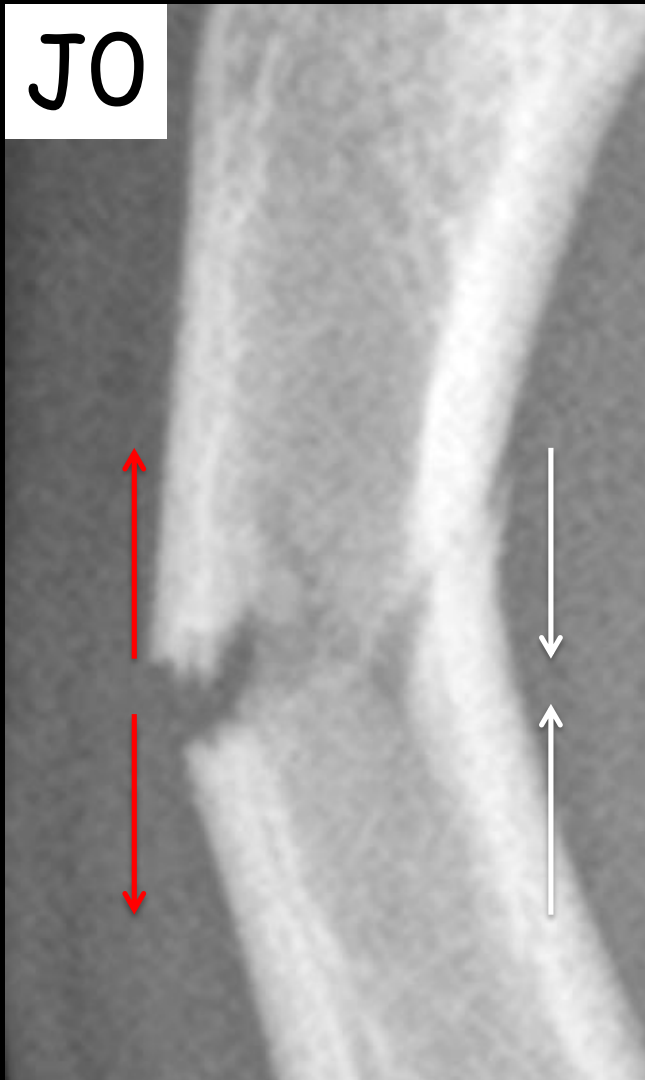


flexion

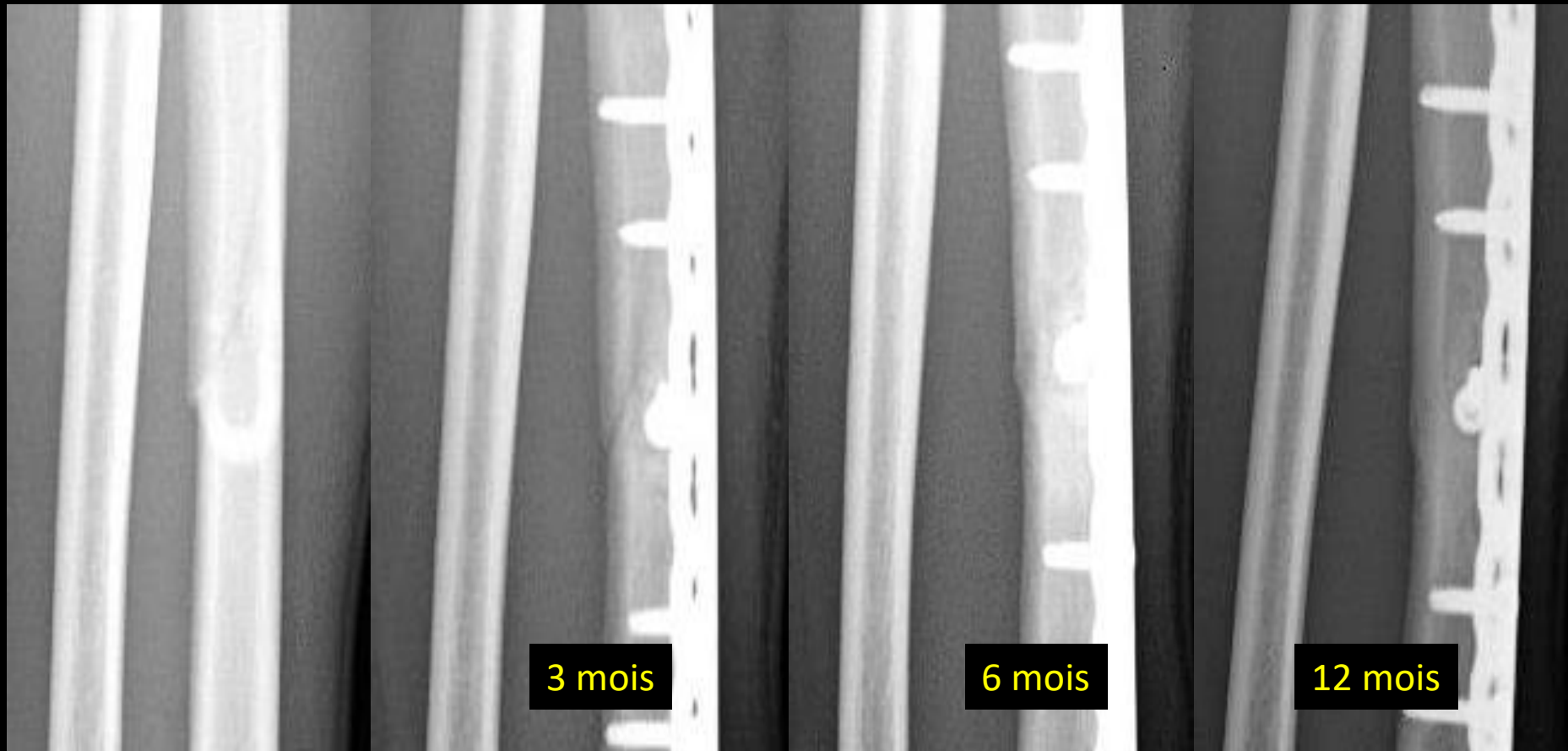


Orientation des contraintes

Compression (favorable) $\gg$ traction, cisaillement, rotation (defavorables)



Fixation statique	Consolidation directe
Type de cal	Cal cortical
Micromobilite résiduelle	Effet inhibiteur
Diastasis toléré	Aucun



FIXATION DYNAMIQUE

Consolidation indirecte

Type de cal

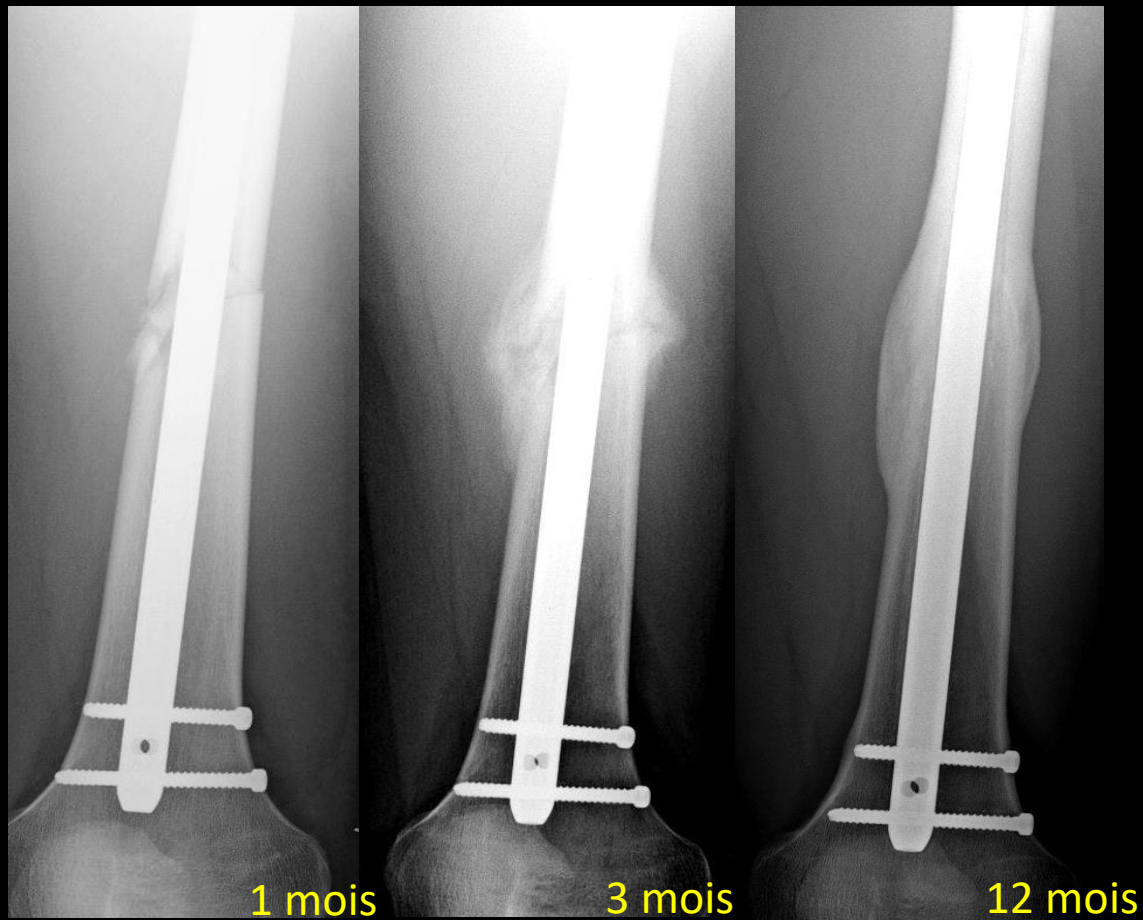
Cal périosté

Micromobilité résiduelle

Effet stimulateur

Diastasis toléré

Quelques mm



Complications des fractures

- Déformations résiduelles
- Troubles de la consolidation
 - retard (< 6mois)
 - Pseudarthrose (> 6 mois)
- Infection (fractures ouvertes)
- Nécrose (osseuse, musculaire, cutanée)
- Capsulite, Syndrome douloureux régional complexe (SDRC)
- Arthrose

Fixation statique

→ consolidation directe

	Consolidation directe
Type de cal	Cal cortical
Micromobilite résiduelle	Effet inhibiteur
Diastasis toléré	Aucun

Fixation dynamique

→ consolidation indirecte

	Consolidation indirecte
Type de cal	Cal périosté
Micromobilité résiduelle	Effet stimulateur
Diastasis toléré	Quelques mm

Objectifs

- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures

Objectifs

- A. Biomécanique des fractures
- B. Consolidation osseuse
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Objectifs

- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures

Objectifs

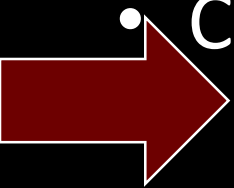
- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures

Objectifs

- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures

Fractures articulaires - Objectifs

- Définition
- Retard de consolidation
- Fragments ostéo-chondral
- Nécrose
- Capsulite



Initial



Suivi à 6 sem



Raréfaction osseuse
dystrophique



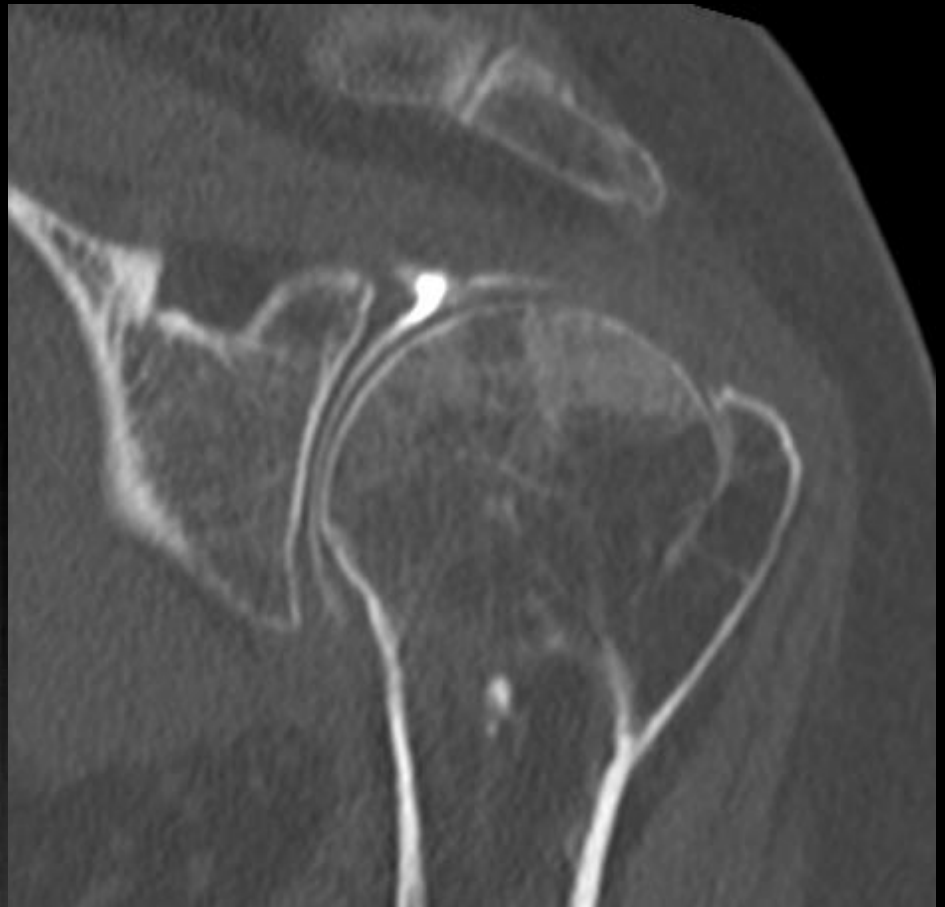
Capsulite

Nécrose post-traumatique présumée et capsulite



Fracture épiphysaire consolidée à 6 mois

Raréfaction osseuse et capsulite



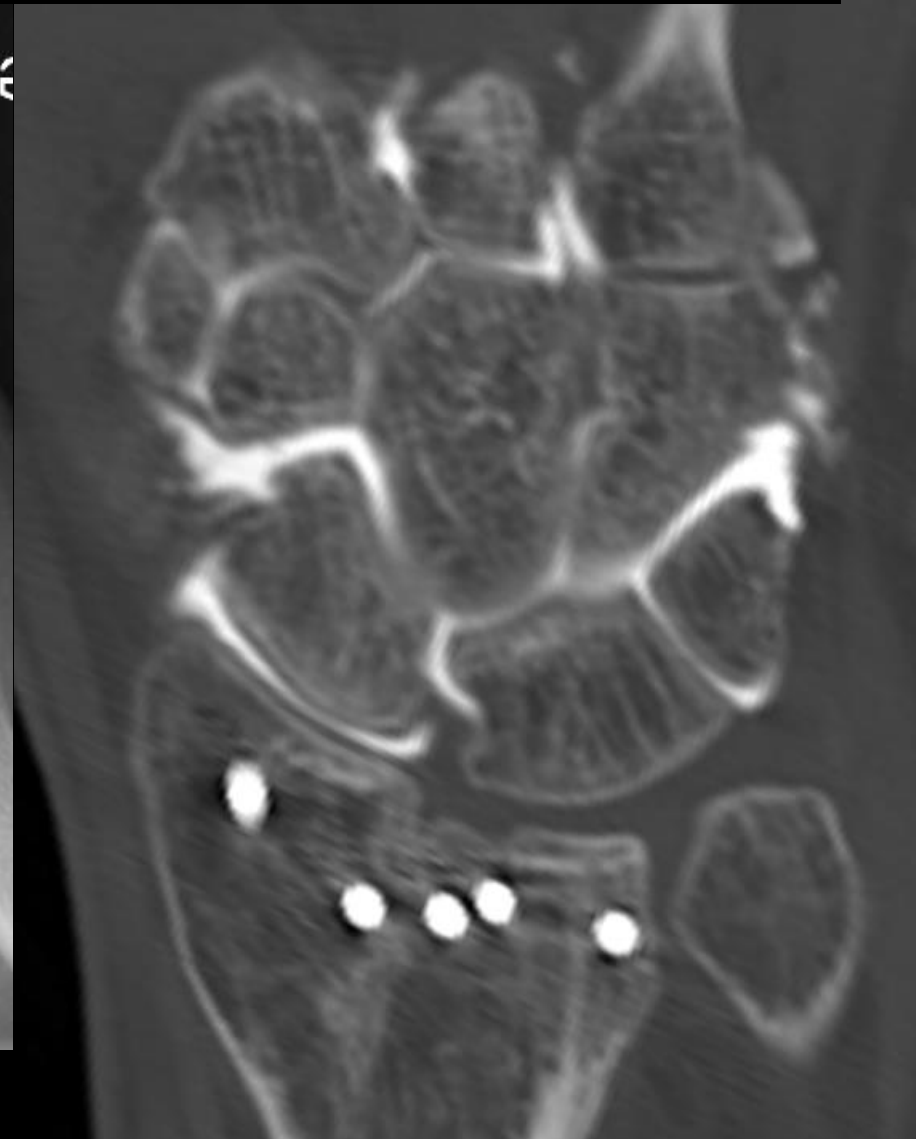
Fracture articulaire consolidée avec déformation résiduelle

Raréfaction osseuse et capsulite





Fracture articulaire consolidée avec déformation résiduelle
Raréfaction osseuse et capsulite
adhérences ? Synéchies ?



Fracture scaphoïde ostéosynthésée

Limitation fonctionnelle

adhérences ? Synéchies ?



Fracture radiale distale

Déficit fonctionnel inexplicable

Raréfaction osseuse et capsulite
adhérences ? Synéchies ?



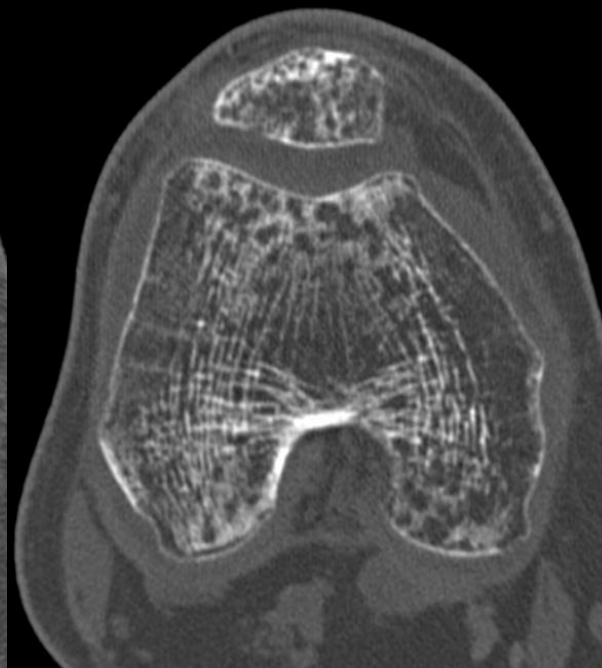


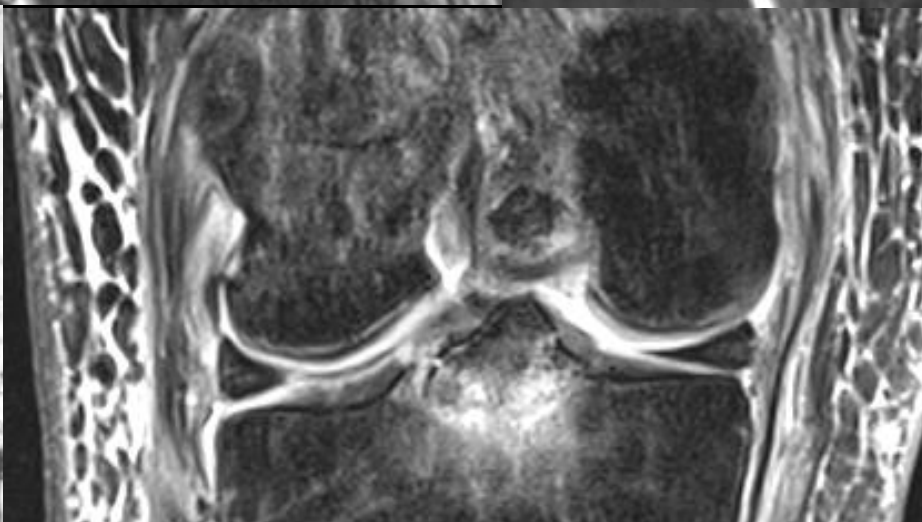
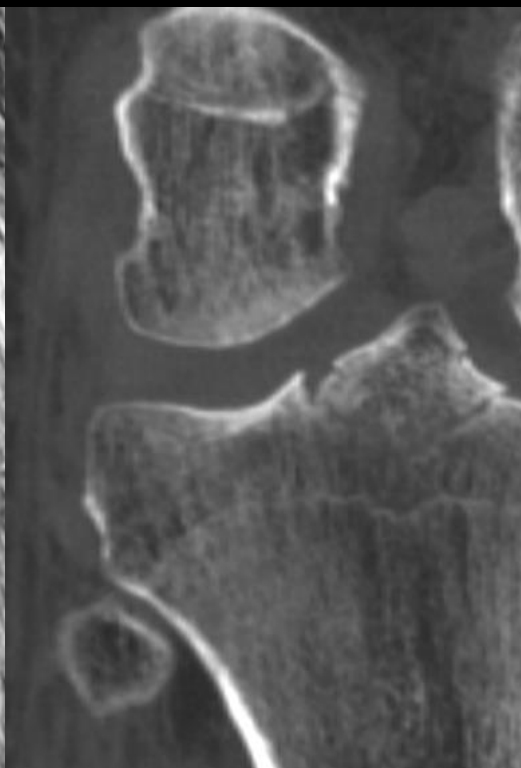
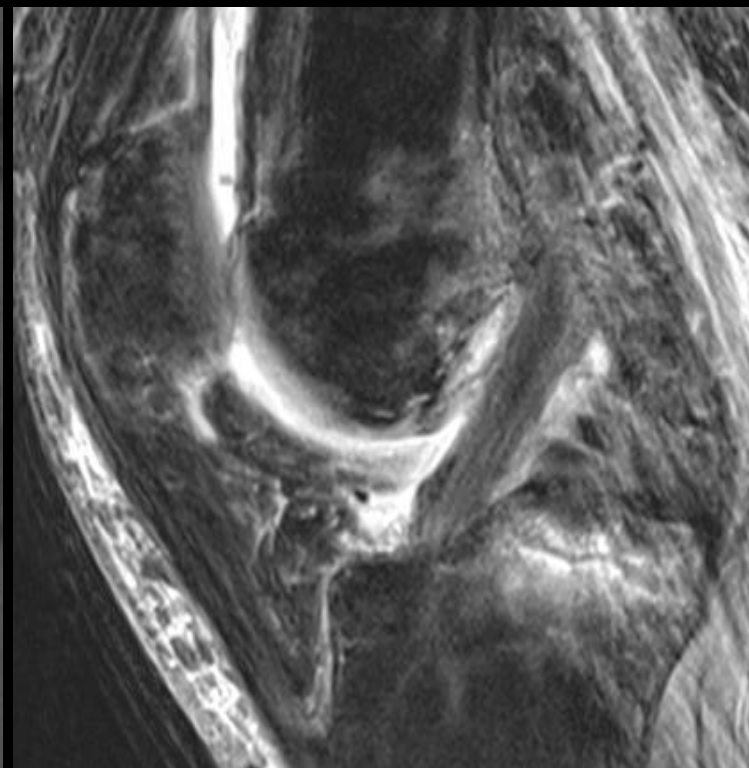
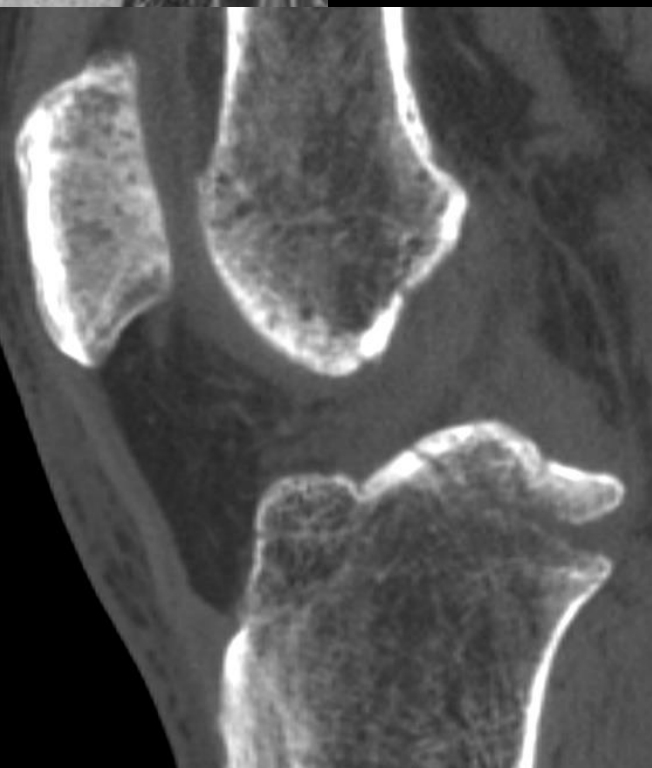
Complications des fractures articulaires

Une approche multi-modale attentive !

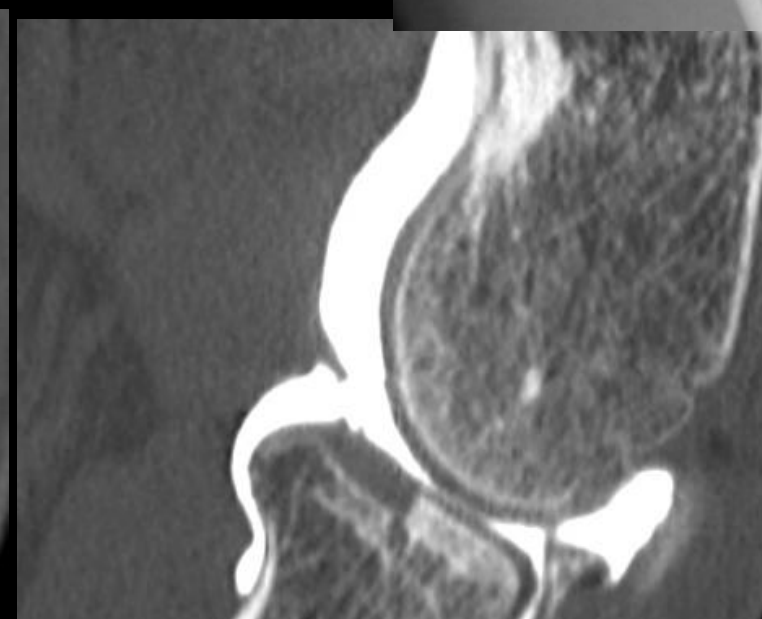
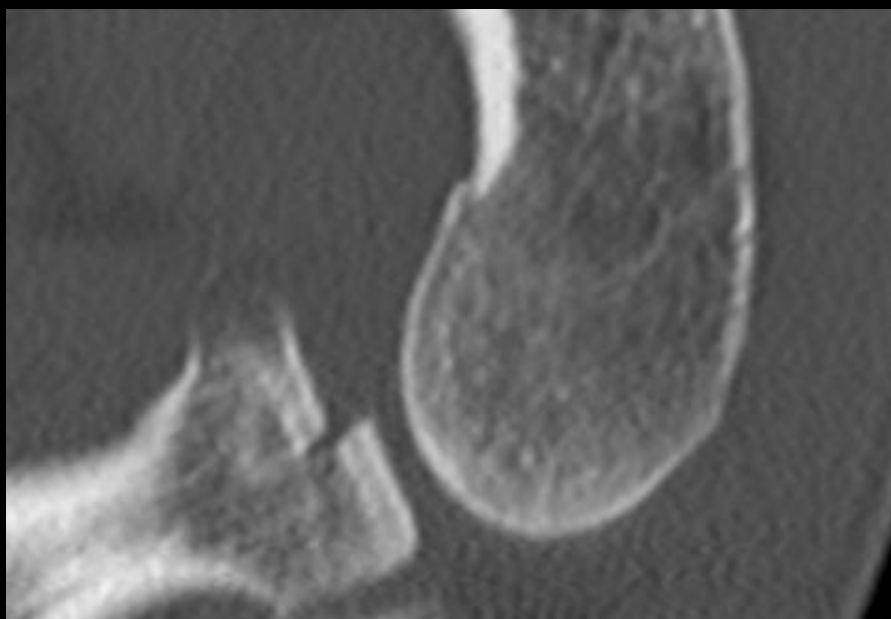
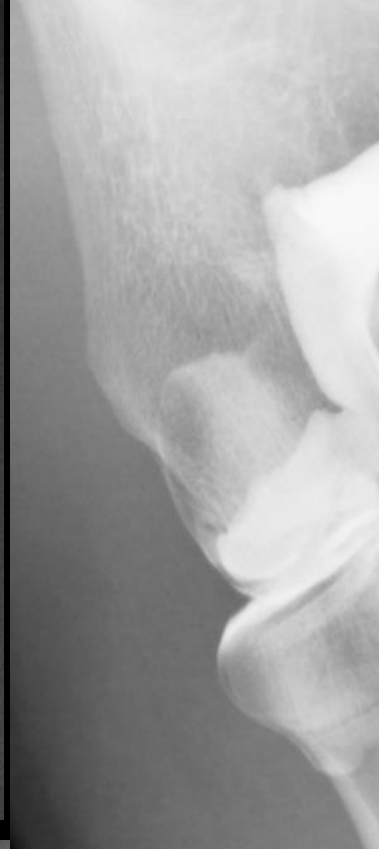
- Retard de consolidation
- Nécrose
- Capsulite – addhérences
- Fragments ostéochondraux

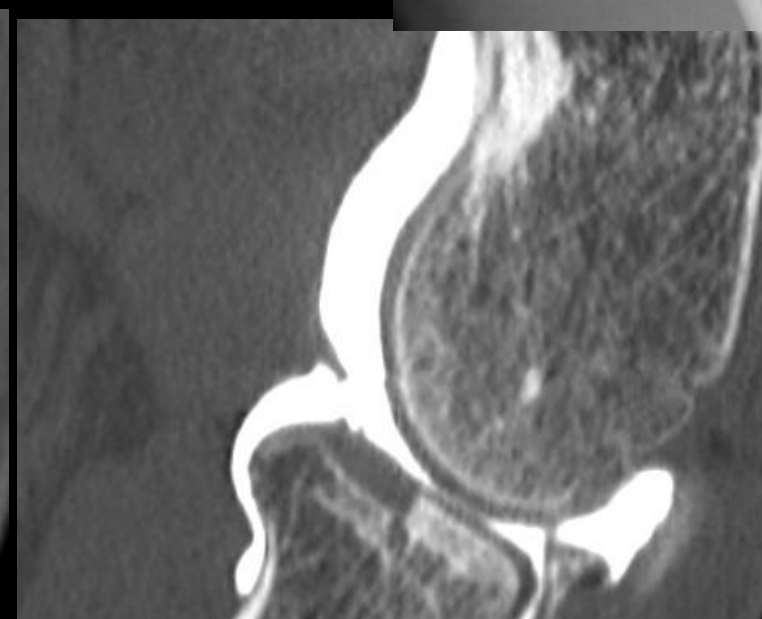
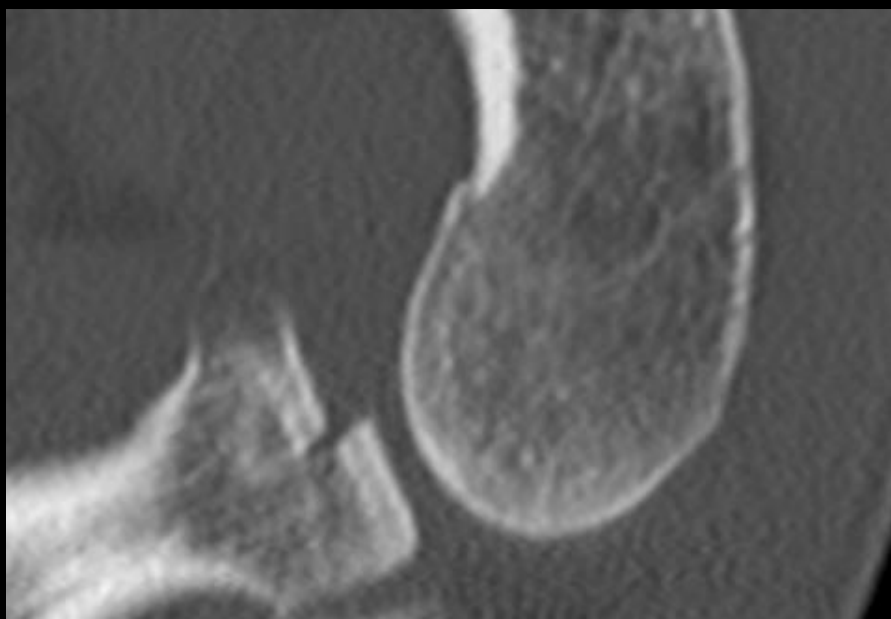
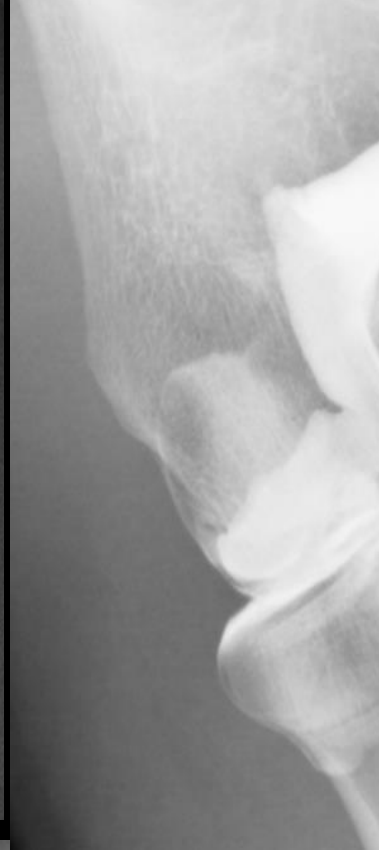
Capsulite

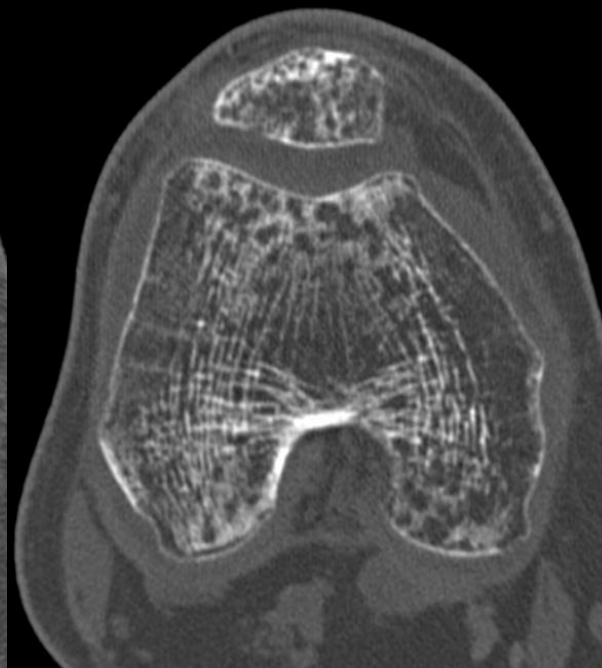


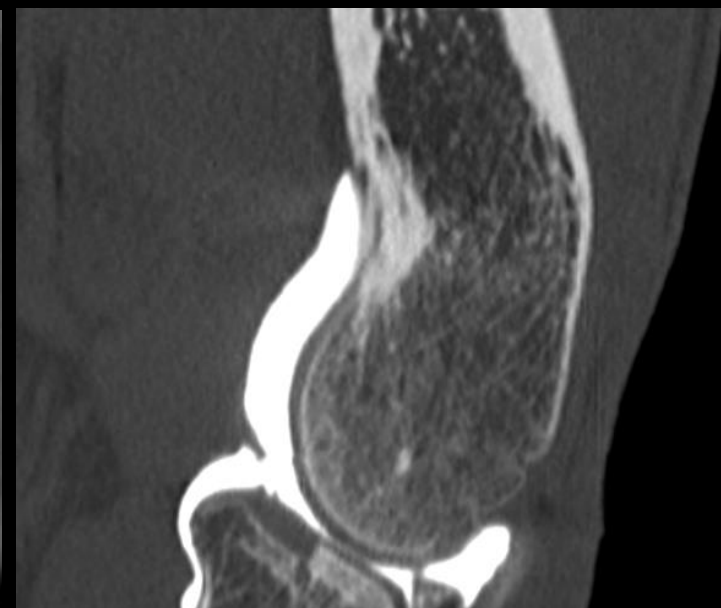
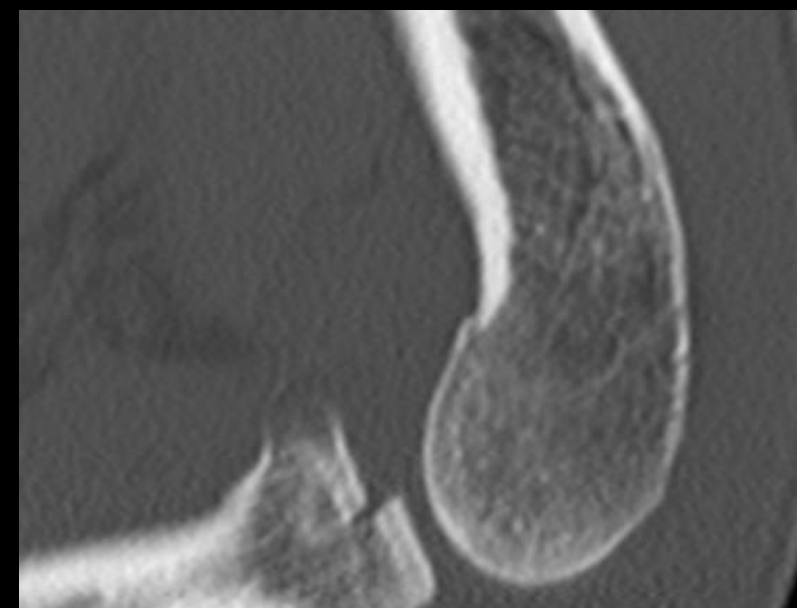
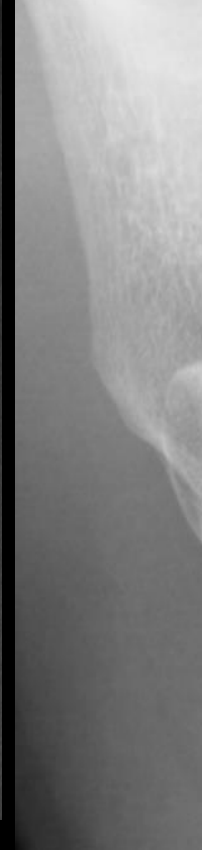


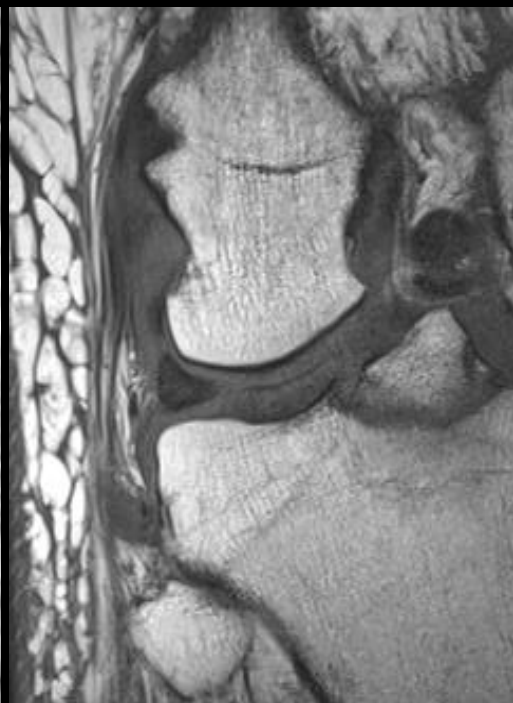
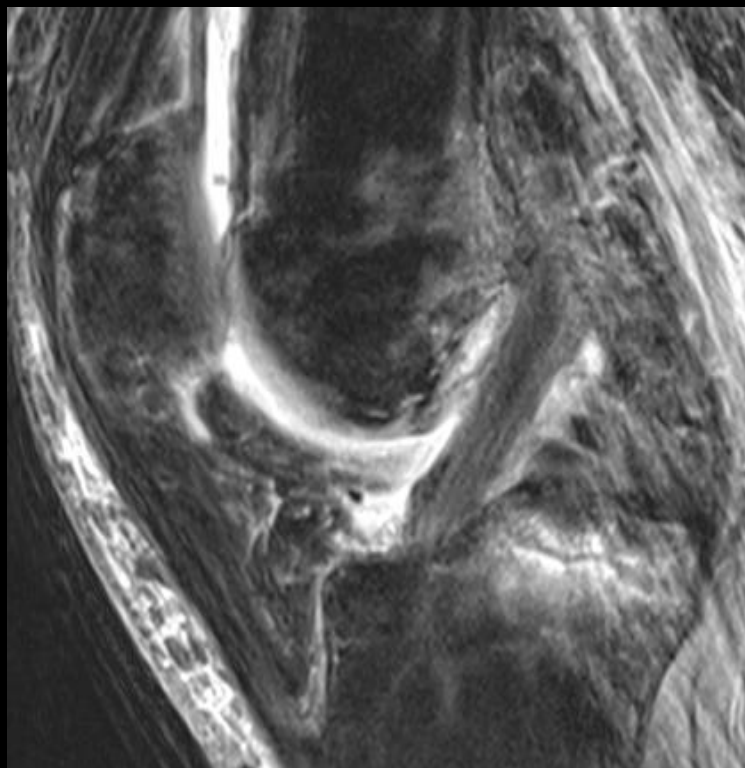
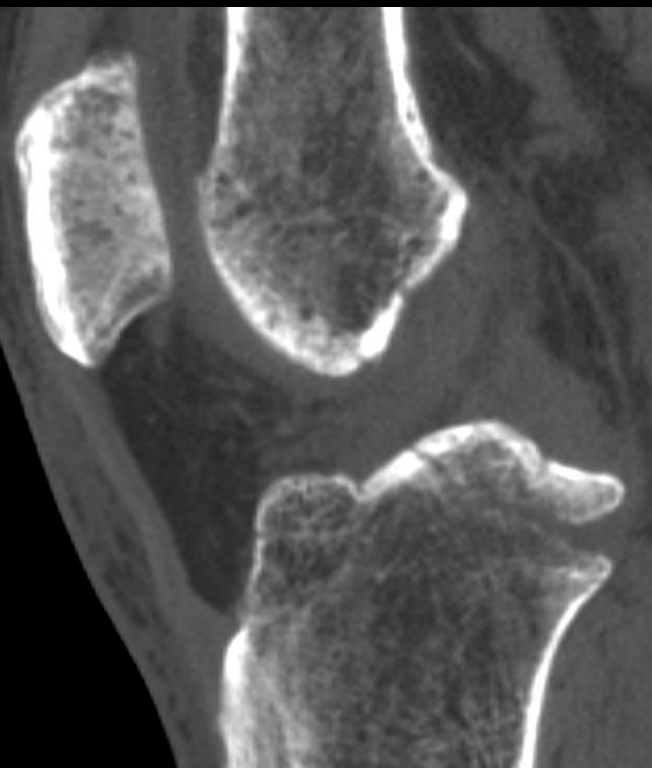


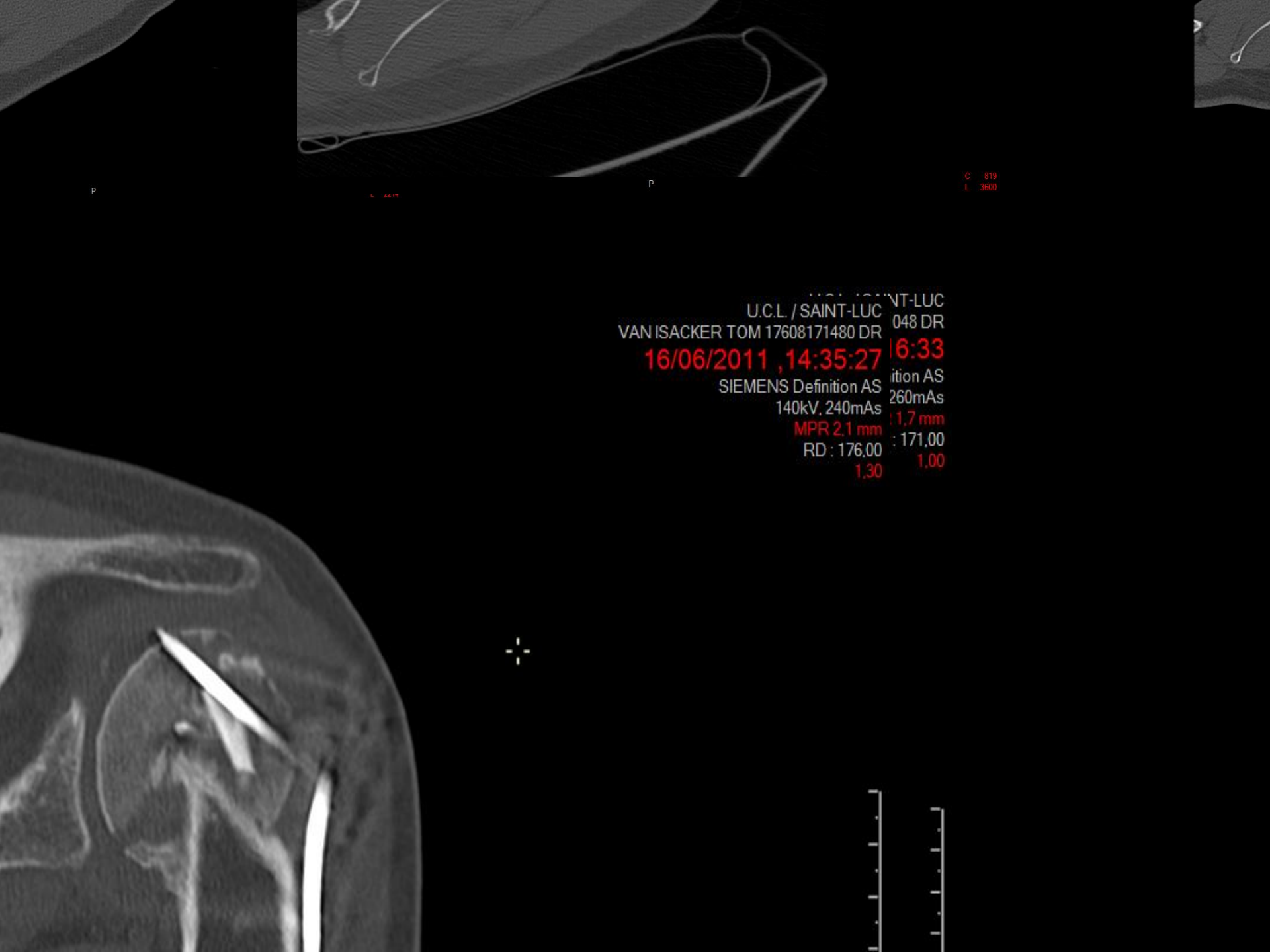












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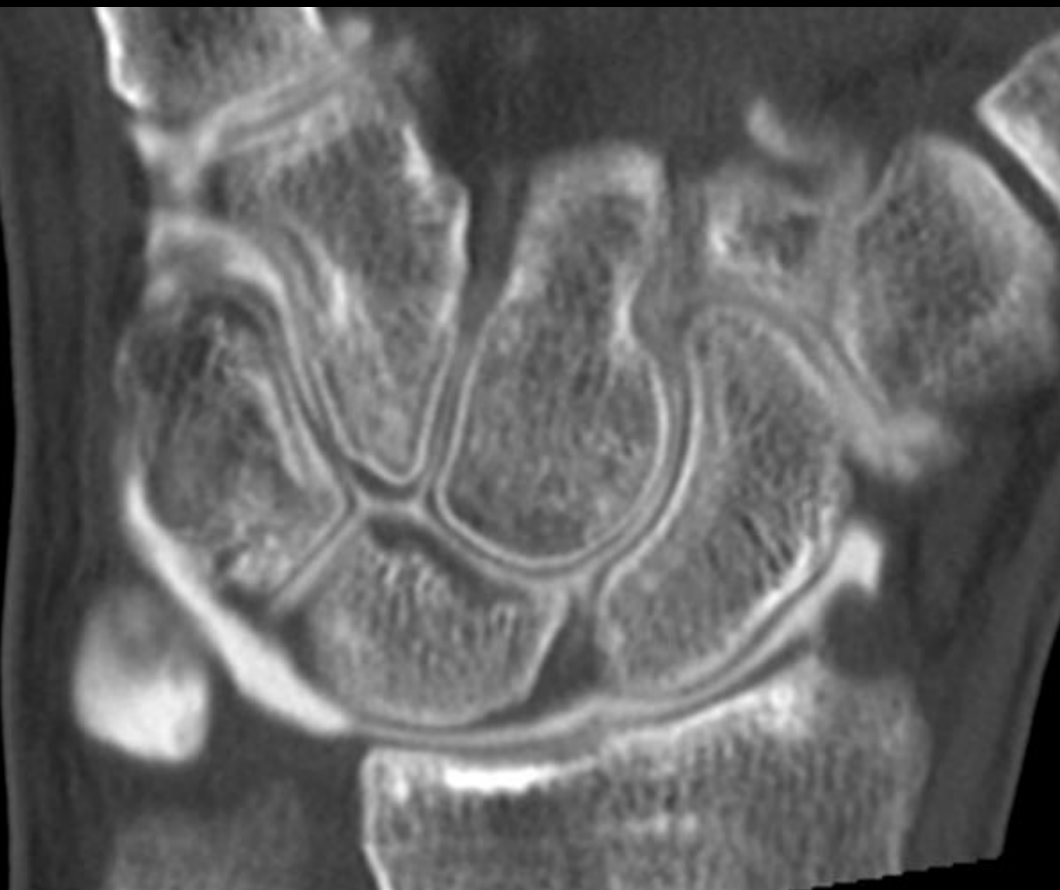
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C 819
L 3600

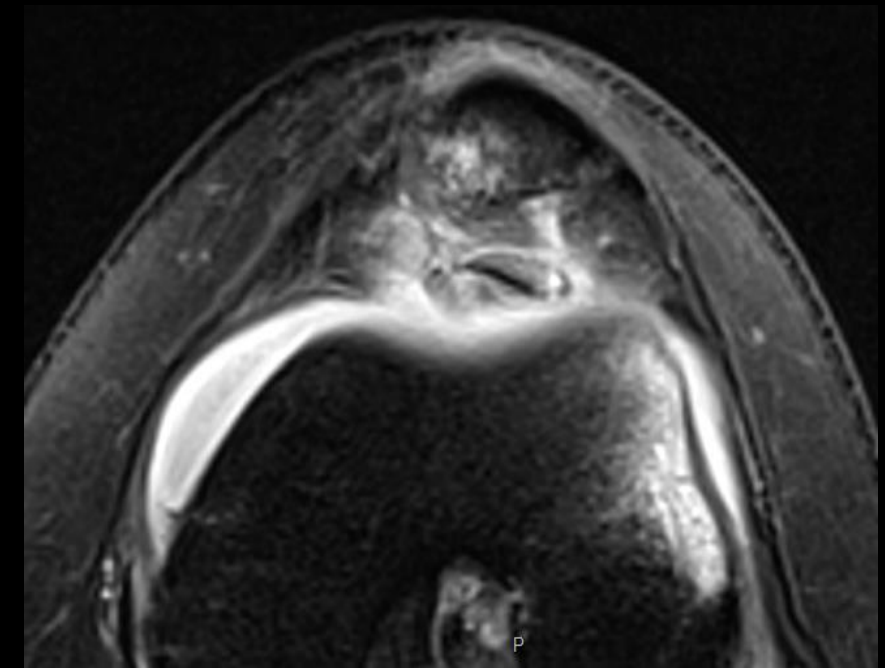
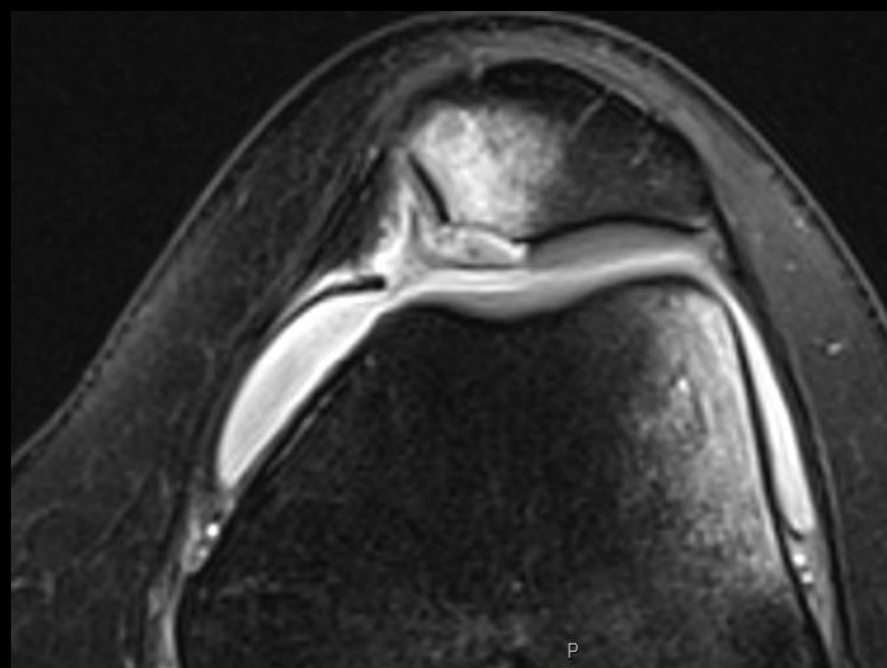
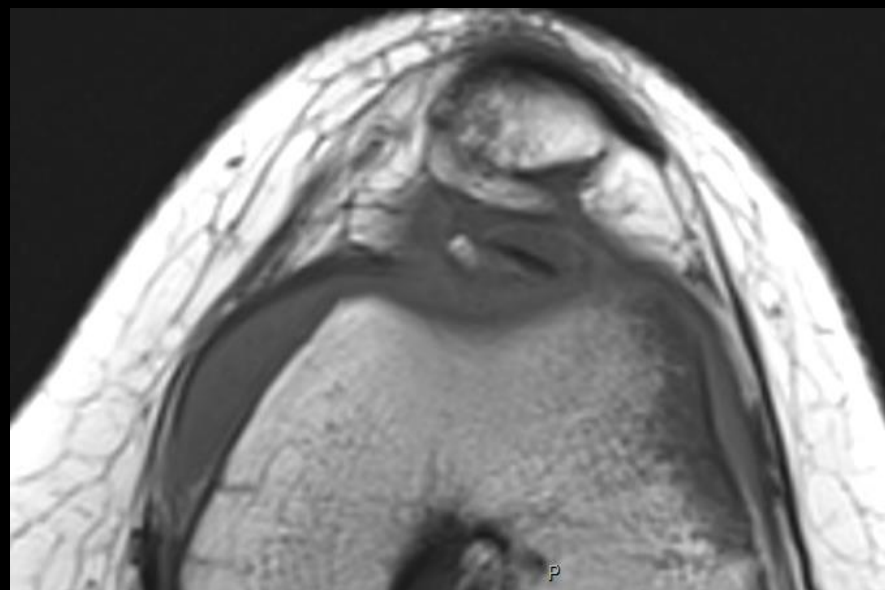
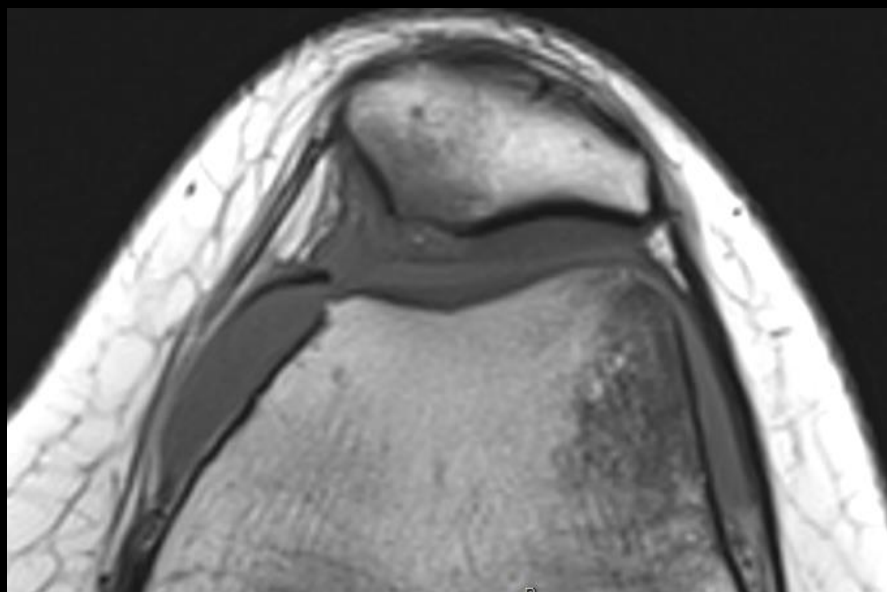
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VAN ISACKER TOM 17608171480 DR
16/06/2011, 14:35:27 6:33
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MPR 2,1 mm
RD : 176,00
1,30

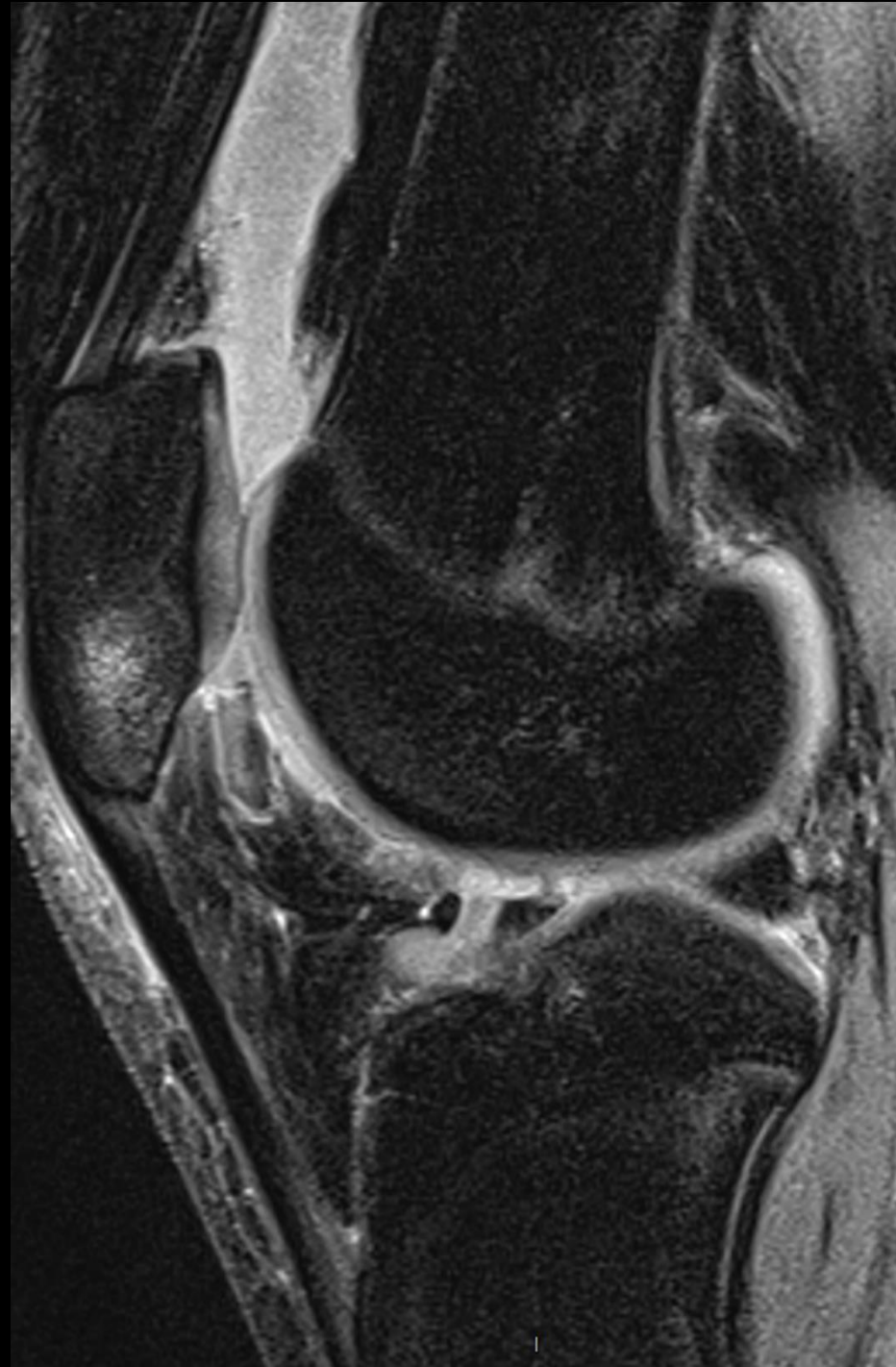
ition AS
260mAs
: 1,7 mm
: 171,00
1,00









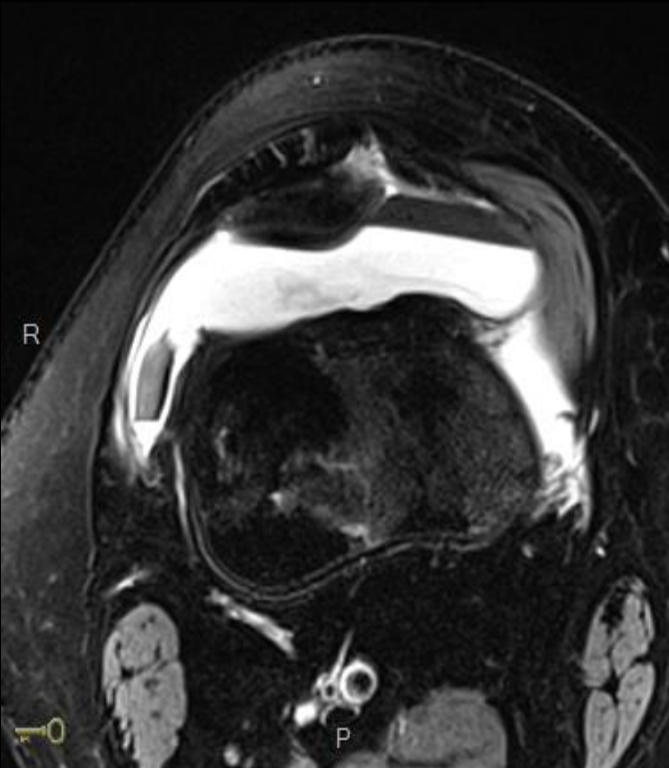




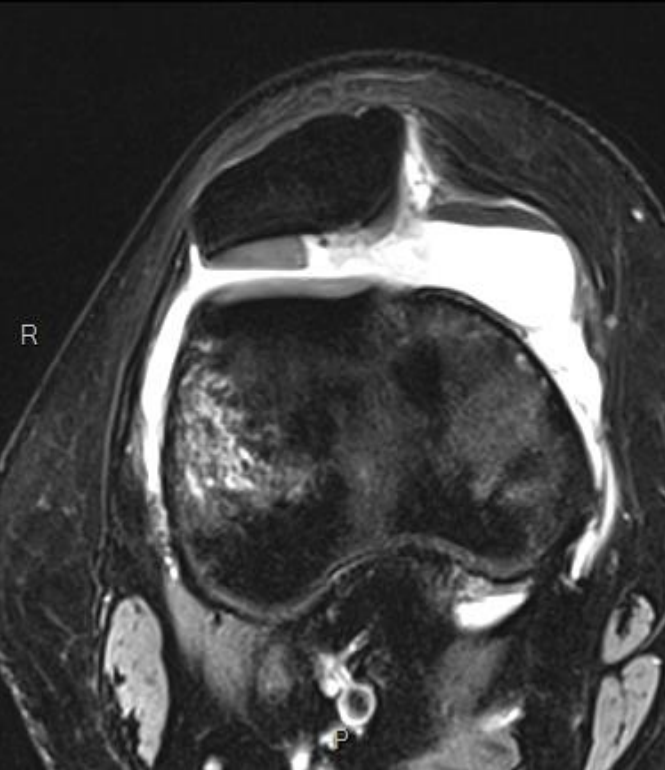




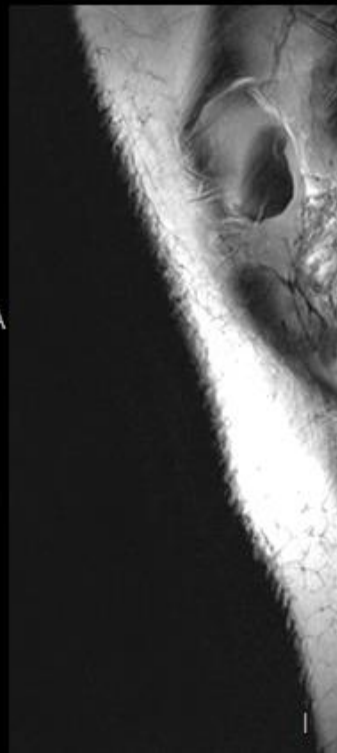
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< 8 - 19 >



< 6 - 26 >



S PELOPIDAS EMANOEL
D

U.C.L / SAINT-LUC
THIENPONT EMMANUEL 10903887480

[27/05/2011 , 10:39:15]

SIEMENS Definition AS

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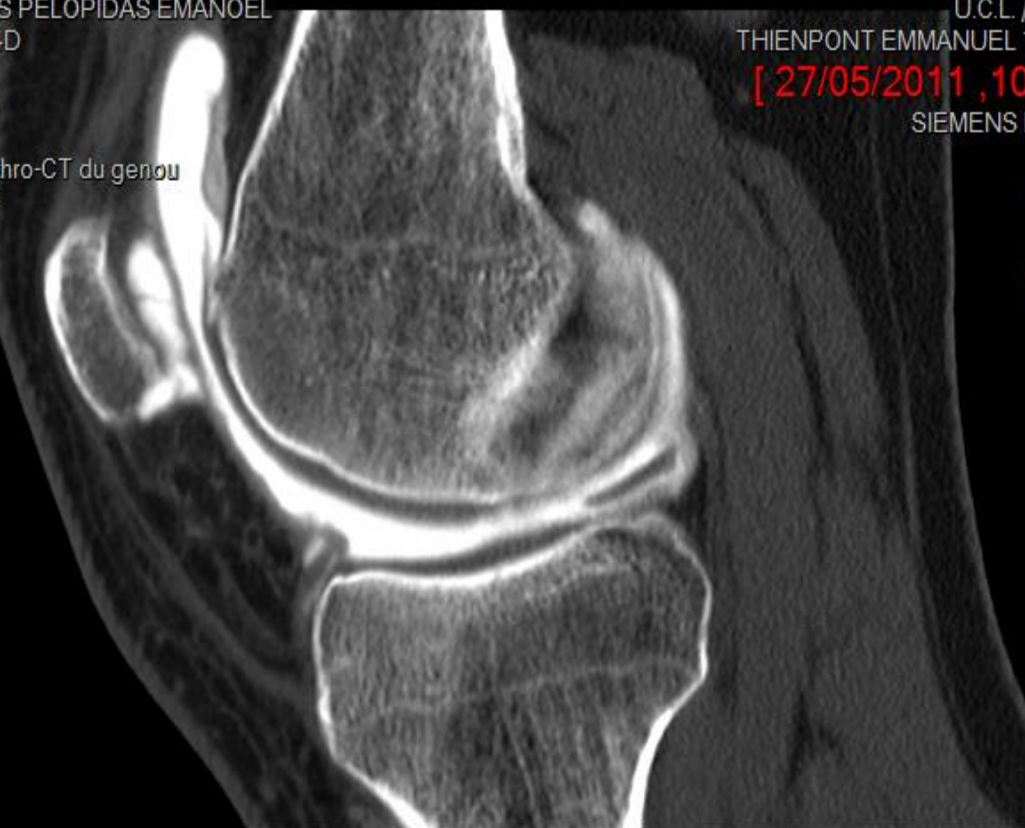
SW 2,0

mec

120% < 603 - 24 >

Visionn

thro-CT du genou

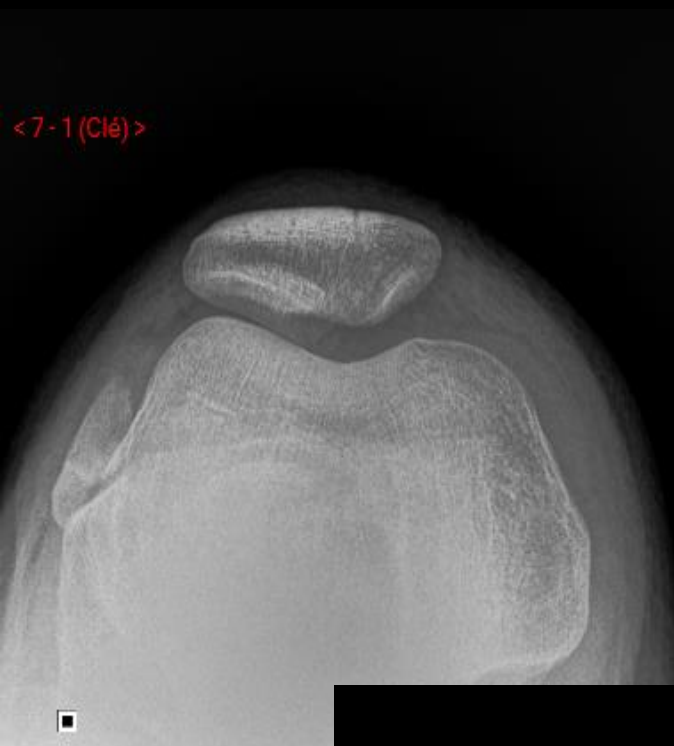


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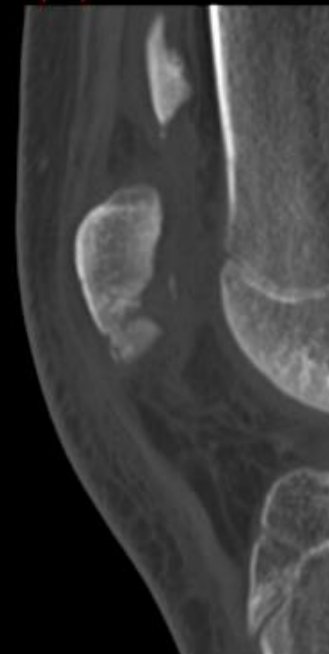
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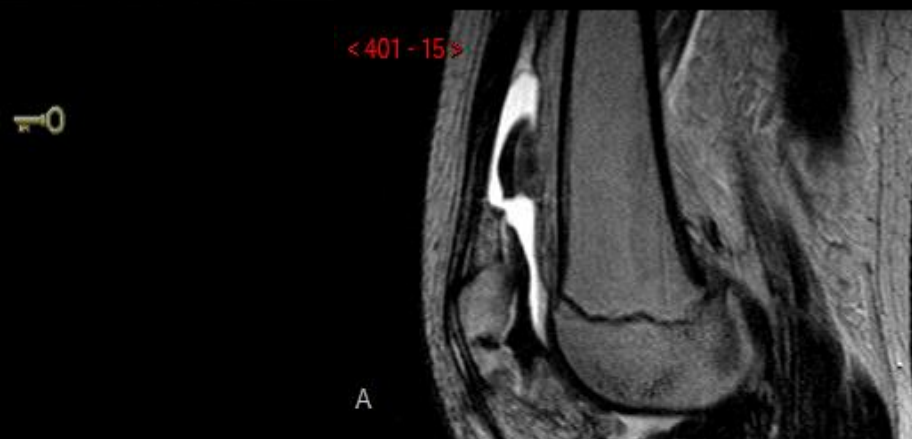




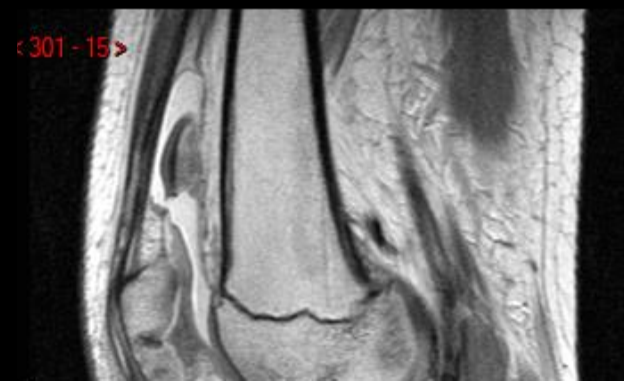
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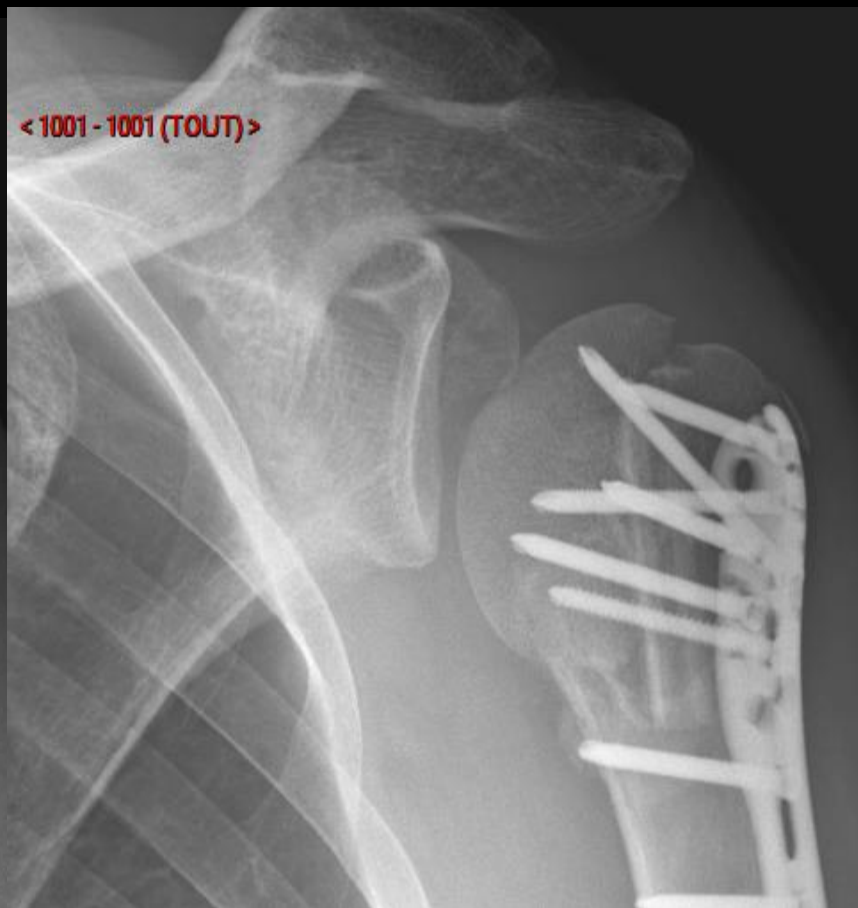


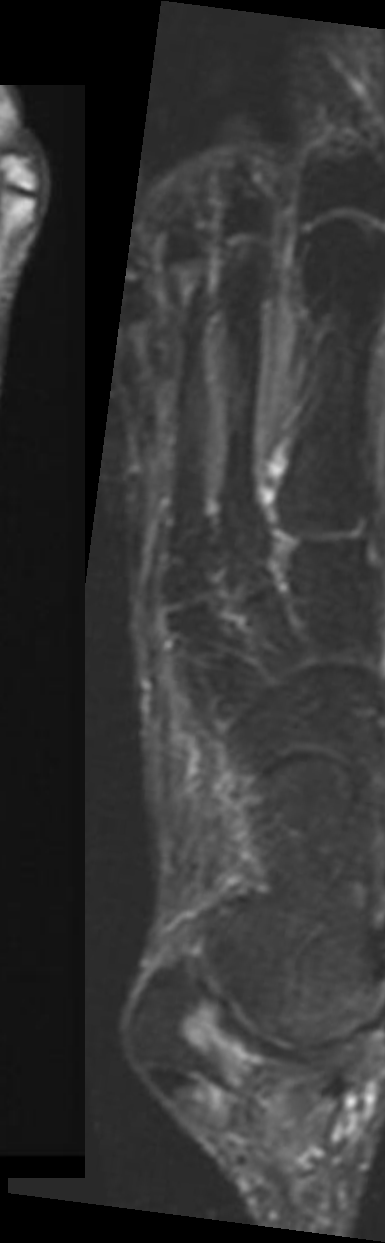
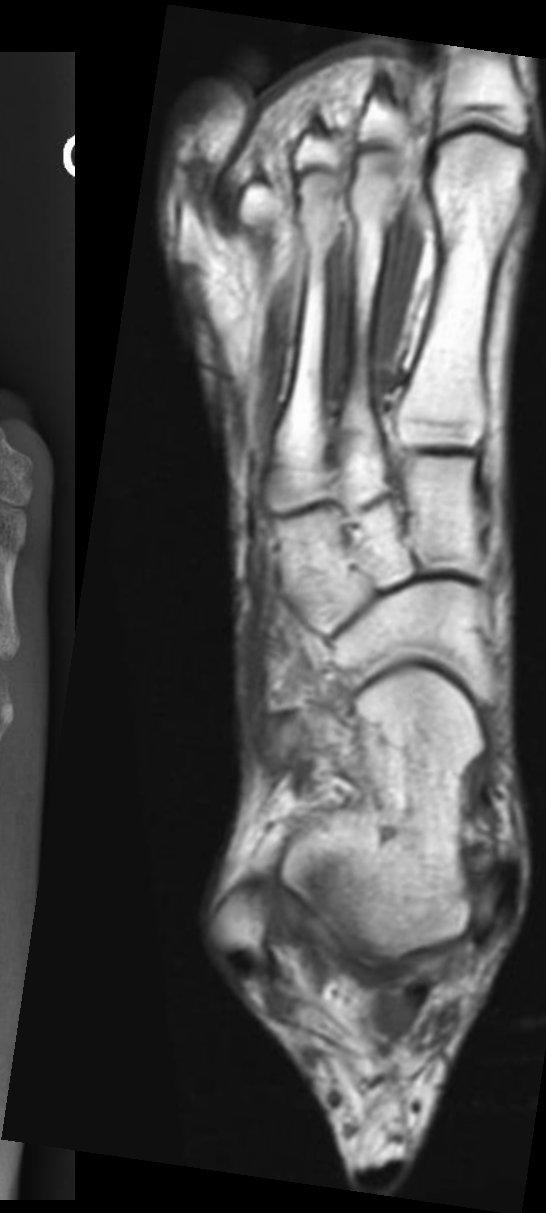
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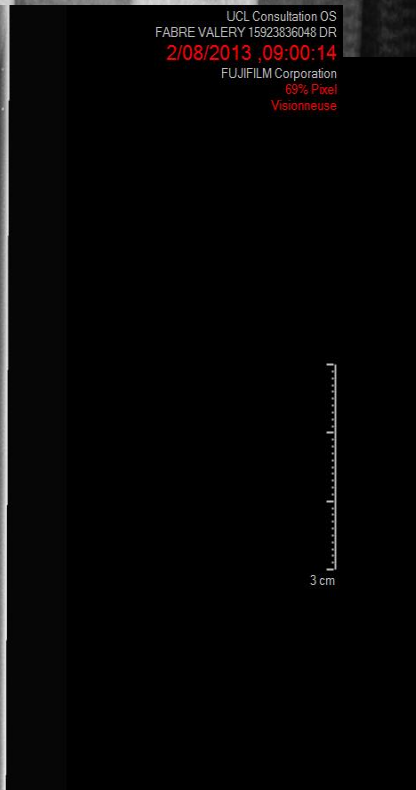
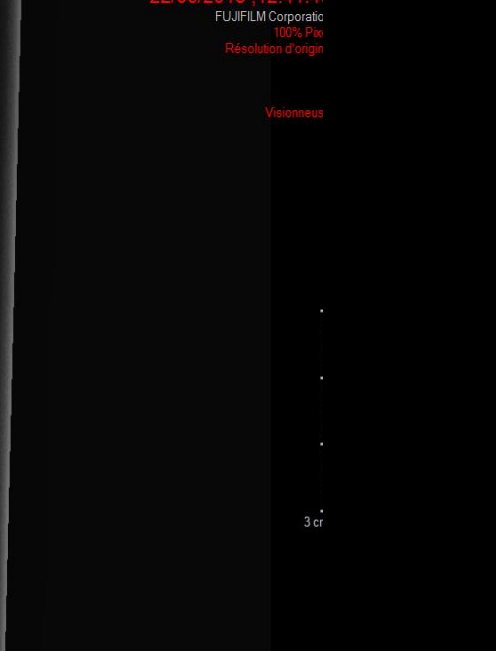


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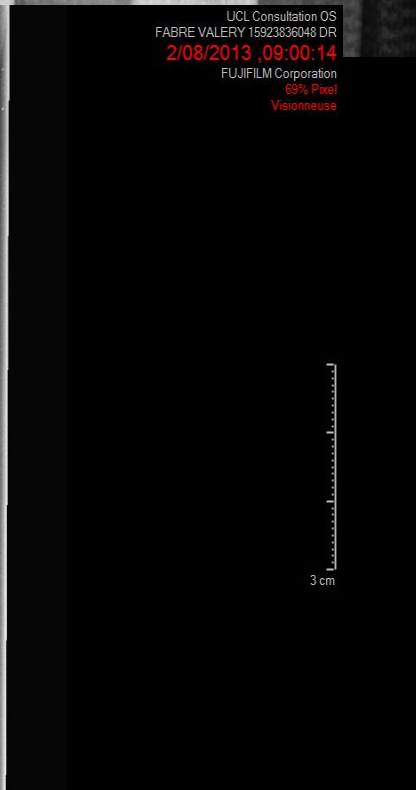






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N° dem.: 5532616
Desc. examen: Clavicule(s)
ID plaque: a48055765c
St: 210.00
<1001-1001 (TOUT)>

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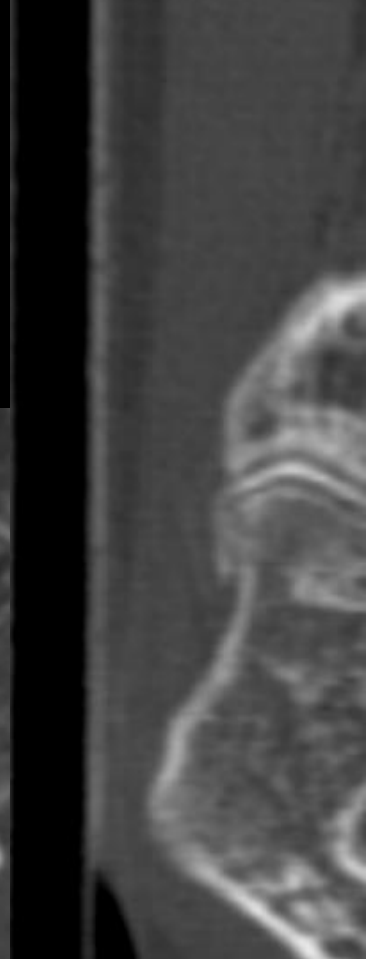
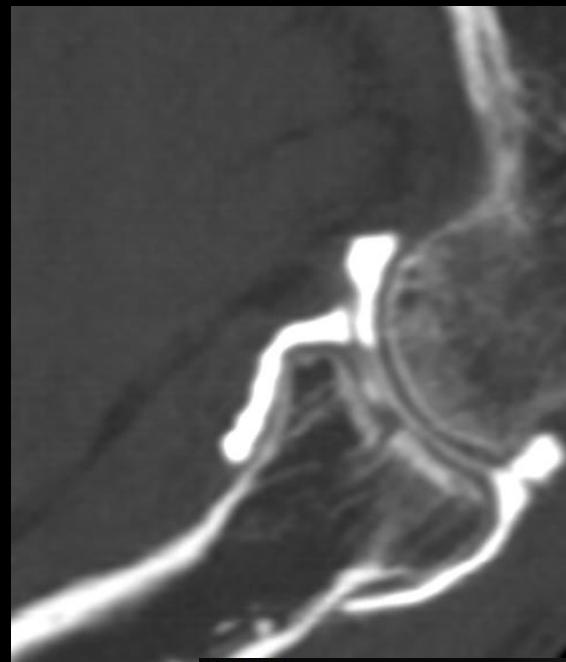


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FABRE VALERY 15923836048 DR
2/08/2013 , 09:00:14
FUJIFILM Corporation
69% Pixel
Visionneuse



3 cm



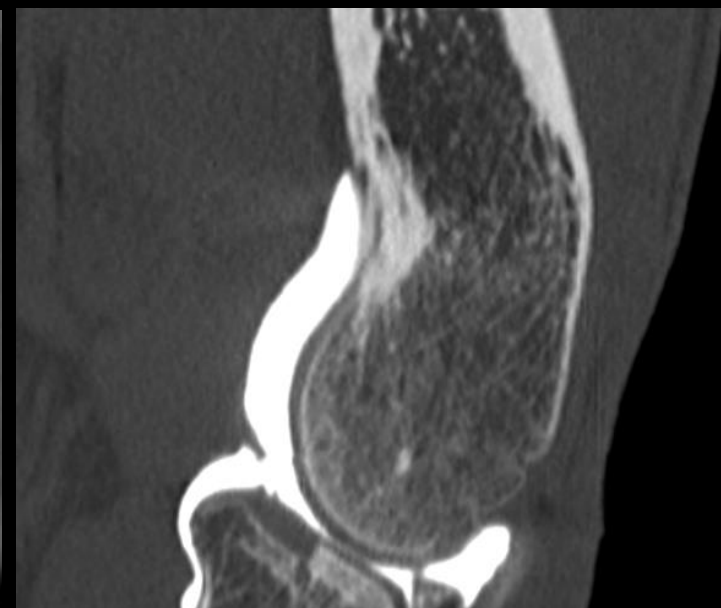
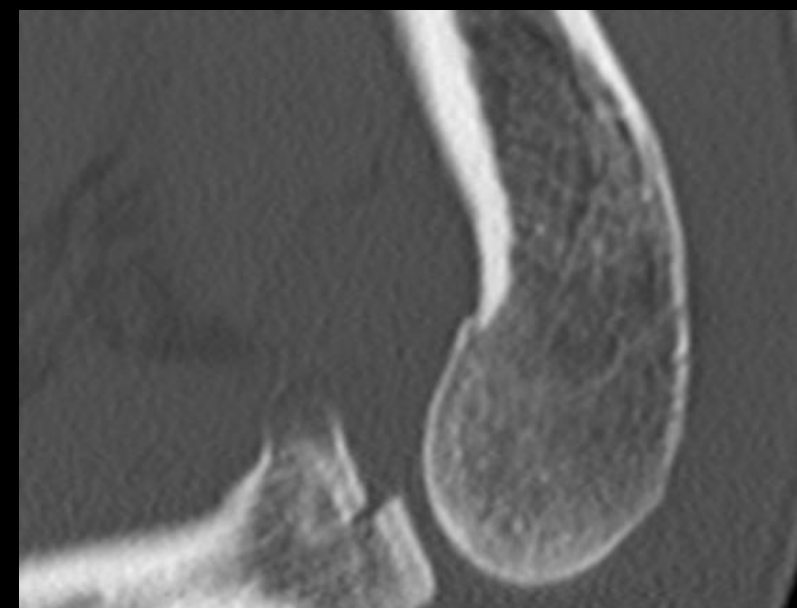
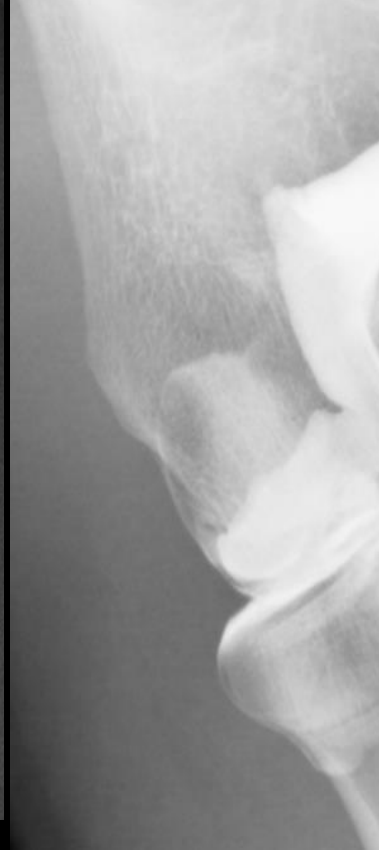


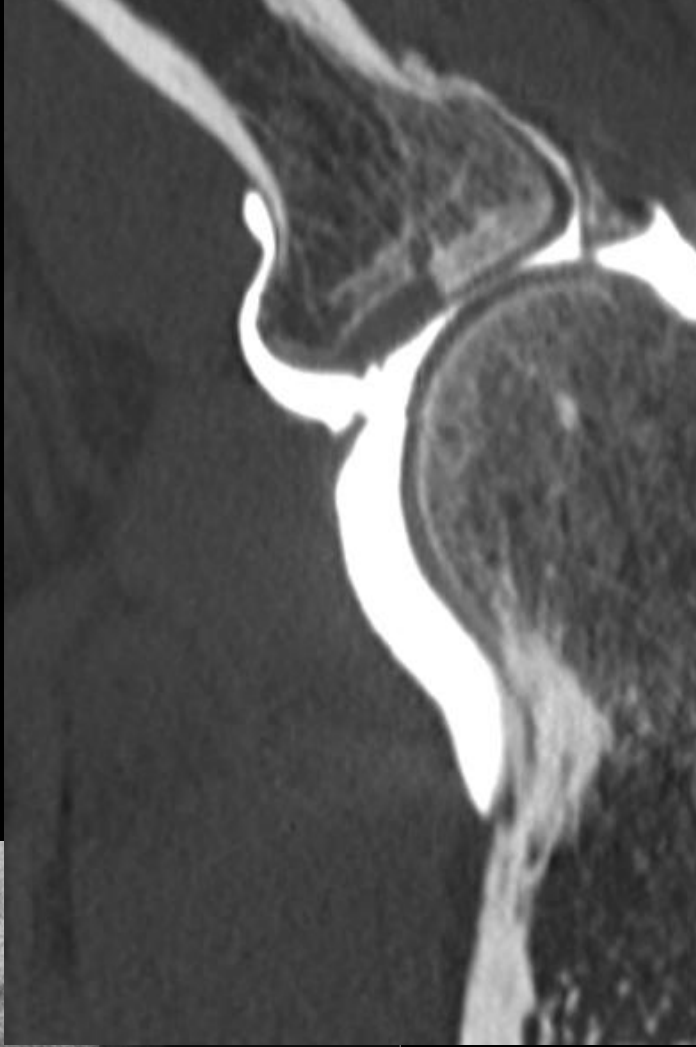
UCL ST. LUC
24/04/2006, 10:06:20
120kV, 200mAs
SW 0.50 mm
316% Pixel
Visionneuse

DUTERME CHRISTEL
33A 10M.F.E51806W
NF dem. 4060286
Dess. examen: Coudes(s)
ID plaque: s43348289e
SI 136.00
+ 1002 - 1802 (TOUT)



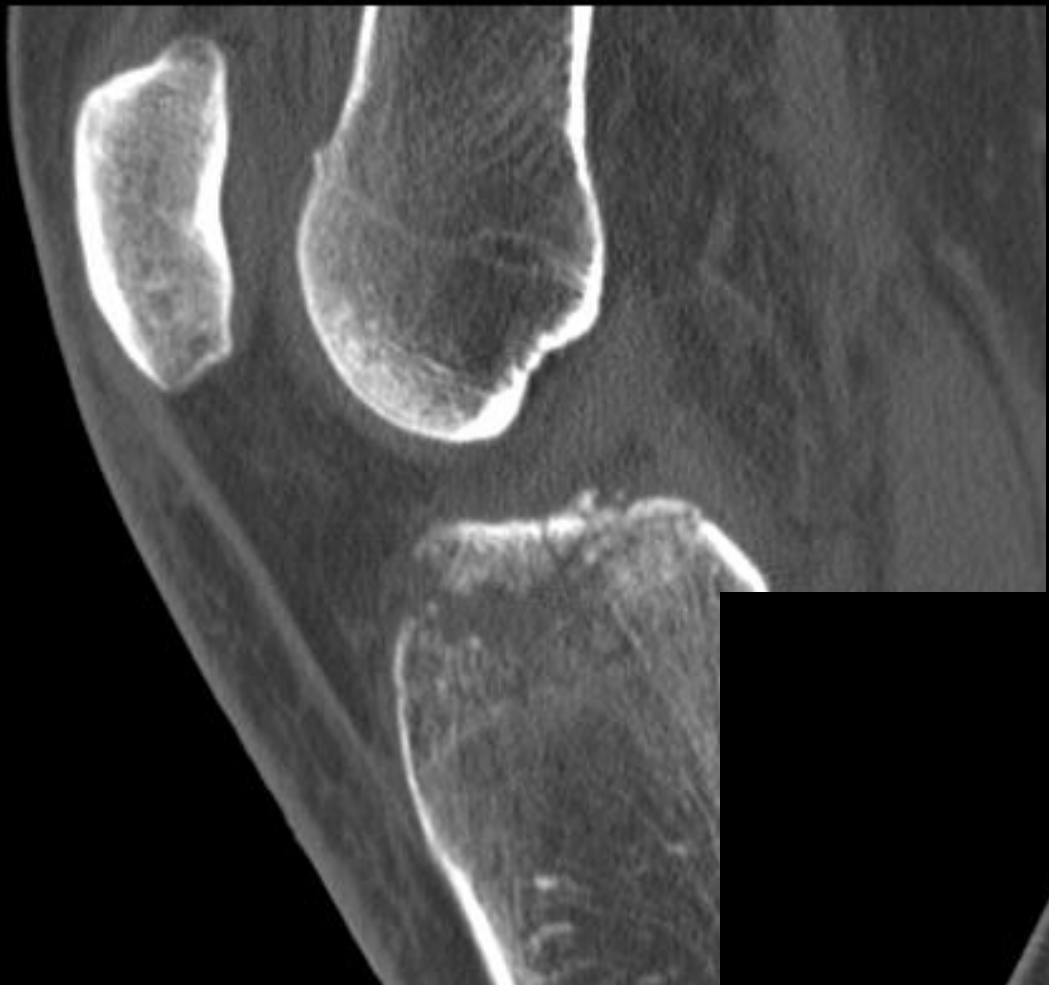
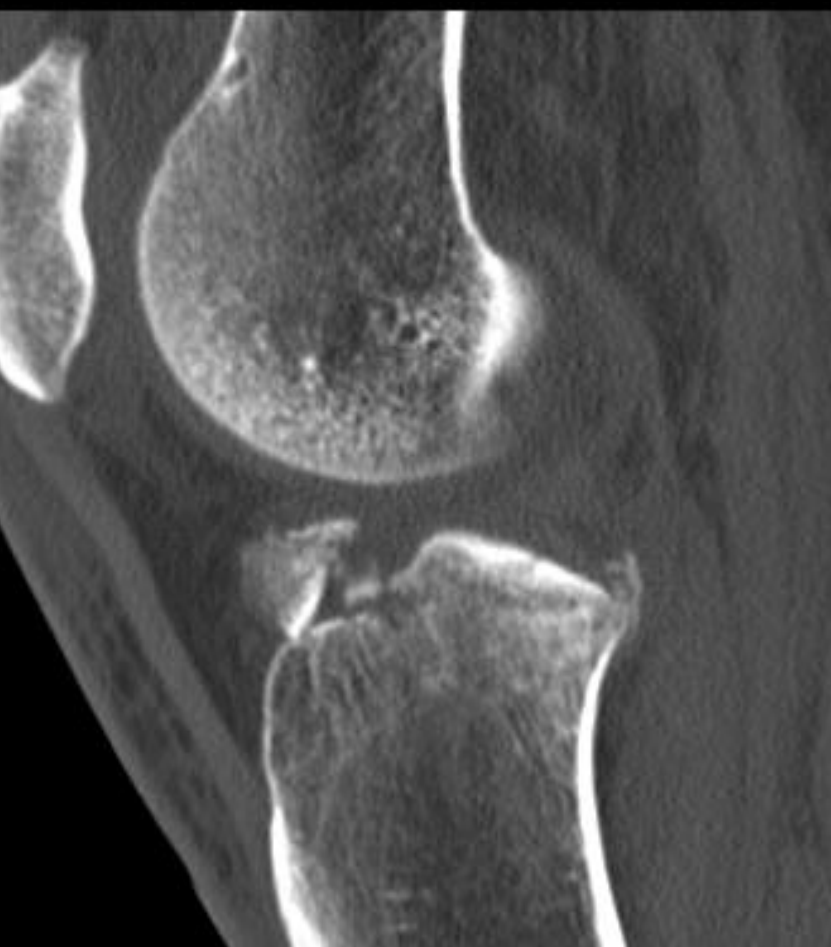


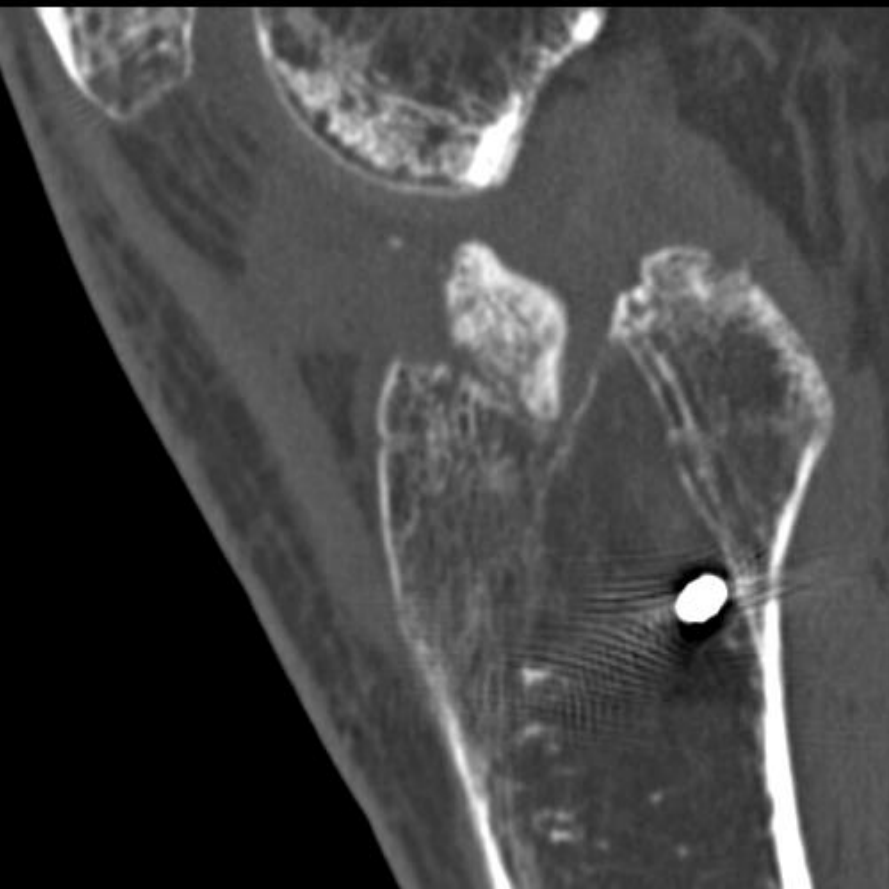




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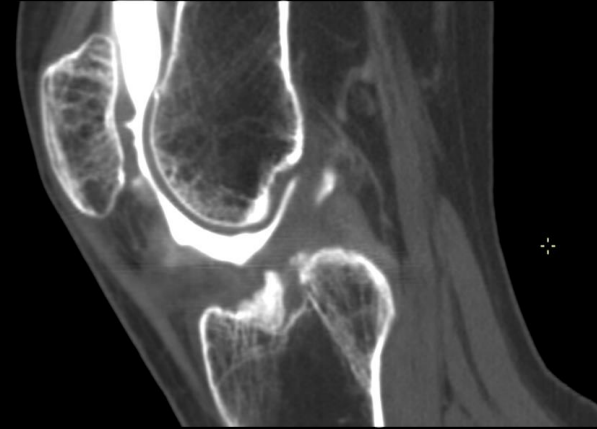
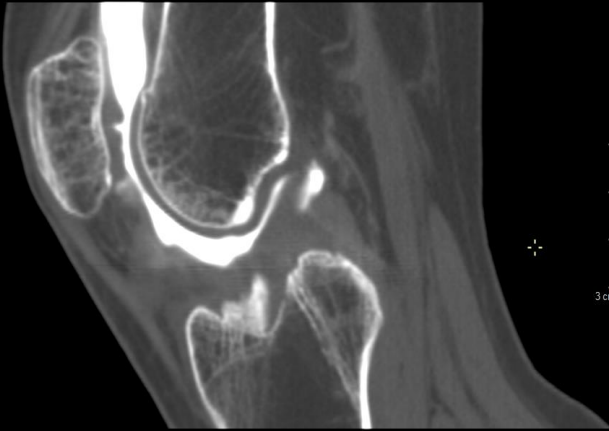
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CASTERMANS CAROLE
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N° dem. : 4382112
Pos. patient: FFS
Desc. examen: Arthro-CT du genou
Desc. série : MPR-
« 2 »

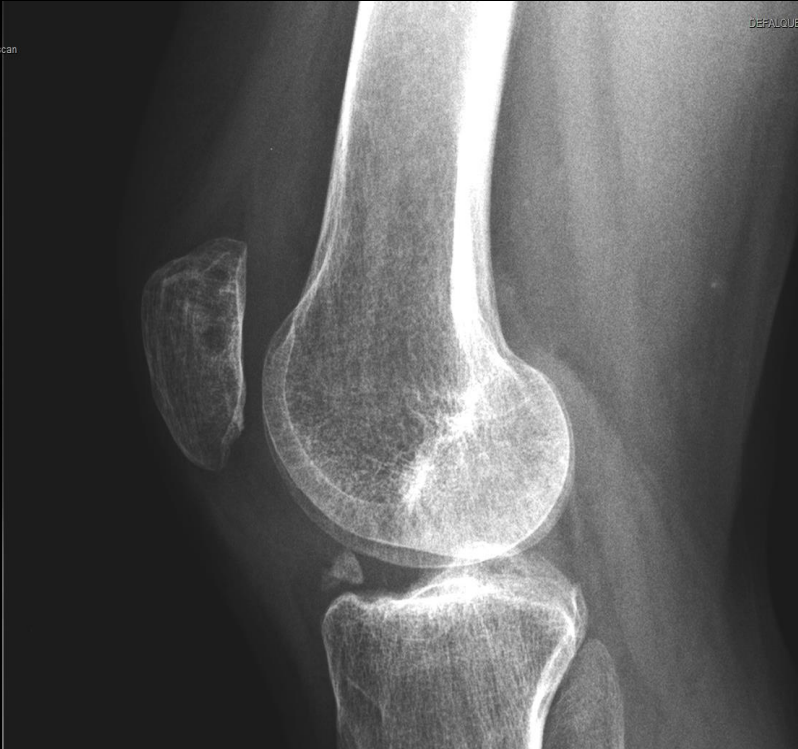
UCL S
DEFALQUE AYMERIC 18841160480 DOCTEUR
7/02/2008 09:1
Philips Brillian
120KV 2
MPR
RD



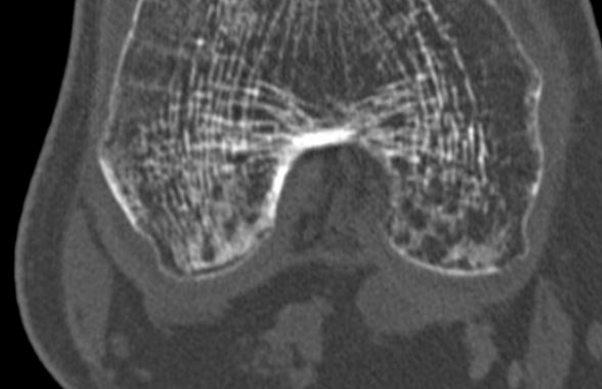
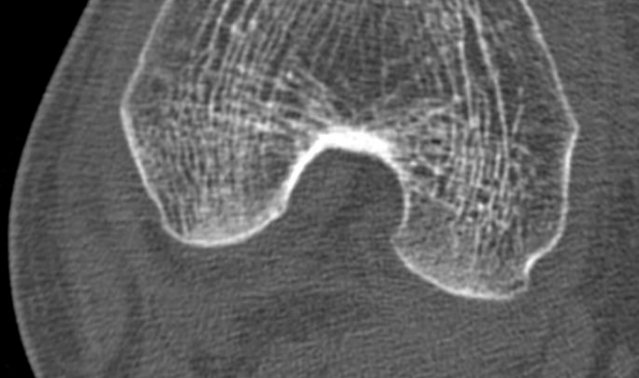
ors de l'arthroscan

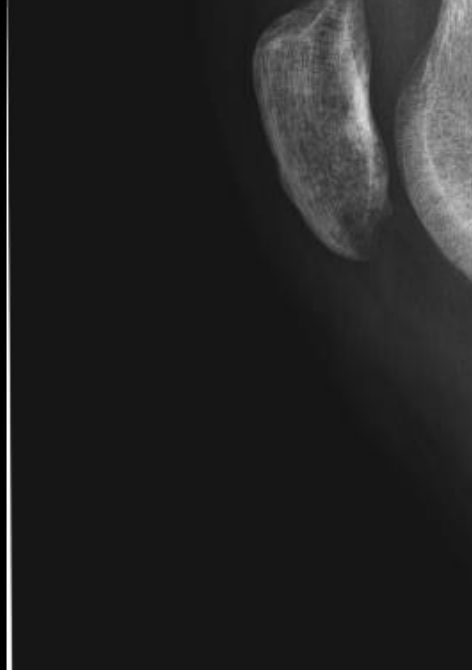
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7/02/2008 08:24:57
CASTERMANS CAROLE
33A 3M.F K04282C
N° dem. : 4382109
Desc. examen: Injection lors de l'arthroscan
ID plaque : a43193936c
SI: 247.00
« 1001 - 1001(TOUT) »

DEFALQUE AYMERIC 188411
7/02/200
FUJI PH







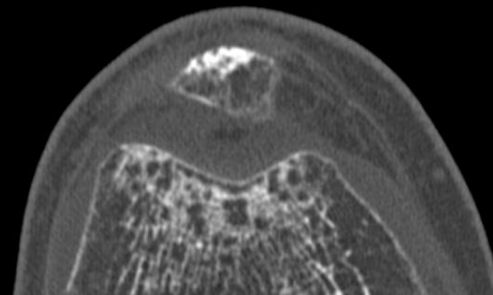
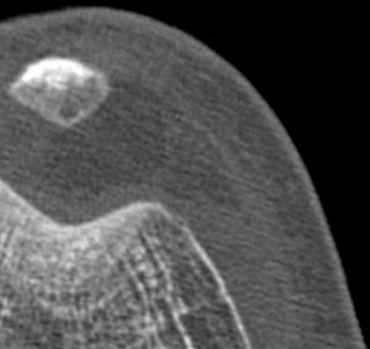


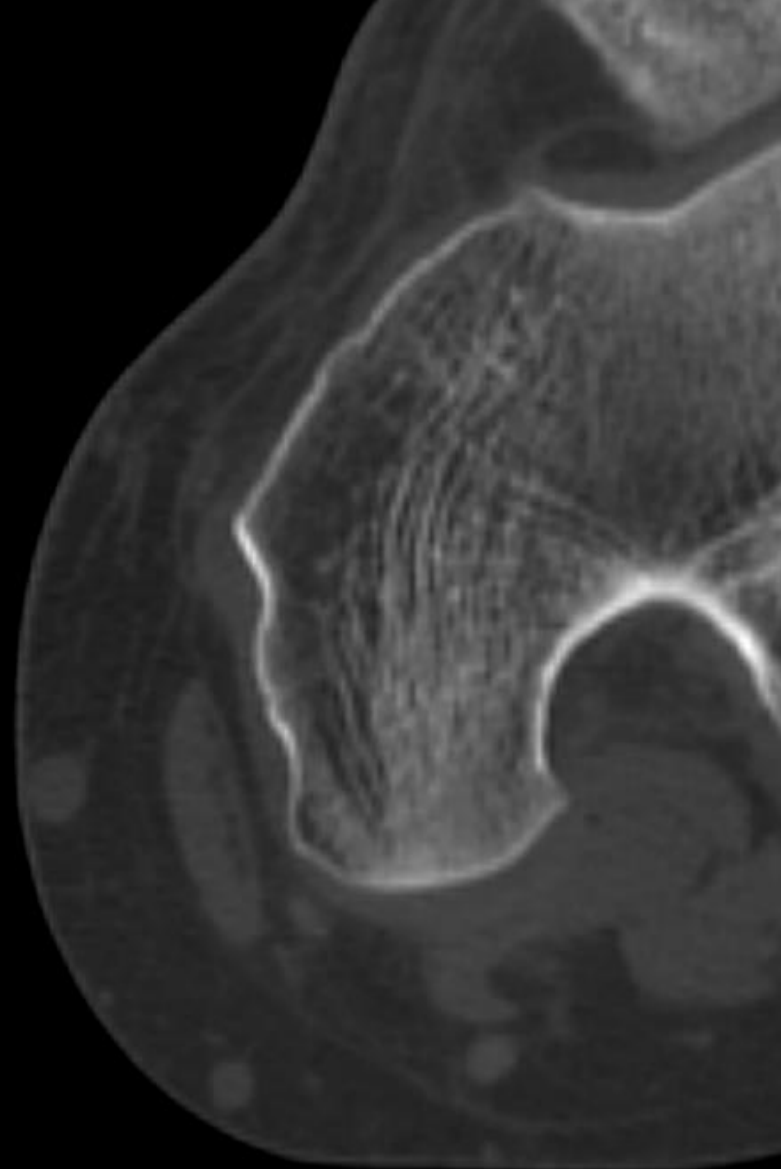
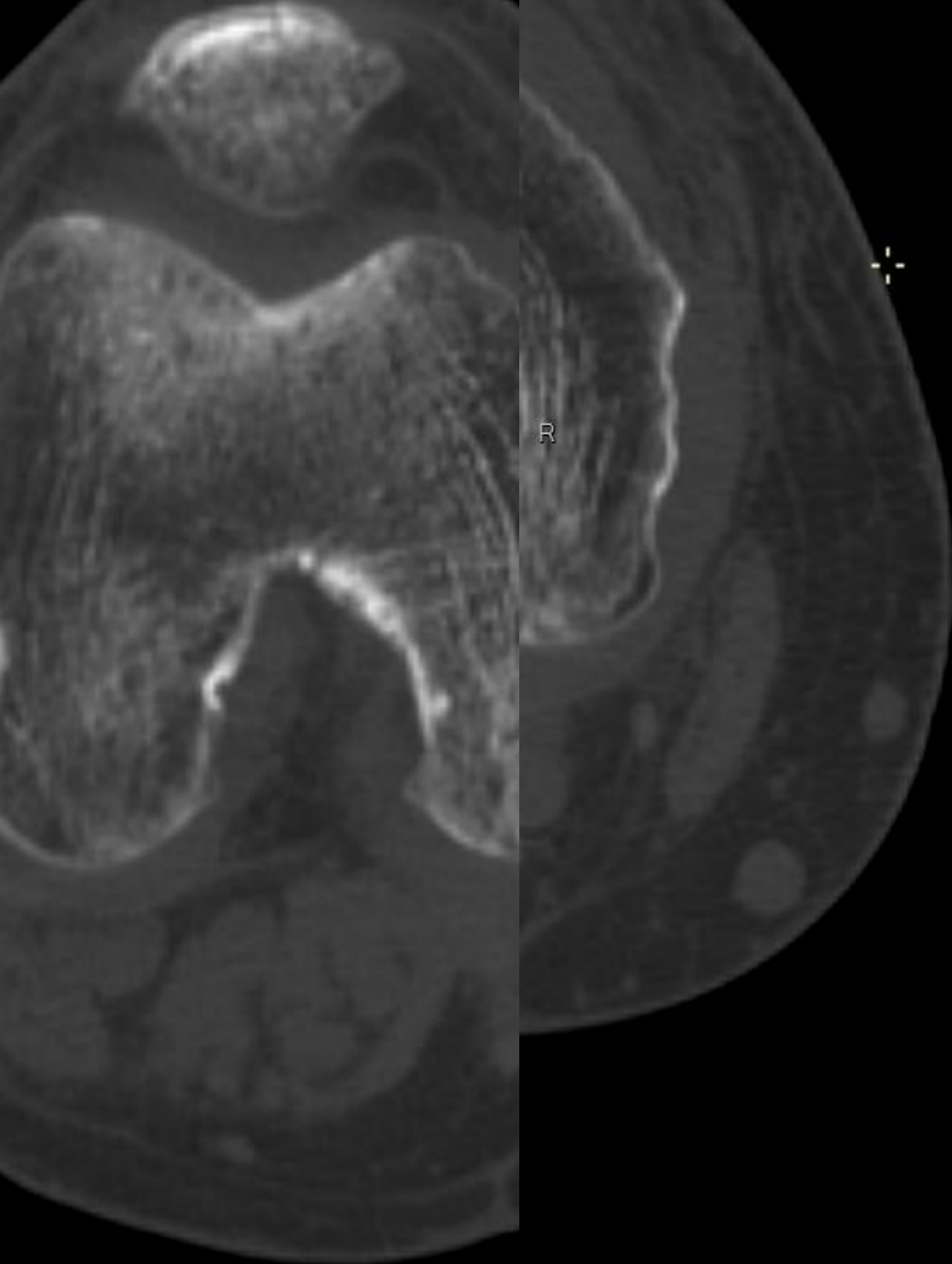
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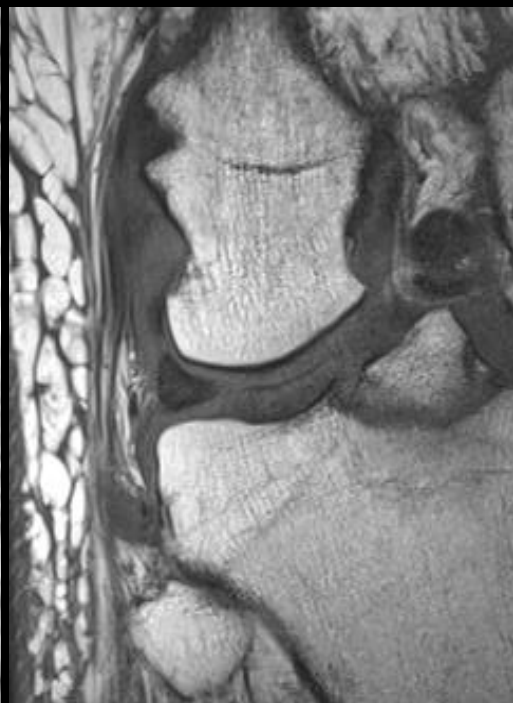
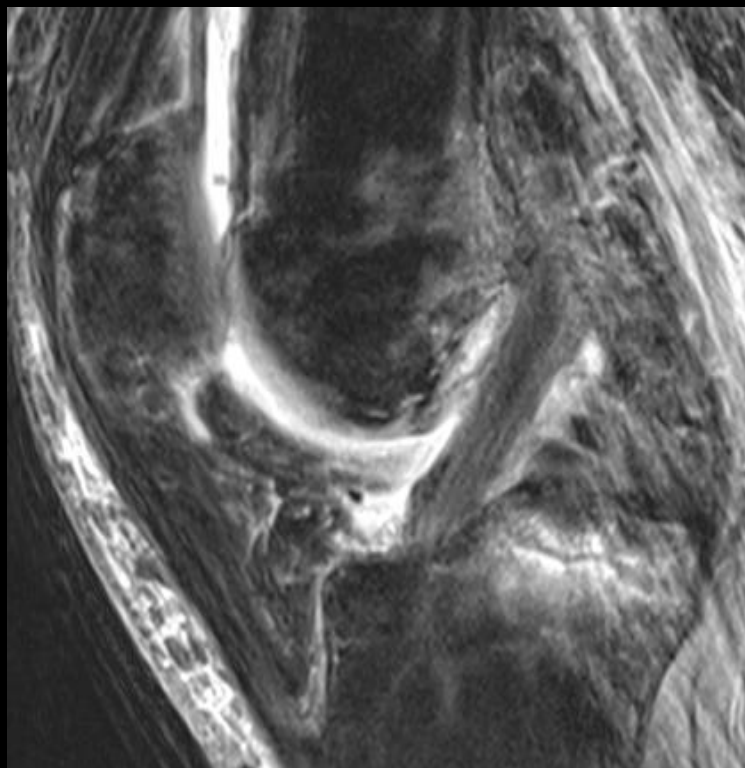
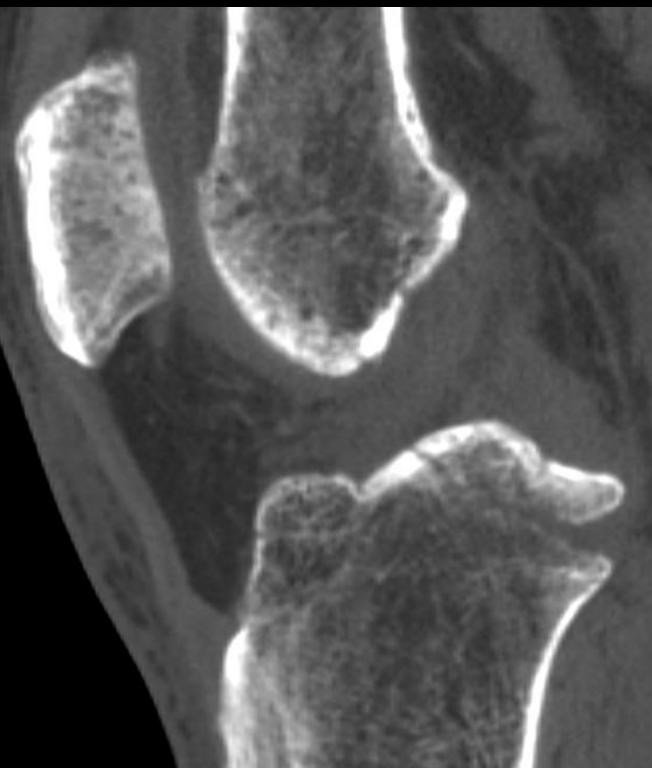


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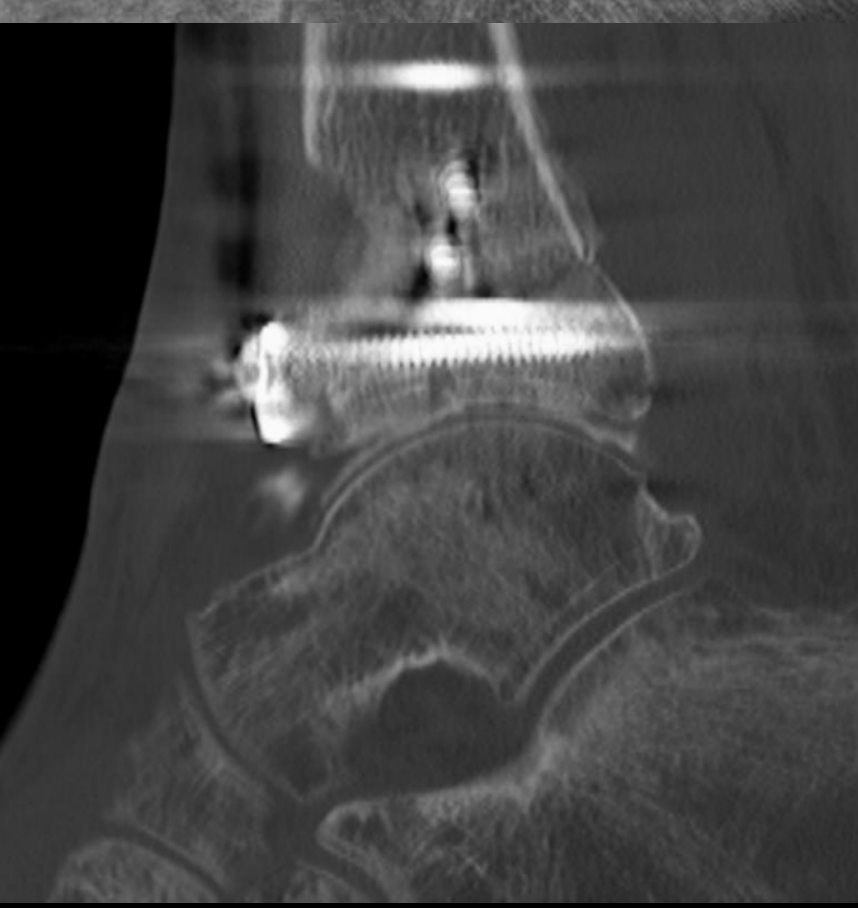
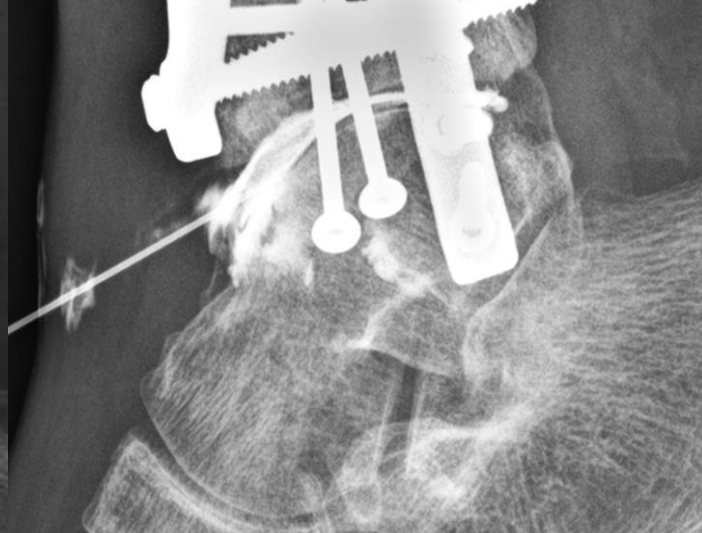


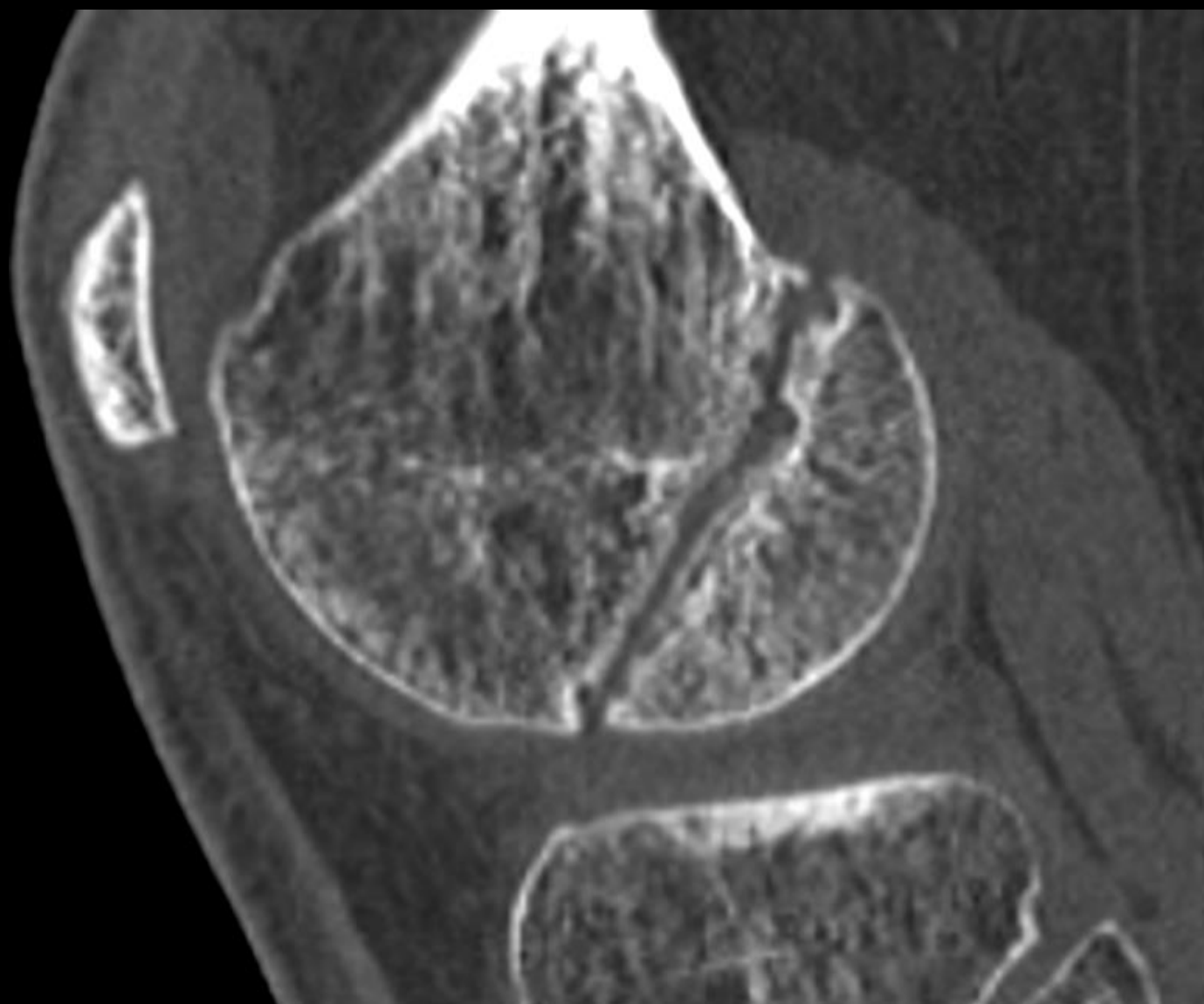


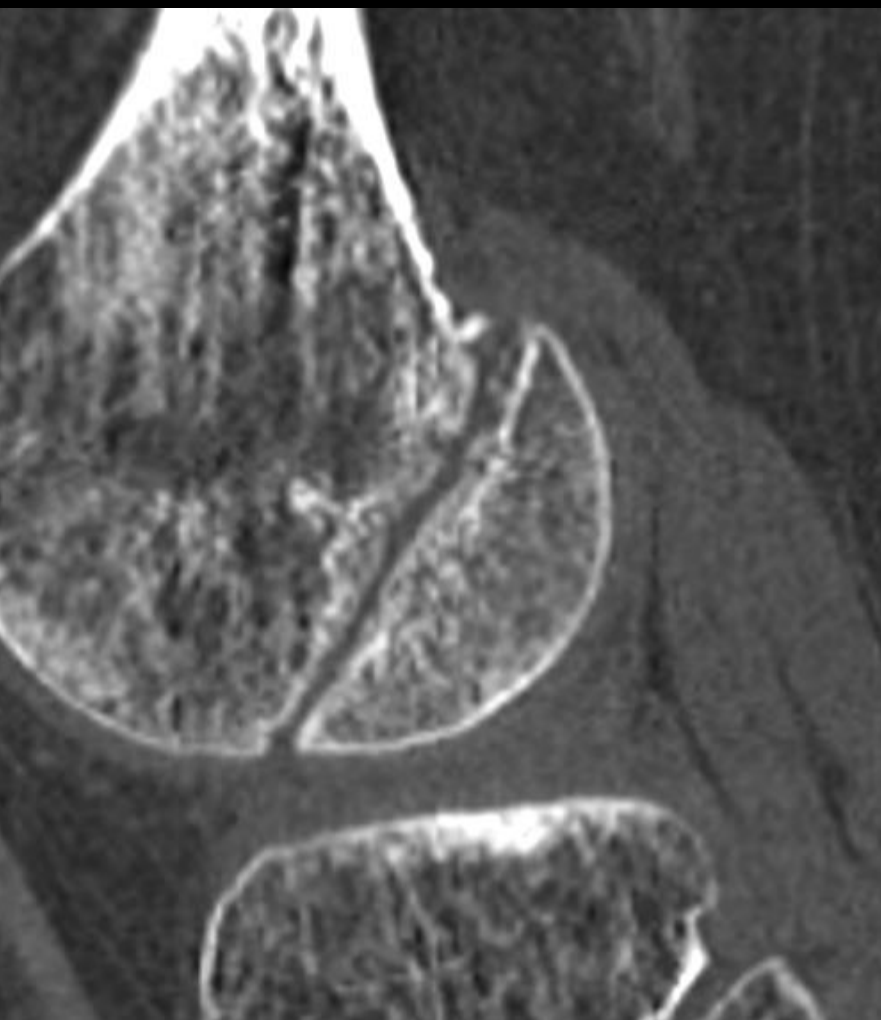
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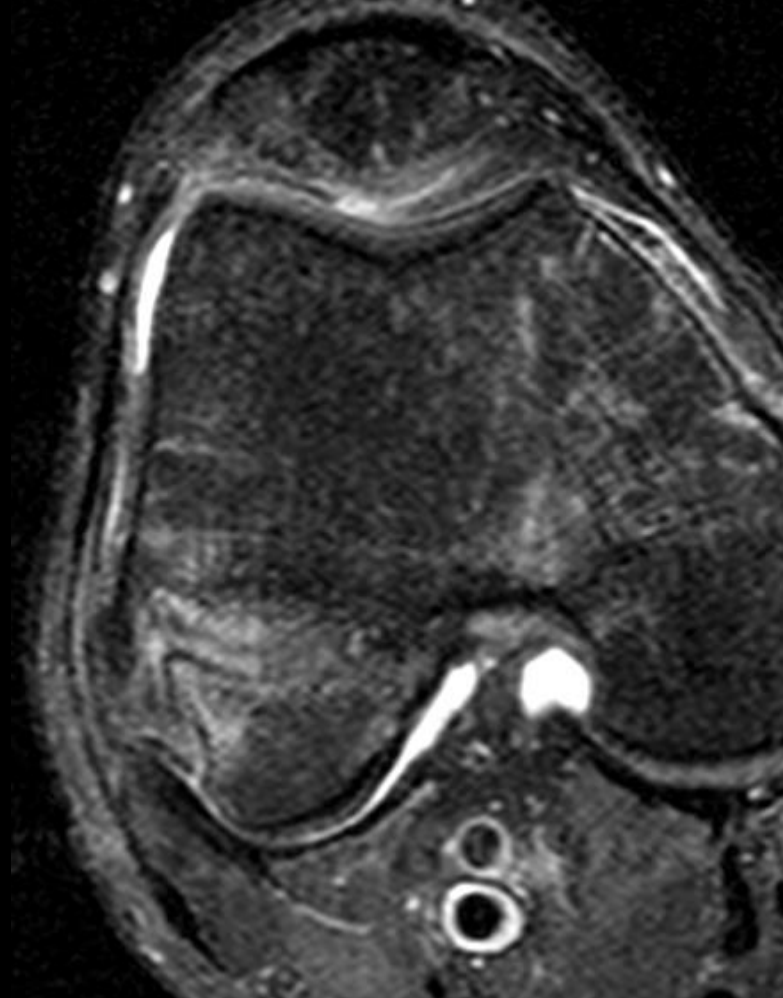
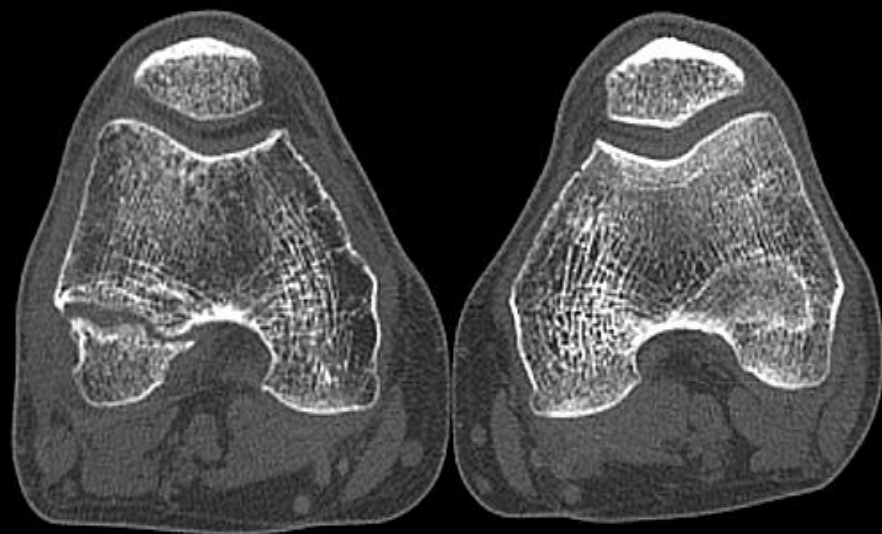




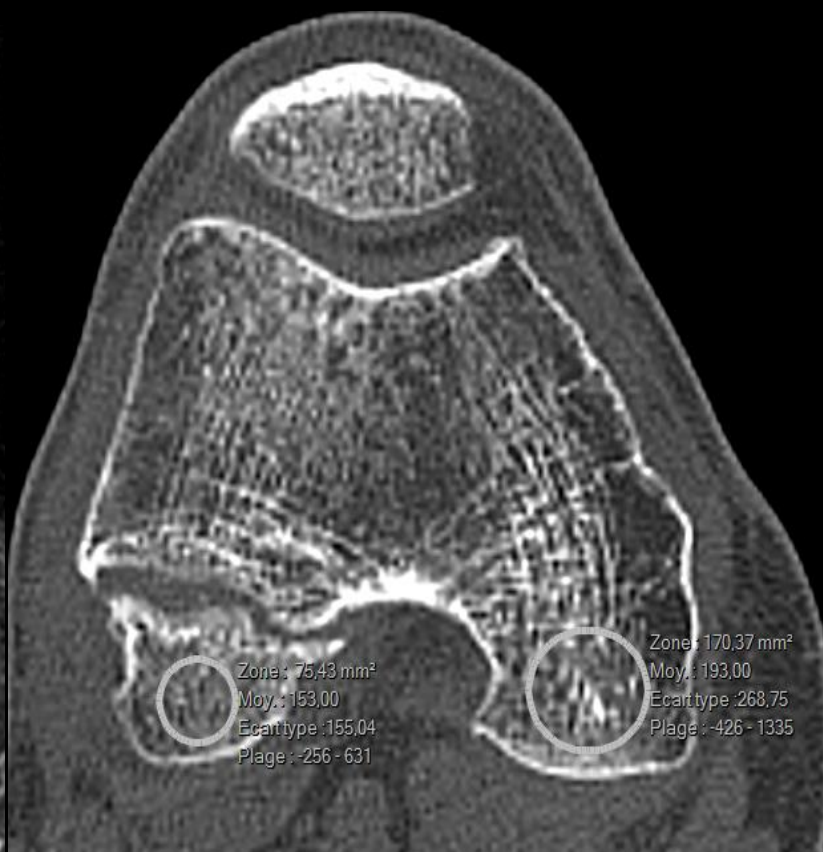
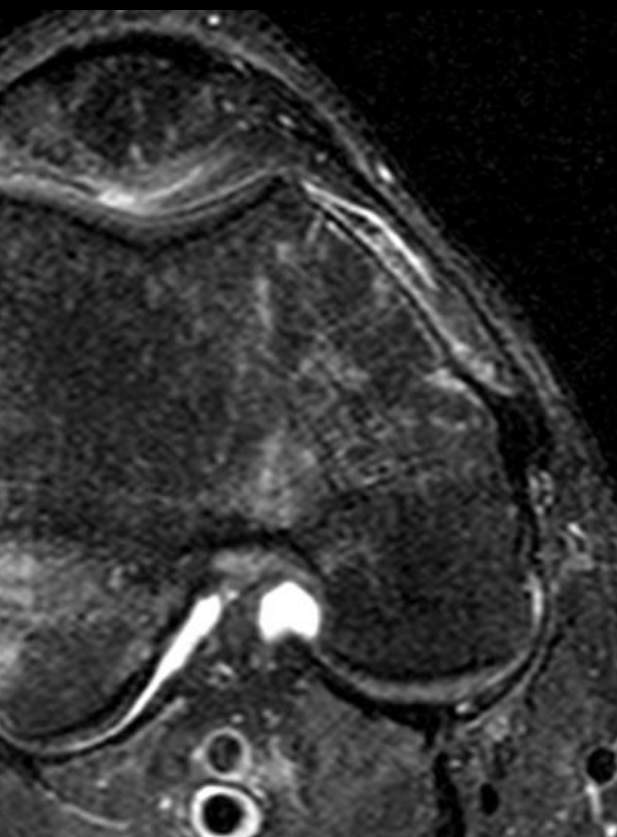
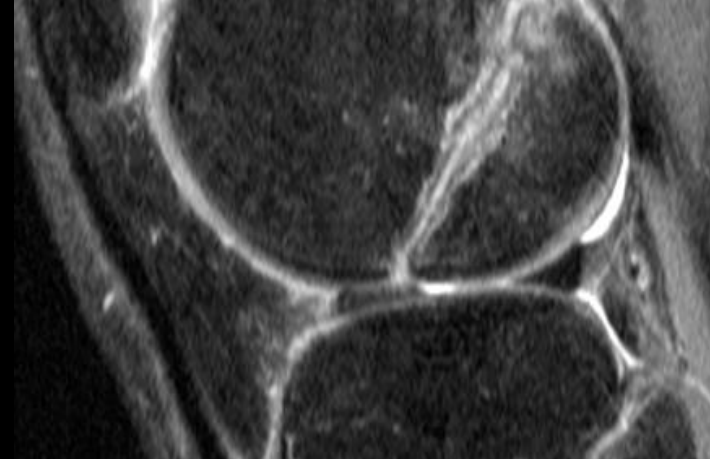
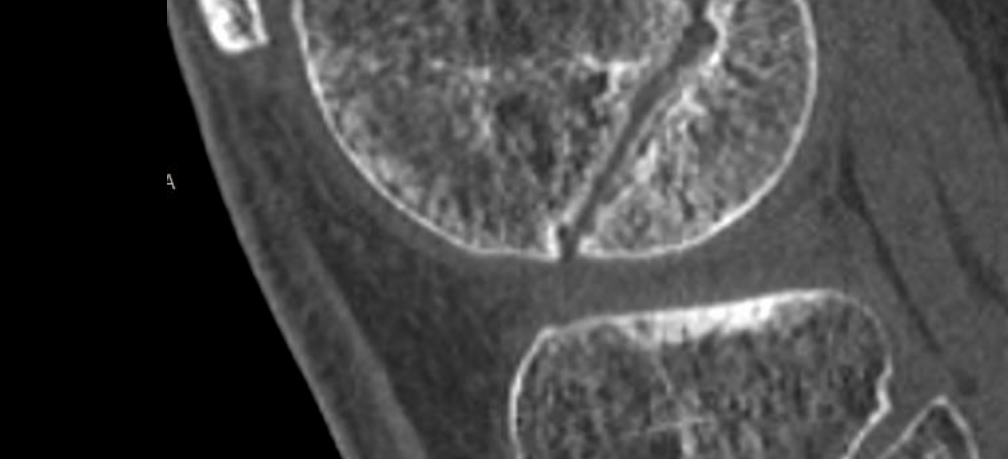




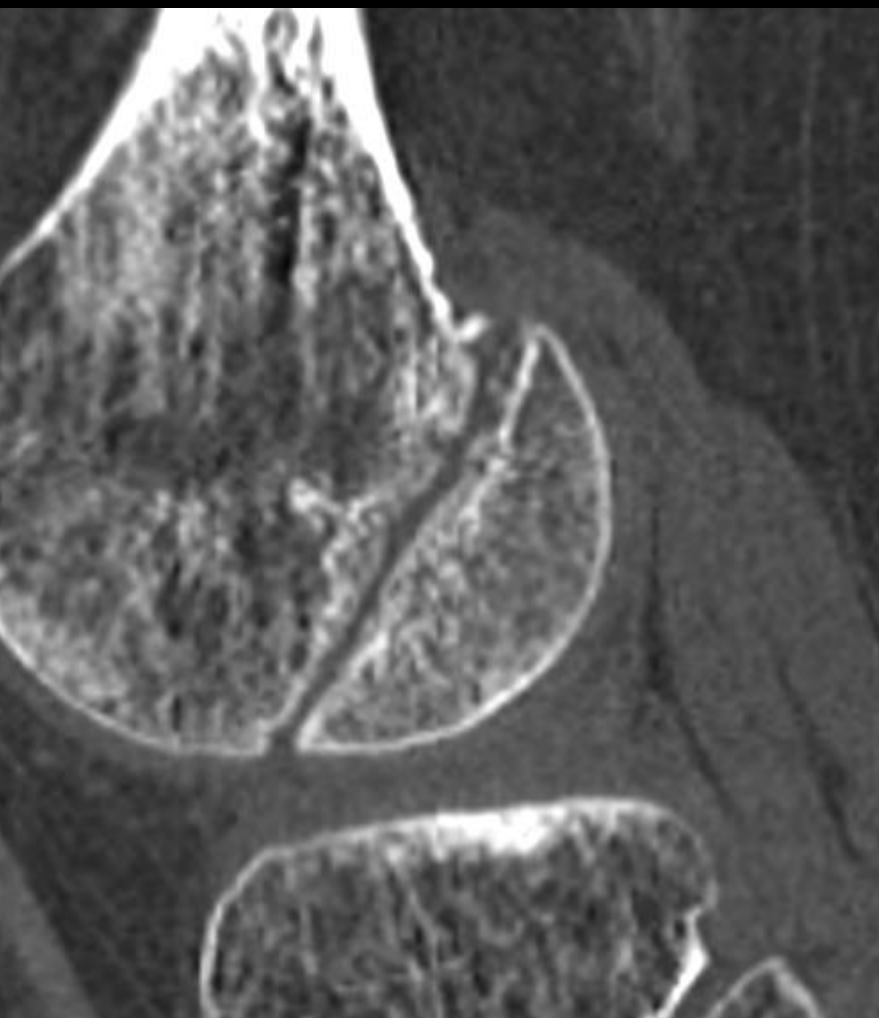




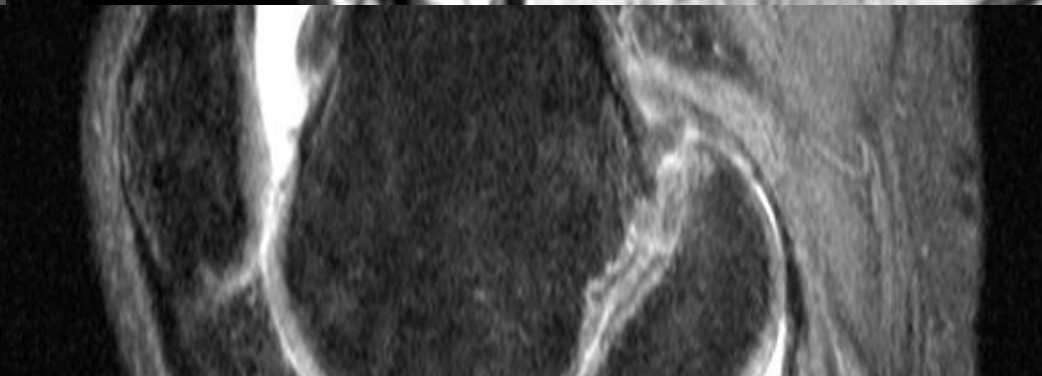
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Moy : 357,00
Ecart type : 345,89
Plage : -611 - 1669

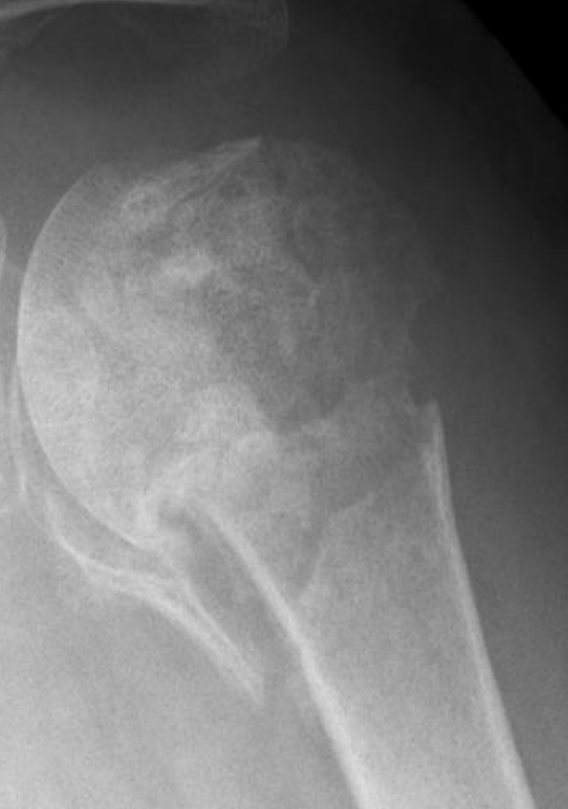


A



D

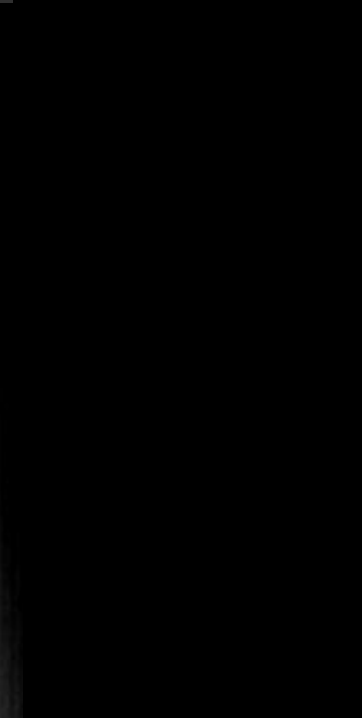
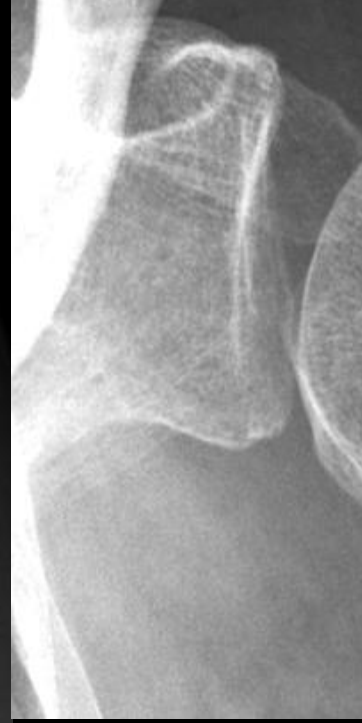


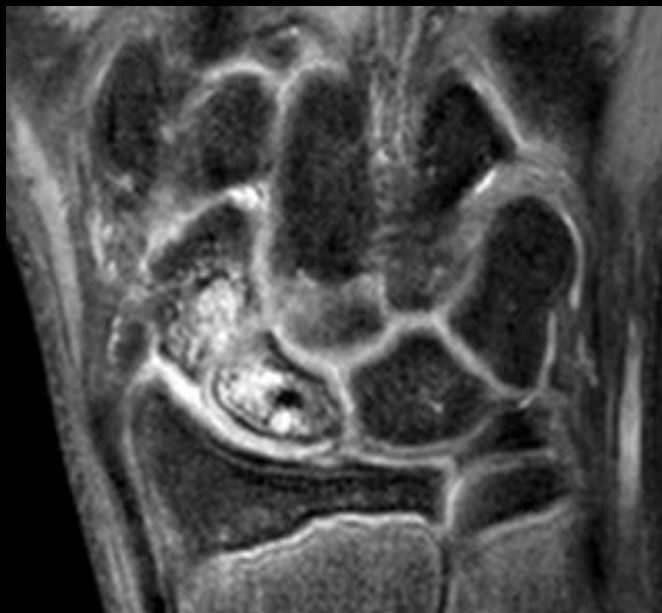
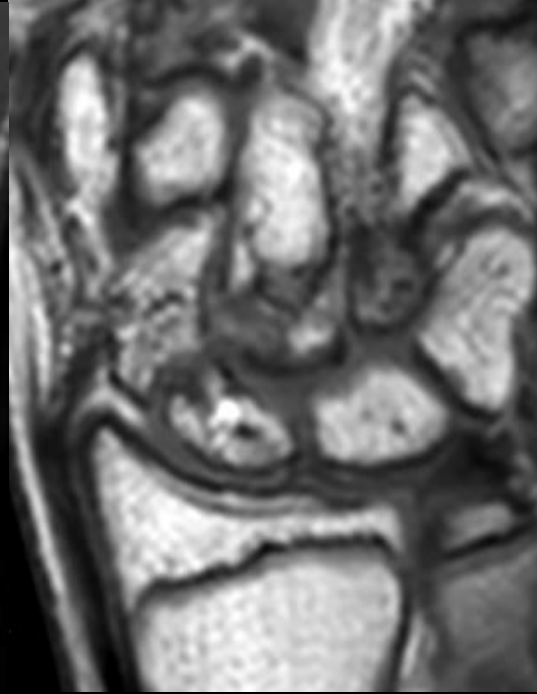






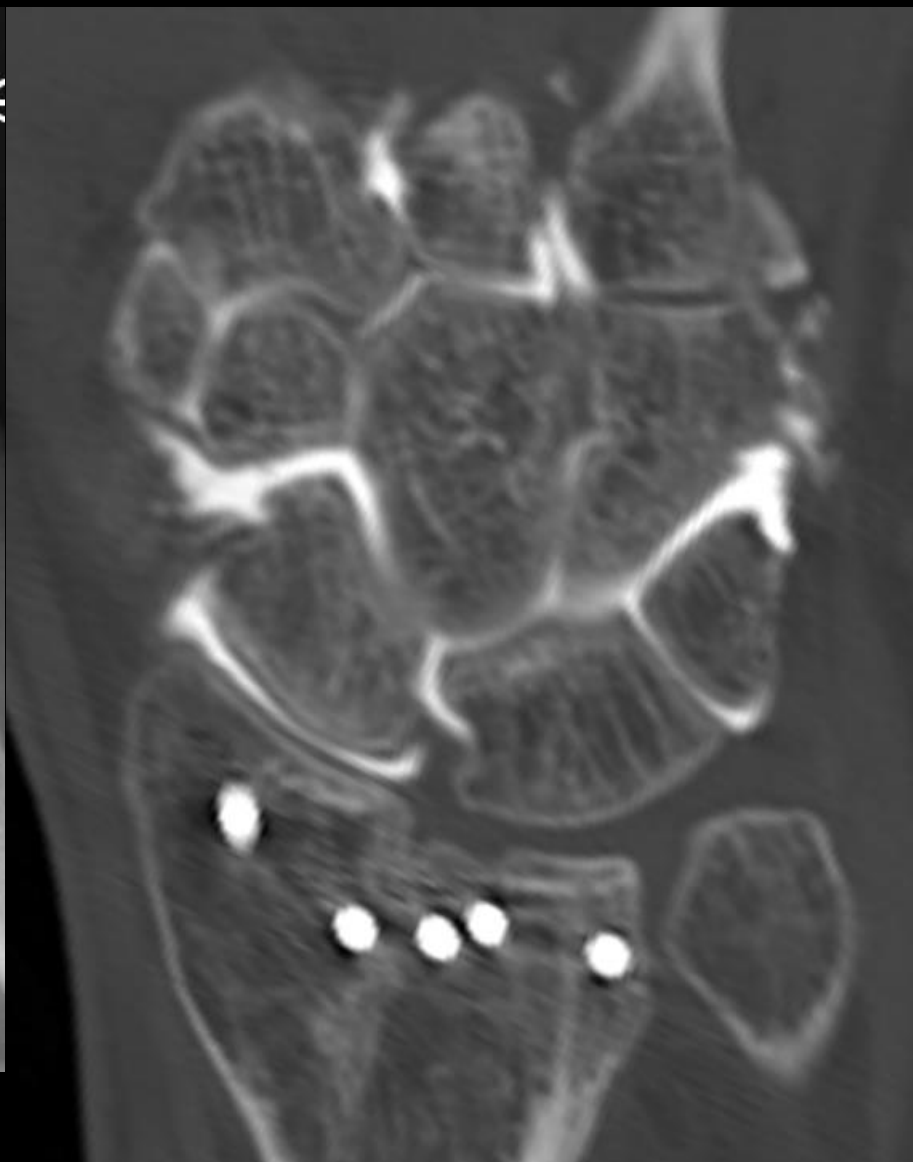










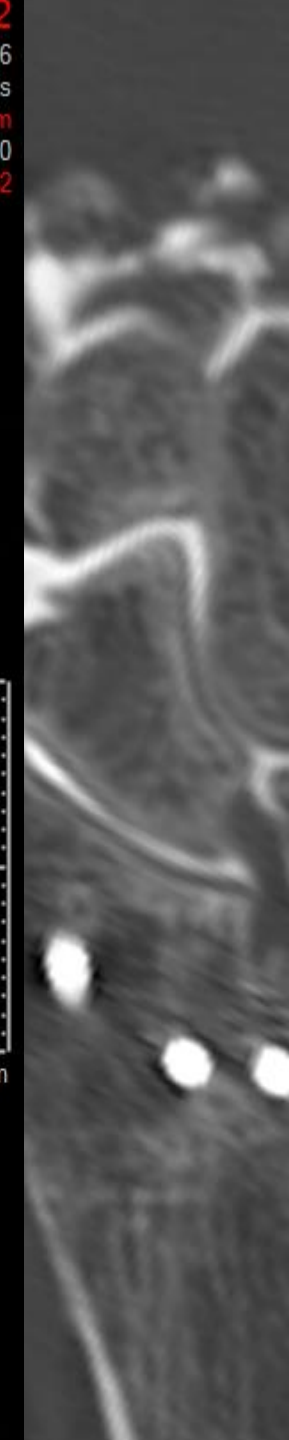




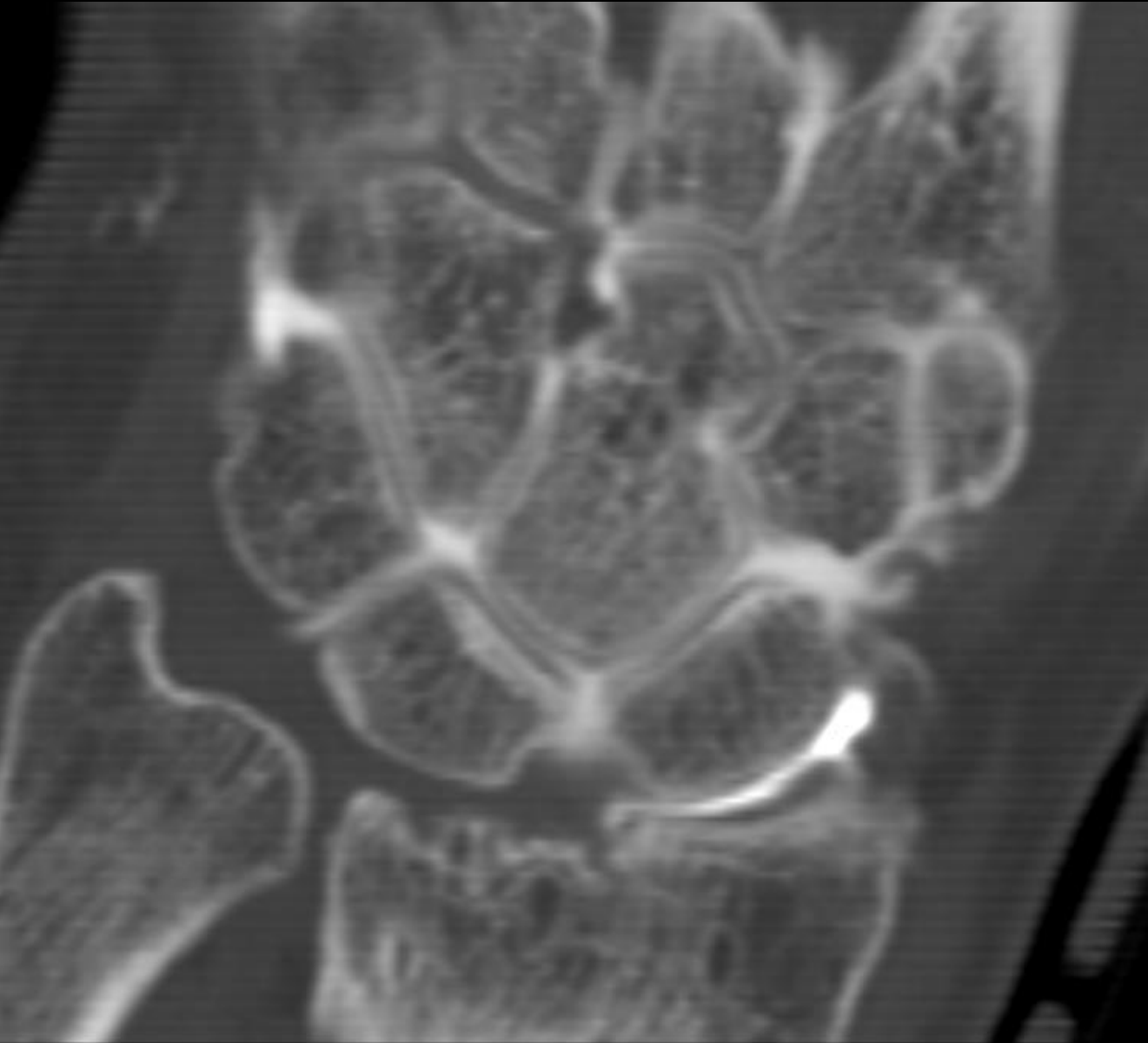




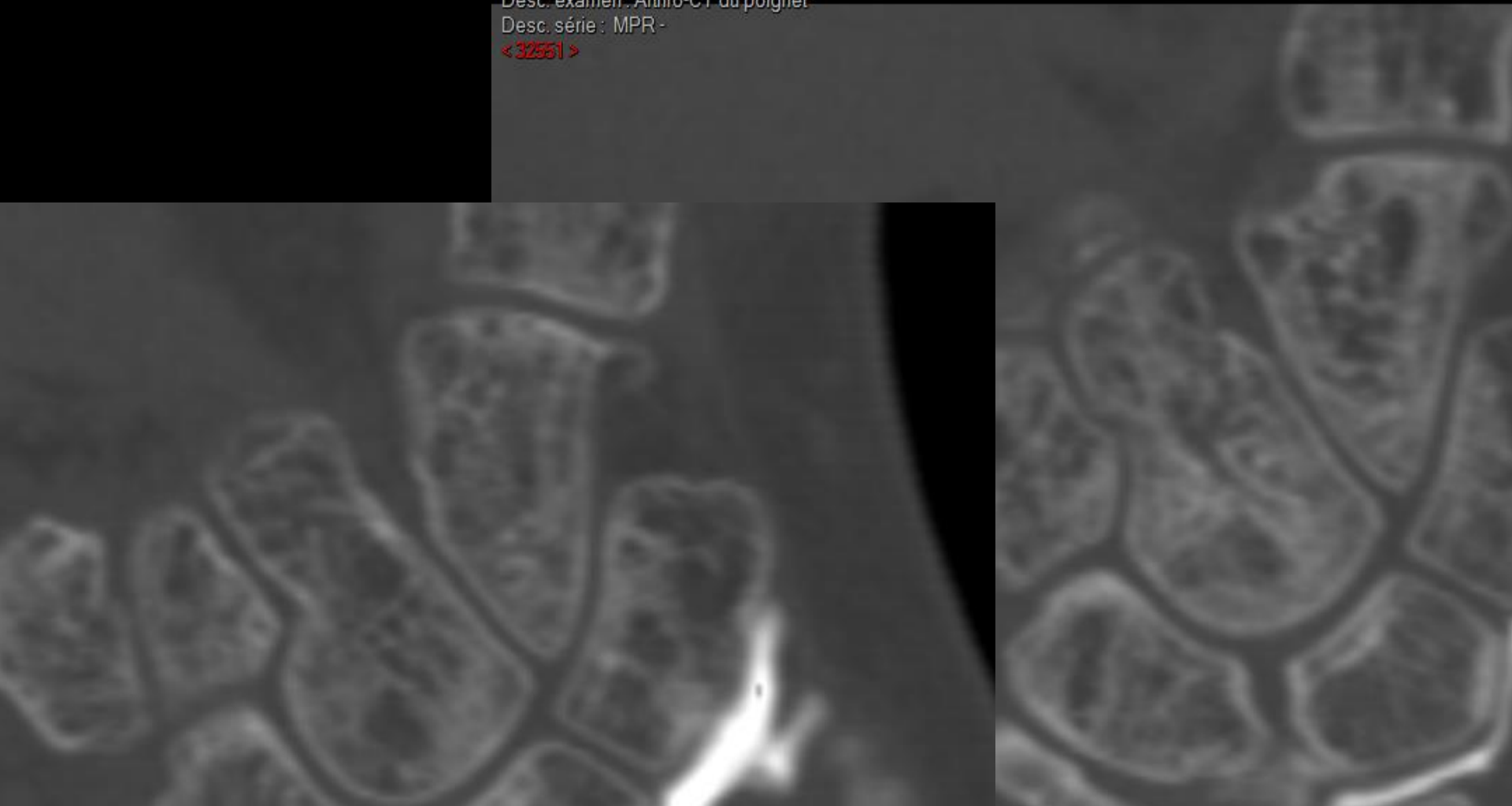
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N° dem. : 4157937
Pos. patient : FFP
Desc. examen : Arthro-CT du poignet
Desc. série : MPR -
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C 476
L 1227

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St: 290.00
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ROSARIO
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C 188
L 107

C 188
L 107

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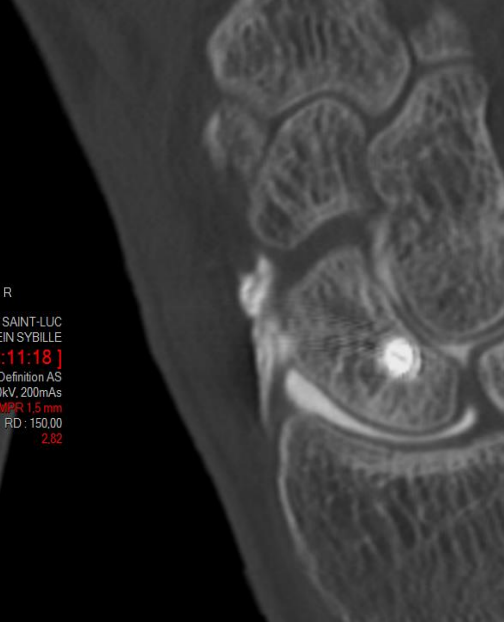


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47A 5M.M.BY7319H
NR dem. : D135489163
Pos. patient : HFP
Desc. examen : ARTHRO-CT DE MEMBRE
Desc. série : MPR - Art Poignet G 0.4 U70u
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U.C.L. / SAINT-LUC
CASTELEIN SYBILLE
[18/06/2014 , 12:11:18]
SIEMENS SOMATOM Definition AS
120kV, 200mAs
MPR 1.5 mm
RD : 150.00
2.82



R

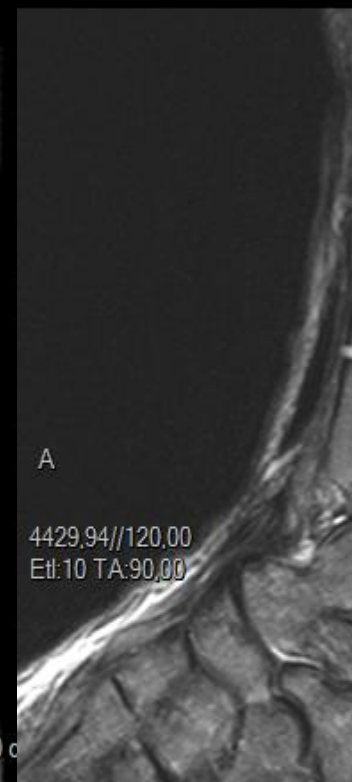
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MOUSSAOUI HAMID
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Pos. patient : HFP
Desc. examen : ARTHRO-CT DE MEMBRE
Desc. série : MPR - Art Poignet G 0.4 U70u
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SIEMENS SOMATOM Definition AS
120kV, 200mAs
MPR 1.5 mm
RD : 150.00



VANWYNSBERGHE LAETITIA
17A.F.R10507J
N° dem. : 4703903
Pos. patient : FFS
Desc. examen : CT membres inférieurs
Desc. série : MPR - Cheville Os G. 0.4 U70u
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Fracture

Retard consolidat

2 mois



Retard consolidation – 2 mois



Fracture
J0

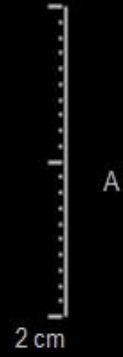
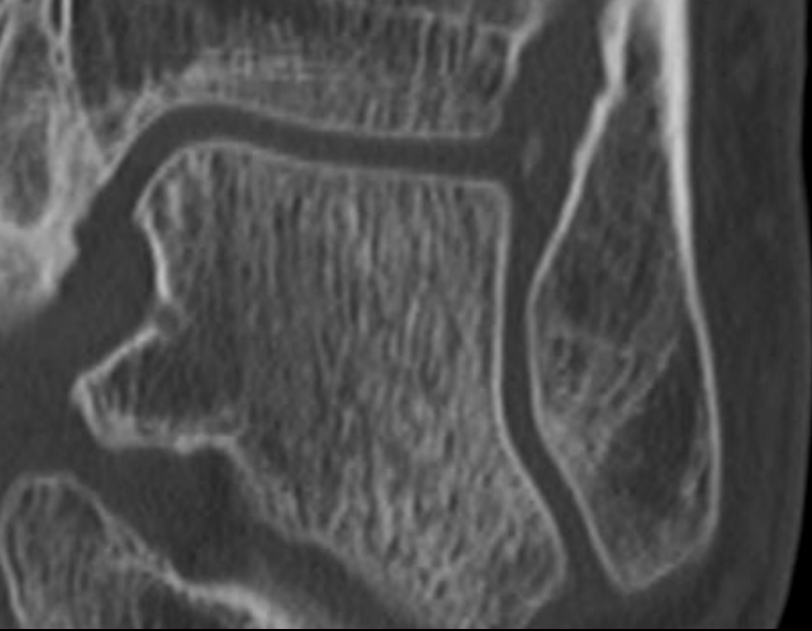


Retard
M2

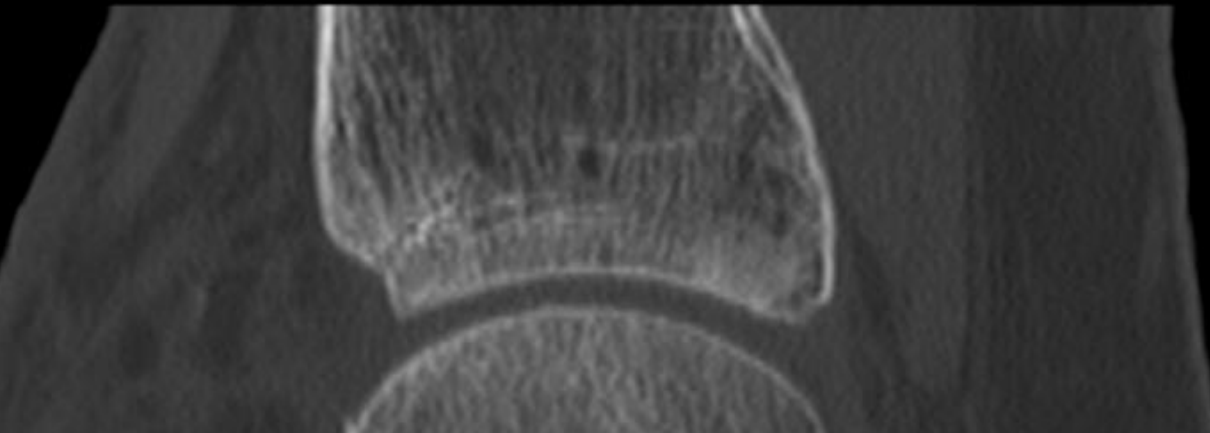
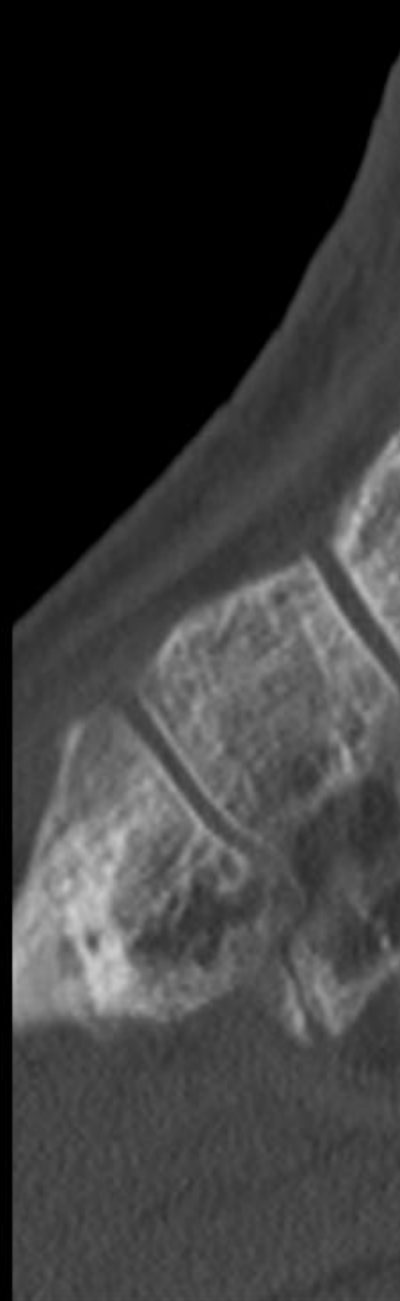


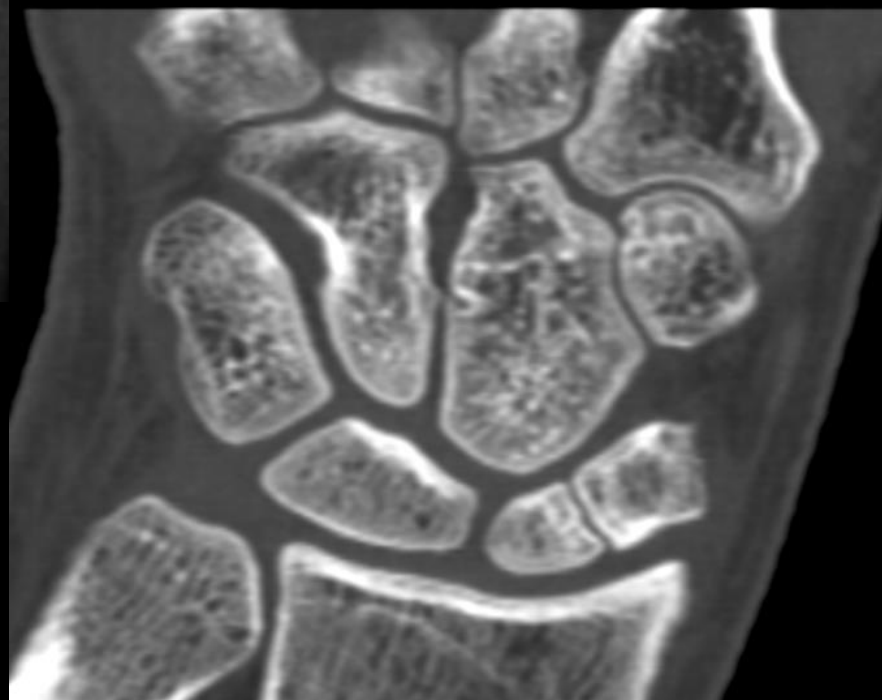
guérison
M 1



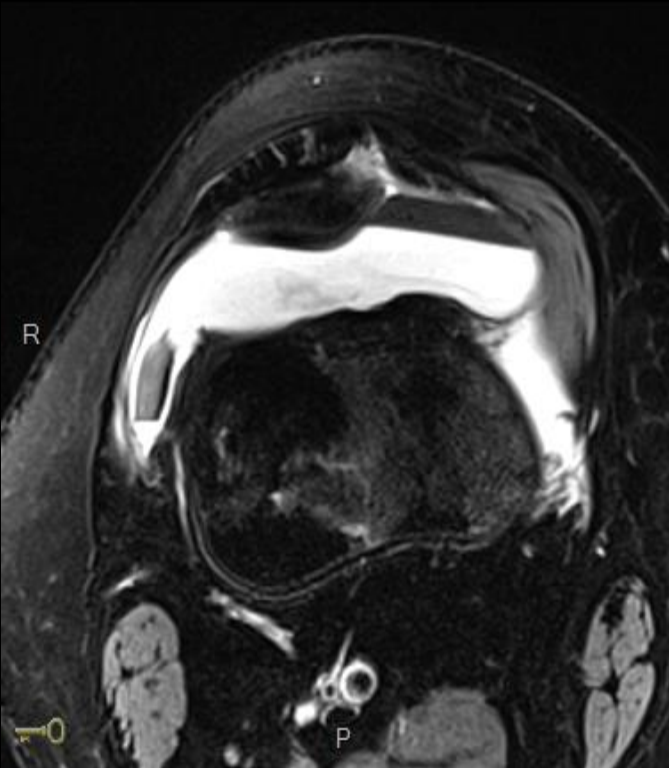


DEVOS BEVERNAGE BERNHAI
26/08/20
SIE

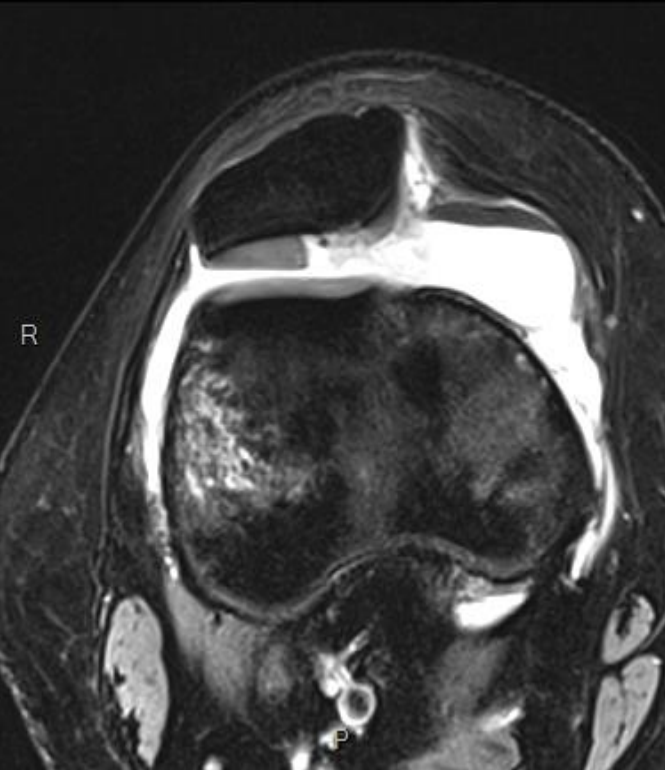




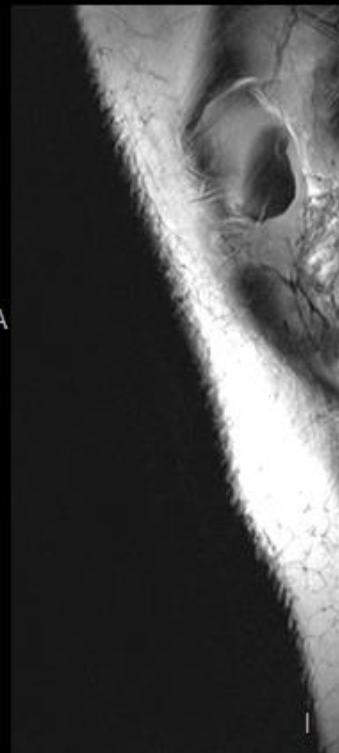
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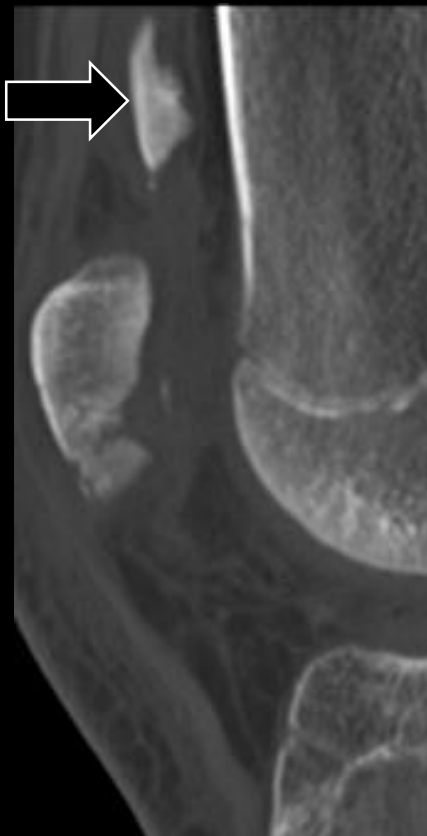


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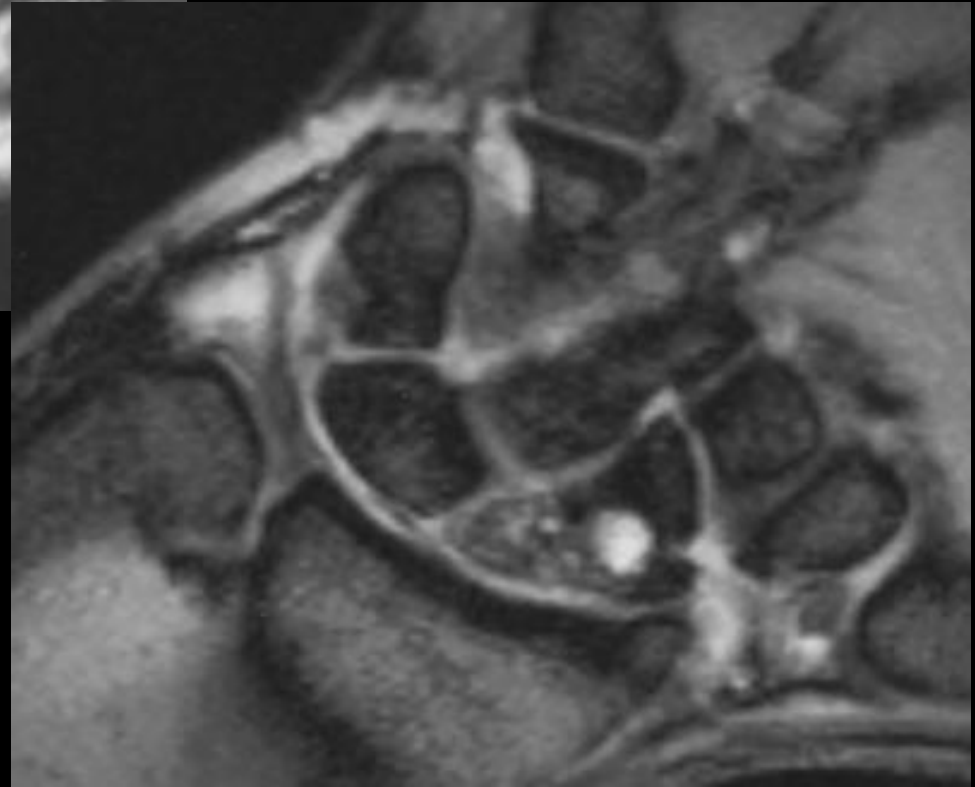
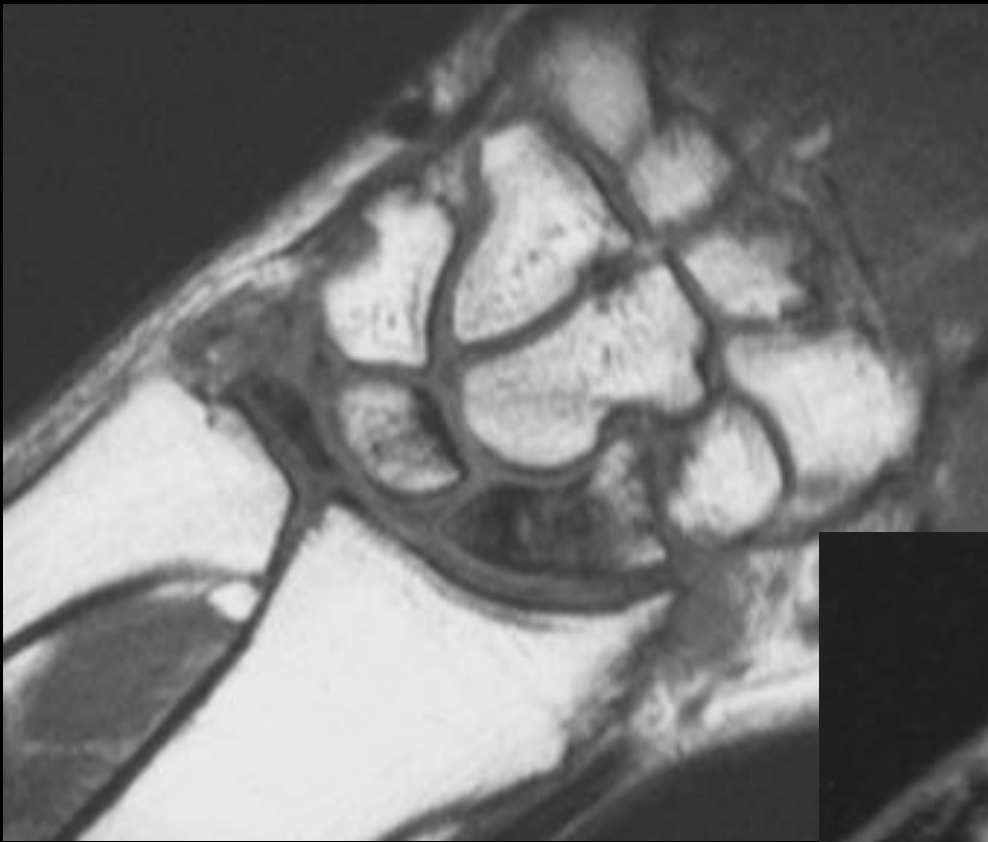


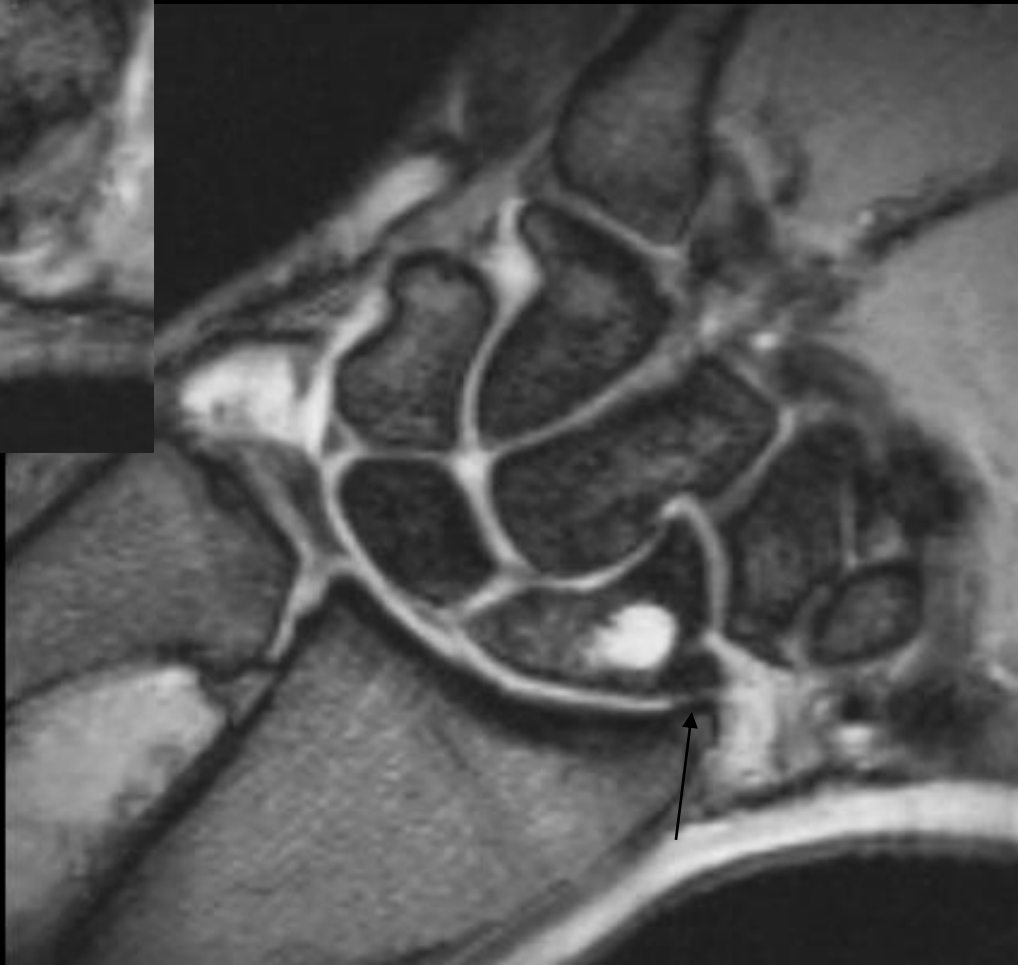
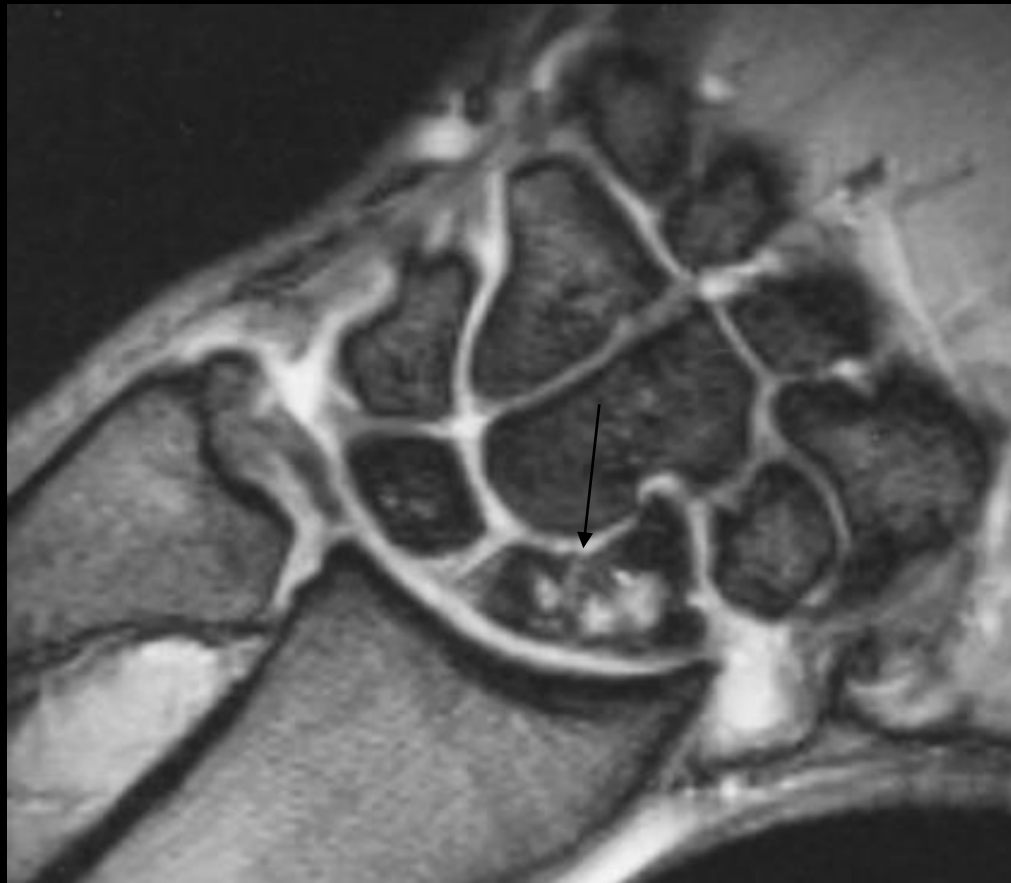
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Infarctus spontané du scaphoïde



+ 6 mois



+ 12 mois



+ 24 mois



+ 33 mois

Rappel

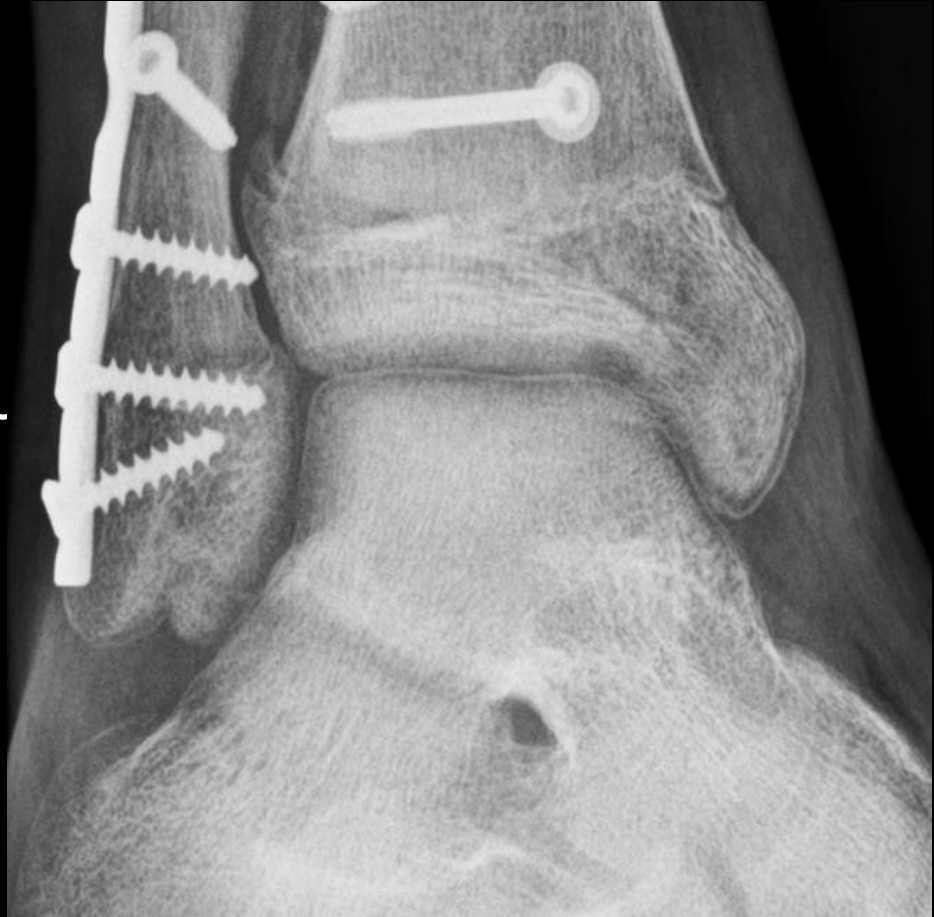
Modifications post-traumatiques

raréfaction osseuse

distribution régionale

surtout trabéculaire

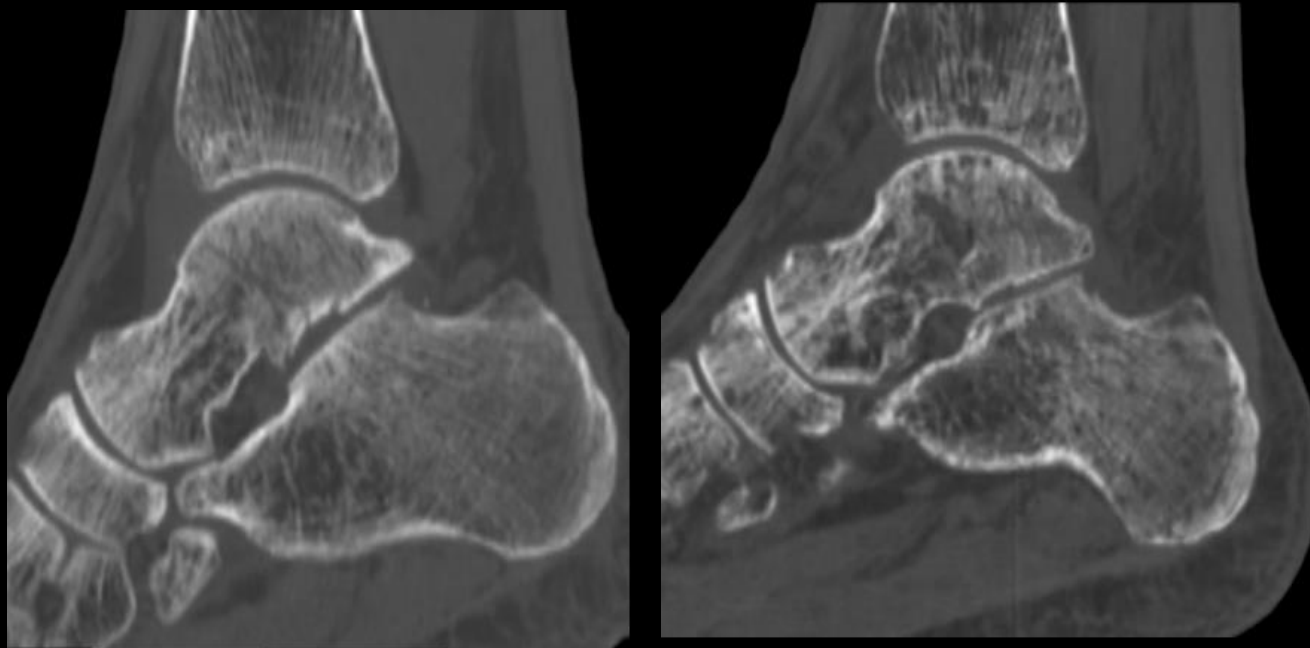
surtout sous-chondrale



Rappel

Modifications post-traumatiques fréquentes

Apparition d'une raréfaction osseuse
distribution régionale
surtout réseau trabéculaire
aspect moucheté (CT)(dystrophique en RX)



+ 2 mois après fracture

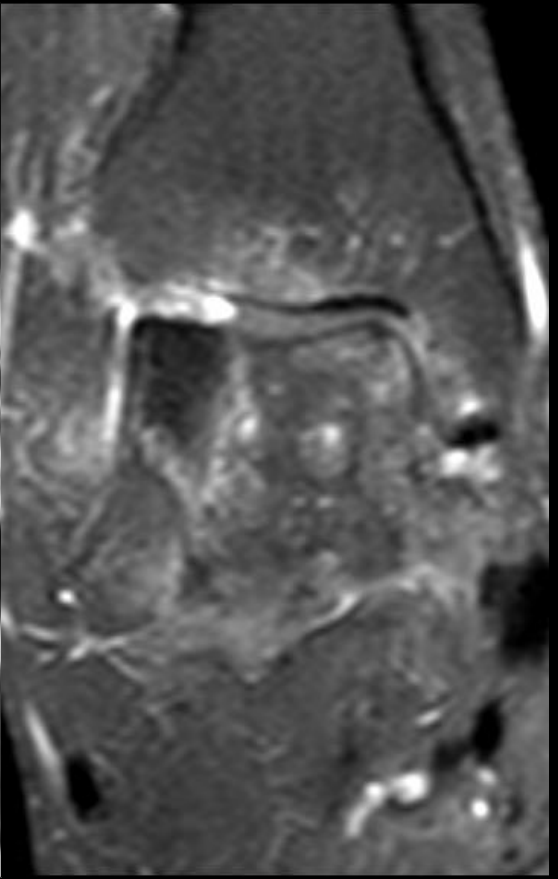
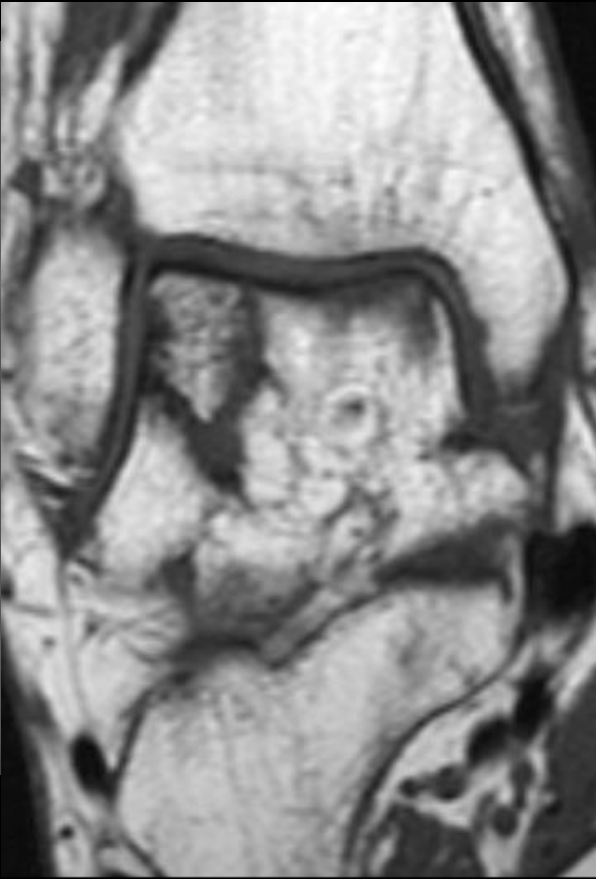
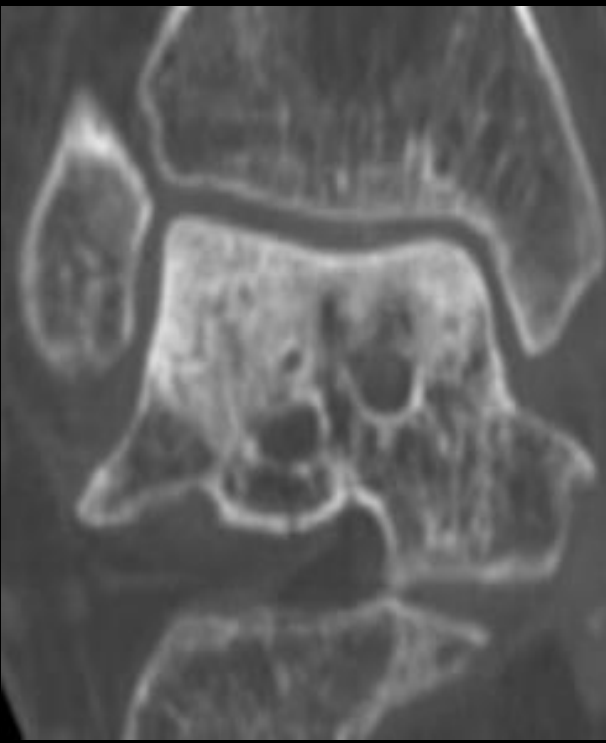




Photo 12
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T1 FS

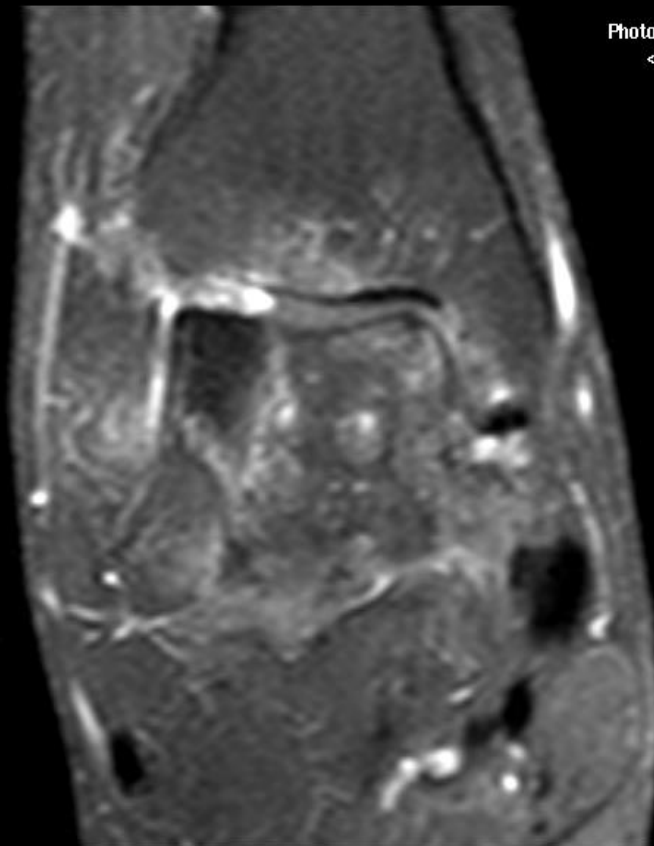


Photo 13
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T1 FS + Gado

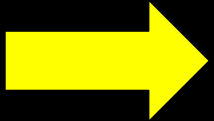
NB

Tous les infarctus ne conduisent pas à un effondrement.
30% des talus avec ischémie relative restent asymptomatiques

Scoring of fracture

TRAINING SESSION

Objectives



- Principles of analysis of radiographs
- Healing of cortical fractures
- mRUS (modified Radiographic Union Score)
- Validation of fracture scoring with mRUS
- mRUS during healing
- TUS (Tomographic Union Score)

Analysis of radiographs



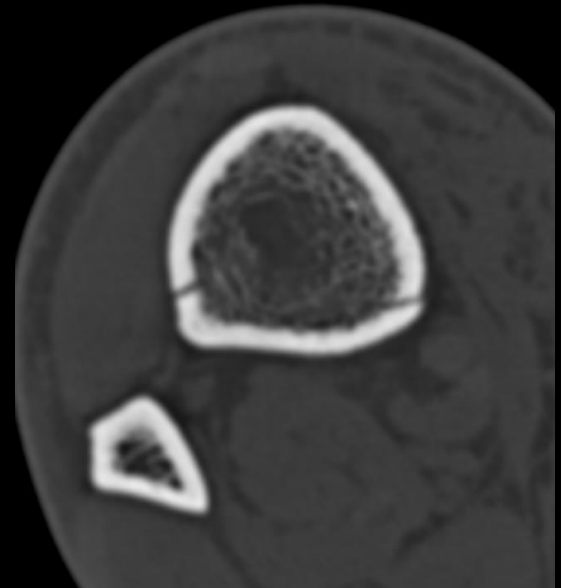
Analysis of radiographs



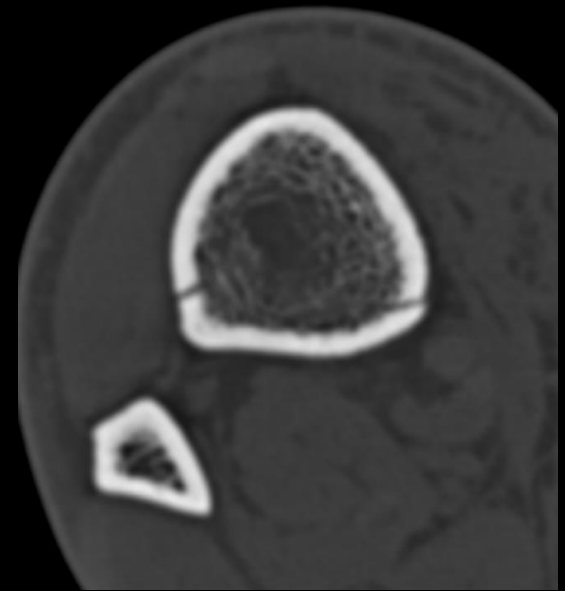
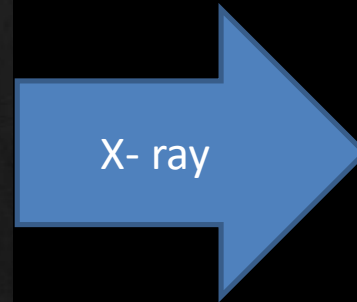
No fracture line



X-ray



Fracture line



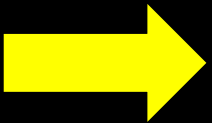
Lack of tangency

Superimposition of other bones



Objectives

- Principles of analysis of radiographs
- Healing of cortical fractures
- mRUS (modified Radiographic Union Score)
- Validation of fracture scoring with mRUS
- mRUS during healing
- TUS (Tomographic Union Score)



Fracture healing



Initial radiograph

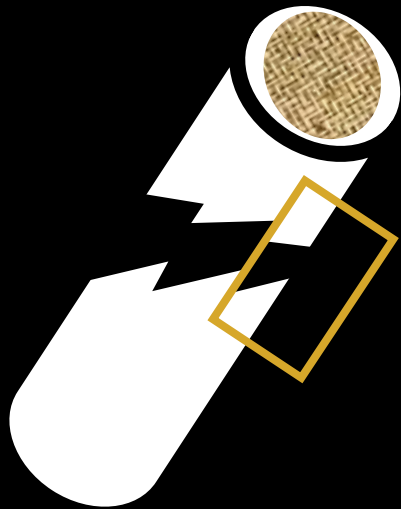


+ 2 months

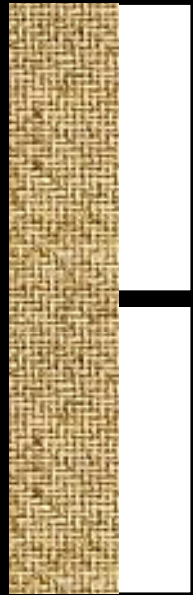


+ 5 months

Fracture healing

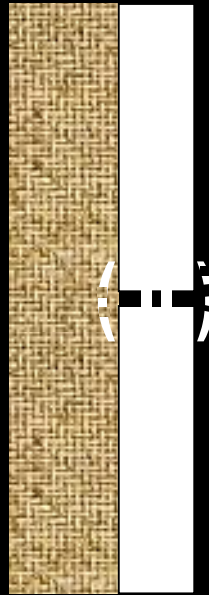


CALLUS

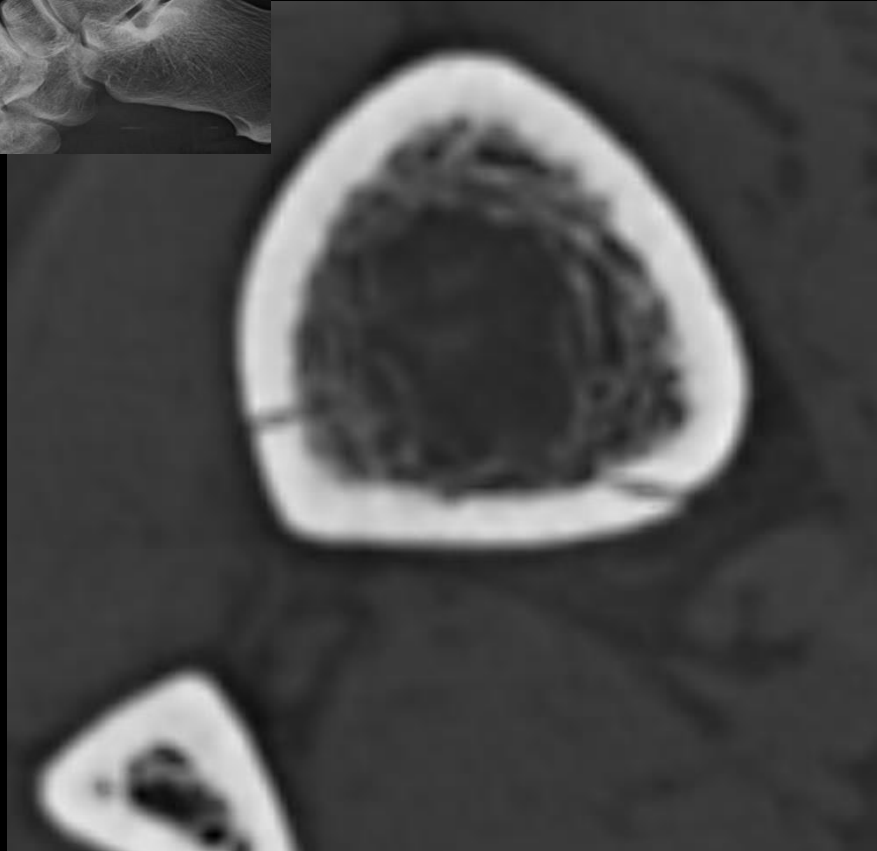


No

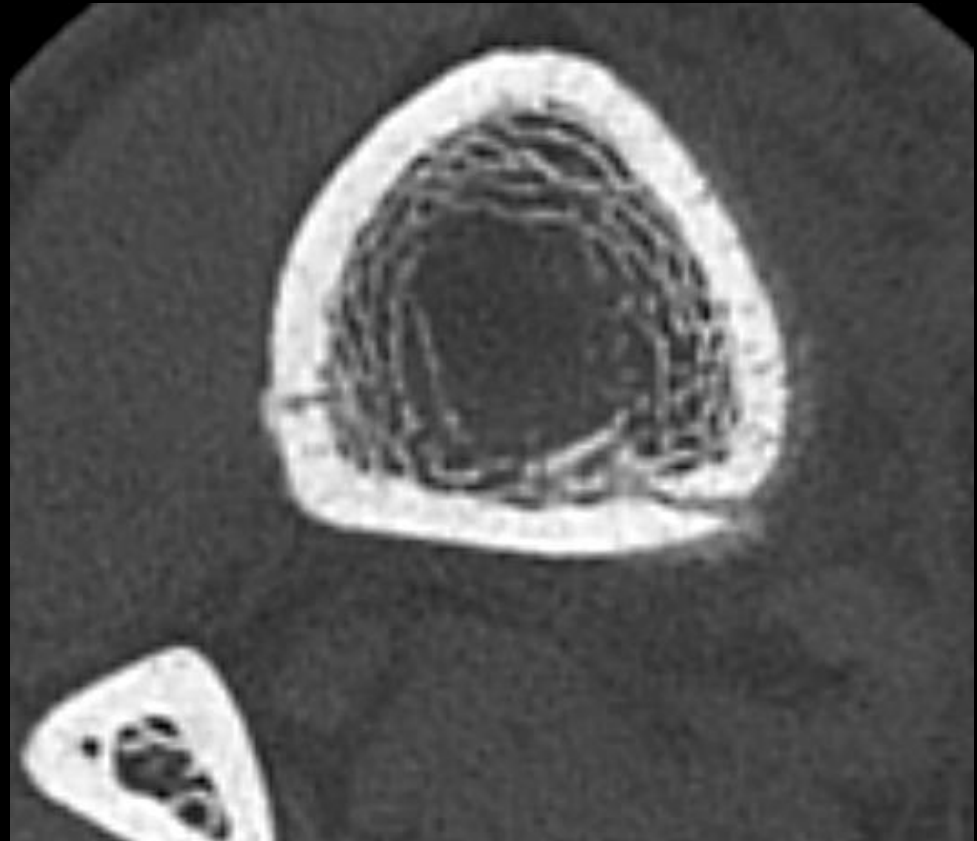
discontinuous



Fracture healing

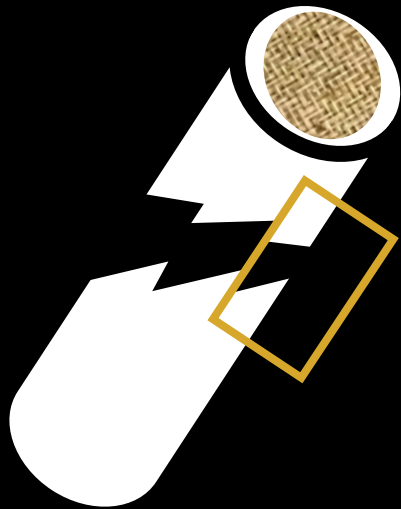


Initial CT

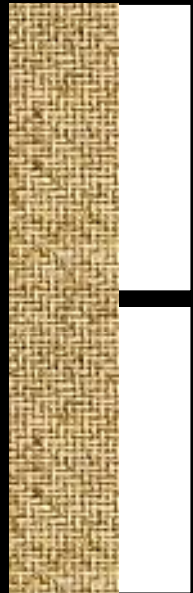


+ 3,5 months

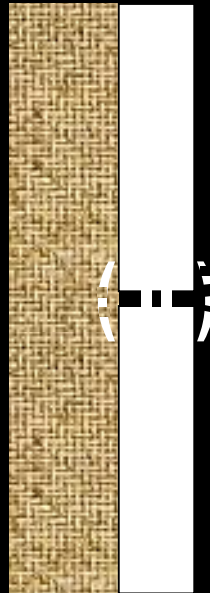
Fracture healing



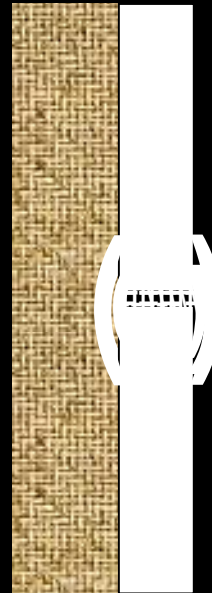
CALLUS



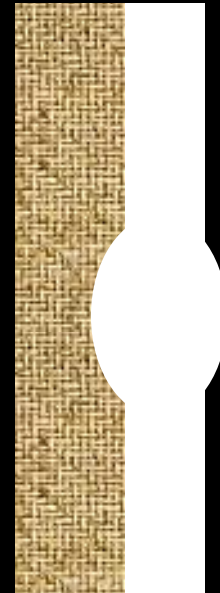
No
discontinuous



Continuous

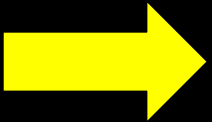


Mature

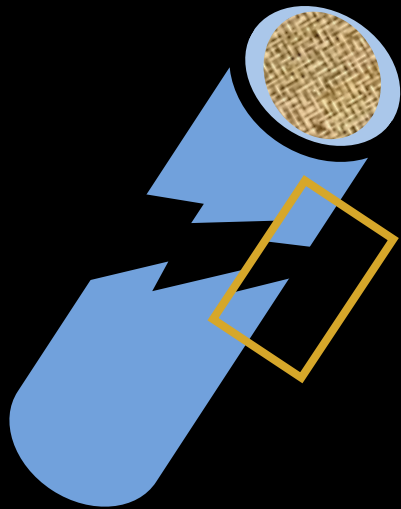


Objectives

- Principles of analysis of radiographs
- Healing of cortical fractures
- mRUS (modified Radiographic Union Score)
- Validation of fracture scoring with mRUS
- mRUS during healing
- TUS (Tomographic Union Score)



Fracture scoring

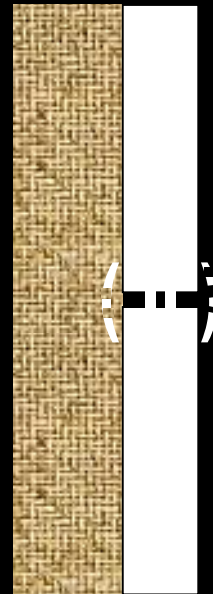


mRUS

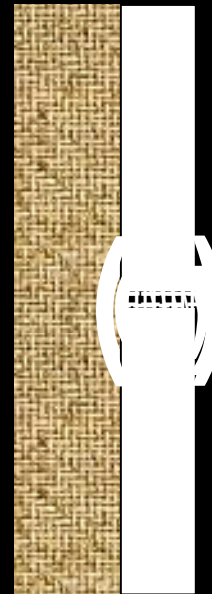
Callus



1



2



3



4

No
discontinuous
continuous
remodelled

mRUS score

Score	Callus
1	No
2	Discontinuous
3	Continuous, immature
4	Continuous, remodelled

mRUS score

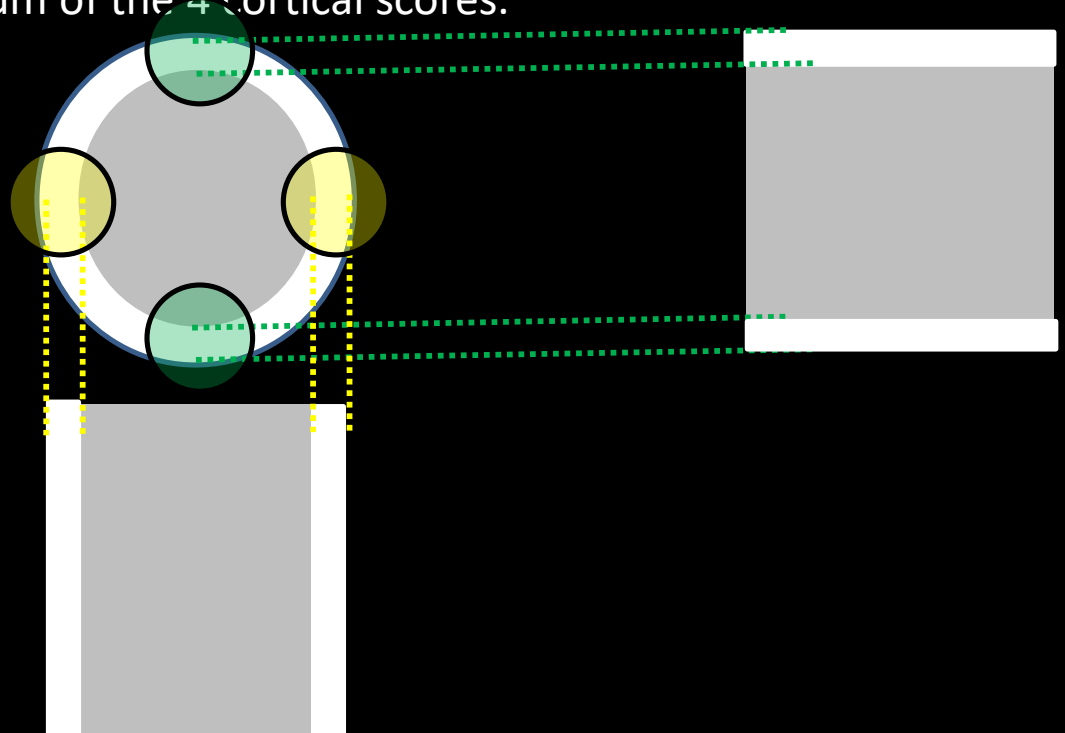
On each set of radiograph, a cortical score is given to 4 areas of the cortical fracture

medial and lateral areas on the AP radiograph

anterior and posterior areas on the lateral radiograph

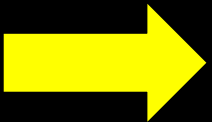
The cortical score ranges from 1 to 4.

The mRUS score corresponds to the sum of the 4 cortical scores.



Objectives

- Principles of analysis of radiographs
- Healing of cortical fractures
- mRUS (modified Radiographic Union Score)
- Validation of fracture scoring with mRUS
- mRUS during healing
- TUS (Tomographic Union Score)



Author	Year	Number of # and type of bone	Type of treatment	Readers	Score	Aim of study	Results
Whelan et al	2010	45 tibial #	Nails	7 orthopedic surgeons	RUST	-Present RUST - Evaluate agreement	ICC inter: 0.86 ICC intra: 0.88
Kooistra et al	2010	549 tibial #		3 orthopedic surgeons	RUST	- Evaluate agreement	ICC inter: 0.84
Chiavaras et al	2013	150 hip # (inter-trochanteric)	Surgical	3 radiologists & 3 orthopedic surgeons	RUSH	- Present RUSH -Evaluate agreement (using a single x-ray, blinded to time from injury)	ICC: 0.66
Bhandari et al	2013	200 hip # (100 femoral neck & 100 intertrochanteric)	Surgical	3 radiologists & 3 orthopedic surgeons	RUSH	-Evaluate agreement using sequential x-rays (time from injury was known)	ICC inter: 0.85 (FN) ICC inter: 0.88 (IT)
Cecic et al	2014	41 tibial #	Nails	1 reader	RUST	-Investigate correlation of RUST with clinical outcomes	RUST correlated with clinical scores (SF-36, VAS and Karlström-Olerud)
Tawonsawatruk et al	2014	Rat tibial #	External fixator	6 orthopedic readers	RUST	-Determine applicability & reliability of RUST, Lane&Sandhu score, and an overall impression of union in a small animal model	For RUST ICC inter: 0.81 ICC intra: 0.86
Patel et al	2014	35 distal radial #	Surgical or not	2 hand surgeons & 3 MSK radiologists	RUSS	-Present RUSS and evaluate agreement	1. ICC intra: substantial ICC inter: moderated for ORIF and substantial for non surgically treated # 2. Excellent predictive accuracy of RUSS for DD healed vs DU (RUSS> or = 6 prerictive of union)

Litrenta et al	2015	Large series of tibial and femoral #	Nails or plates	Many orthopedic surgeons	RUST and modified RUST (4 cortical scores)	-Evaluate agreement -Set a threshold score that would indicate union	1. ICC modified RUST> standard RUST 2. Agreement substantial for nails& moderate for plates 3. Union for 90% readers: RUST= 10 and modified RUST=13
Richards et al	2015	36 sets (preoperative, 6 months&1 year postop) of radiographs from 12 NF1 patients with congenital tibial pseudarthrosis	Nails	4 readers (3 ped. radiologists and 1 surgeon)	RUST (But if cortex not visible on a projection because of nail→ score 1)	-Assess RUST reliability in NF1 pt with CPT	K=0.89 intra K=0.76 inter
Leow et al	2016	-15 tibial # -45 tibial #	Nails	-3 readers -5 readers	RUST (standard and after discussion: score 2 for discontinuous callus and score 3 for continuous bridging callus)	-Assess reliability RUST (standard, after further interpretation of the score, and with the immediate post-operative radiograph available for comparison)	ICC standard RUST: 0.67 ICC RUST after discussion: 0.75 ICC RUST with comparison: 0.79
Frank et al	2016	250 hip #	Surgical	2 readers	RUSH	-Find a RUSH score specific for femoral neck NU at 6-months	A threshold score < 18 → Sp 100% and PPV of 100% for radiographic nonunion at 6 months.

AP radiograph



Lateral radiograph



AP radiograph

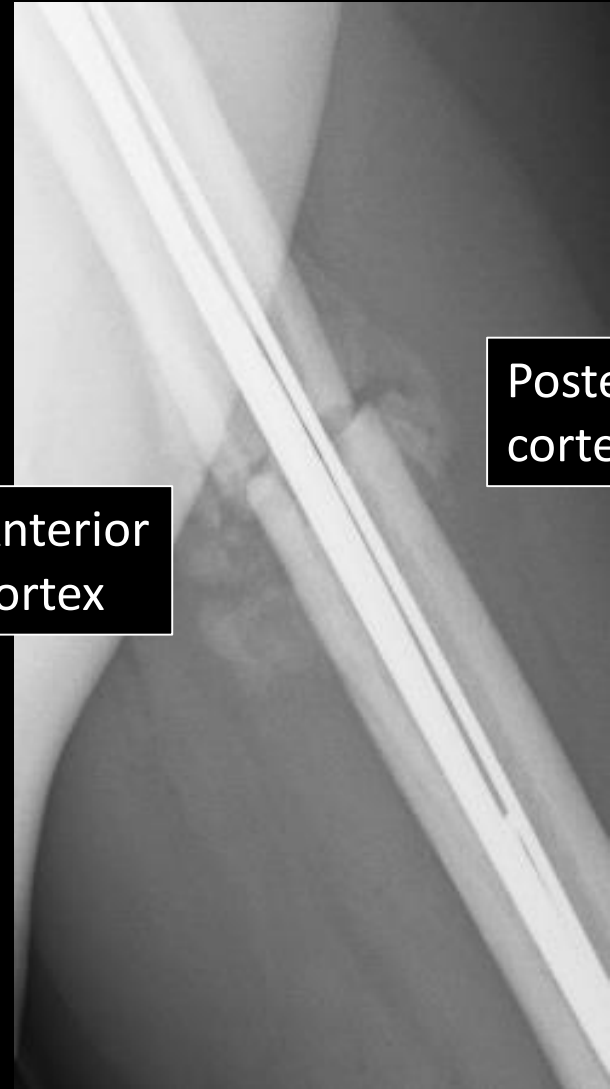


Medial
cortex



Lateral
cortex

Lateral radiograph



Anterior
cortex

Posterior
cortex

AP radiograph

Medial
cortex

Lateral
cortex

mRUS = Medial
cortex + Lateral
cortex

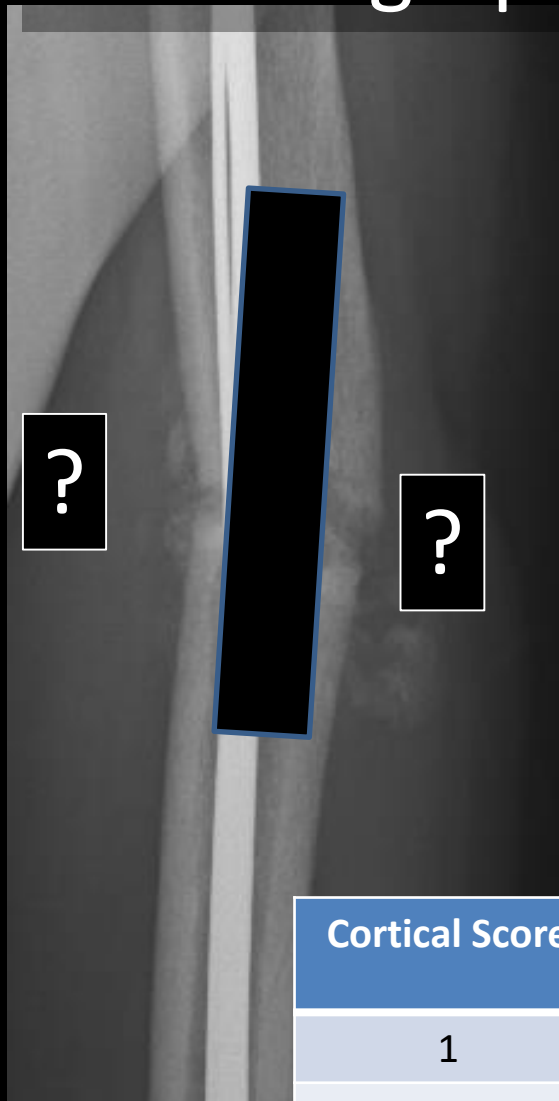
Lateral radiograph

Anterior
cortex

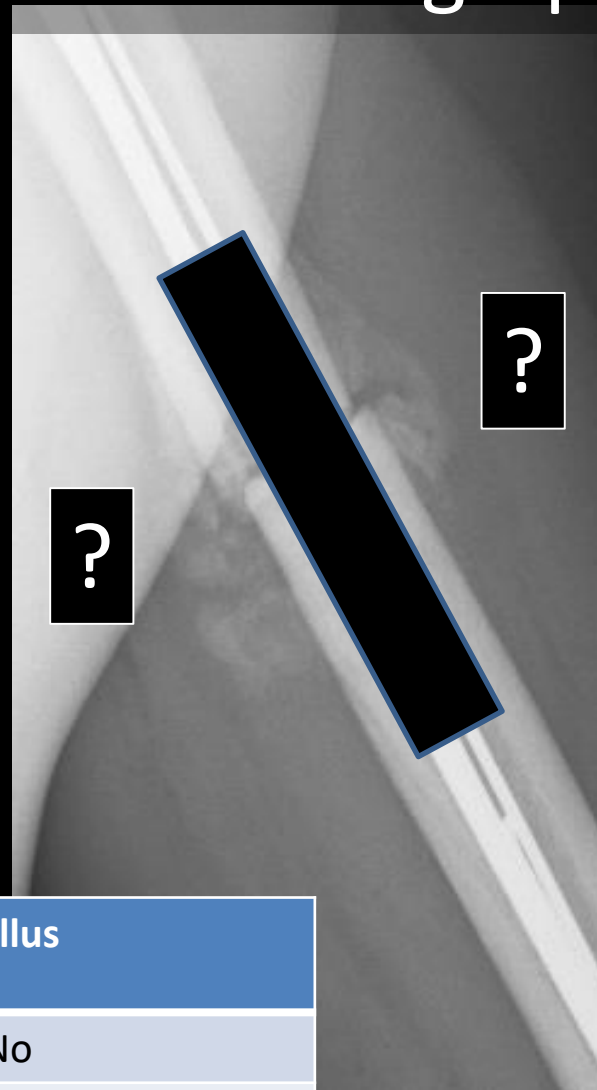
Posterior
cortex

+ Anterior
cortex + Posterior
cortex

AP radiograph

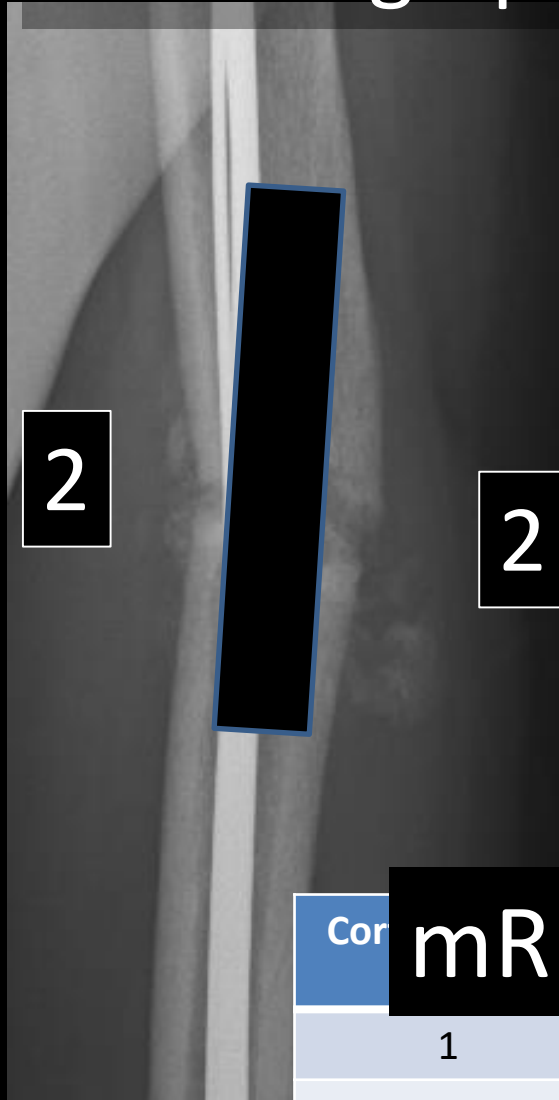


Lateral radiograph

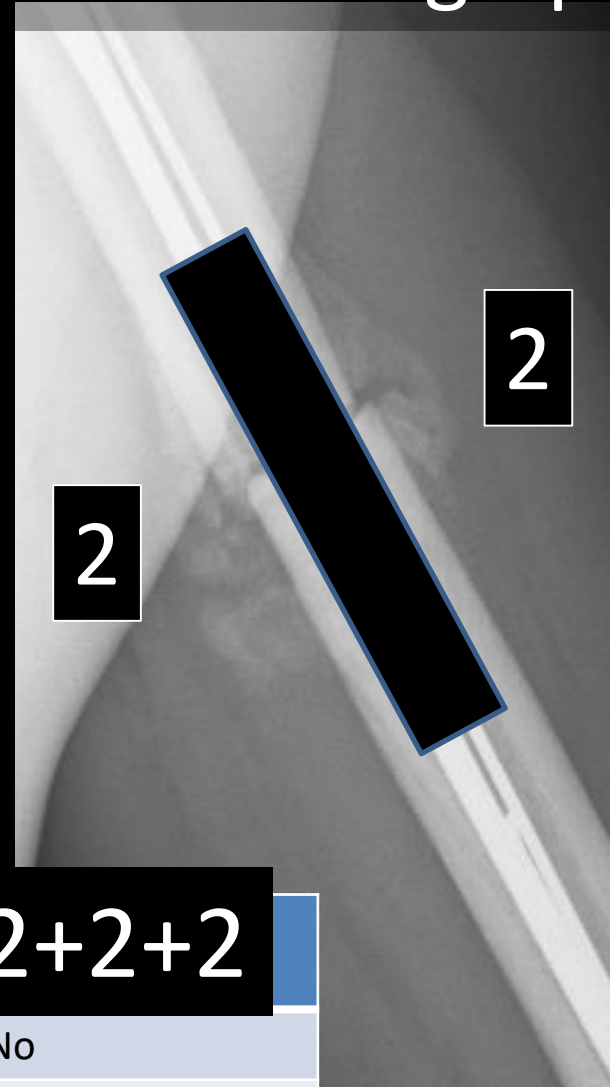


Cortical Score	Callus
1	No
2	Discontinuous
3	Continuous, immature
4	Continuous, remodeled

AP radiograph

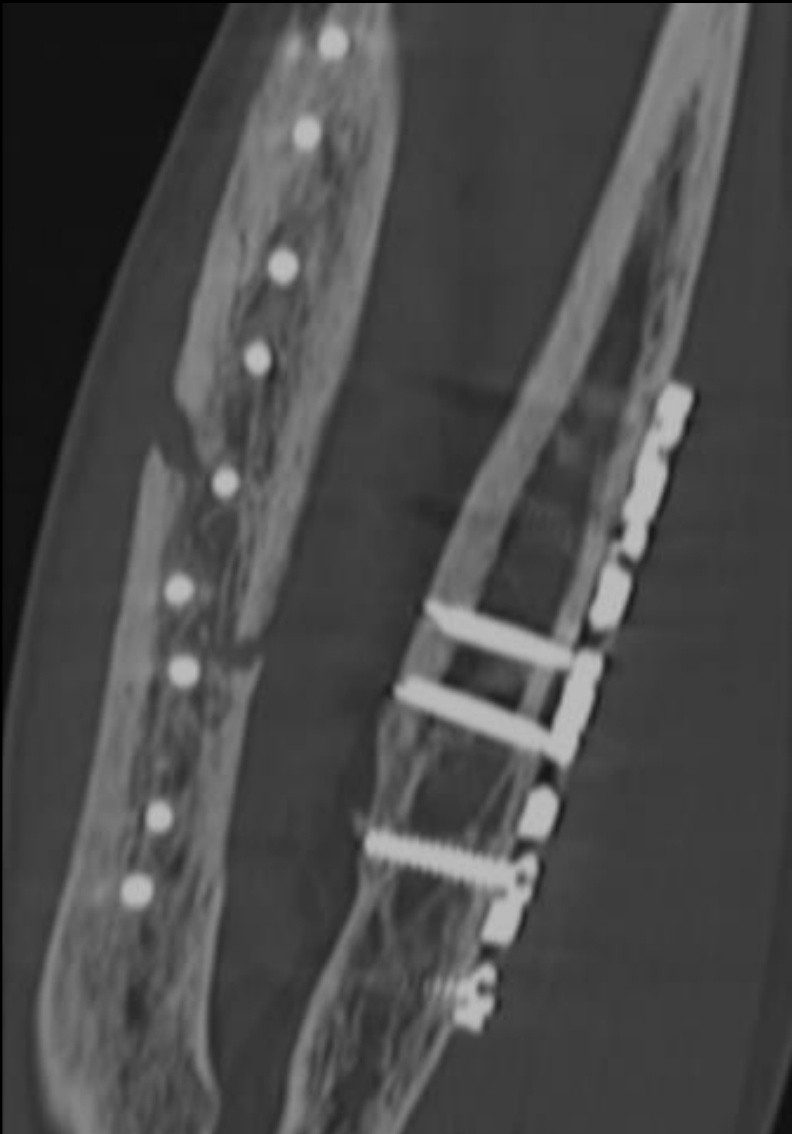


Lateral radiograph



Cor	mRUS = 2+2+2+2	
1	No	
2	Discontinuous	
3	Continuous, immature	
4	Continuous, remodeled	

DuDE0303



Case 1



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1

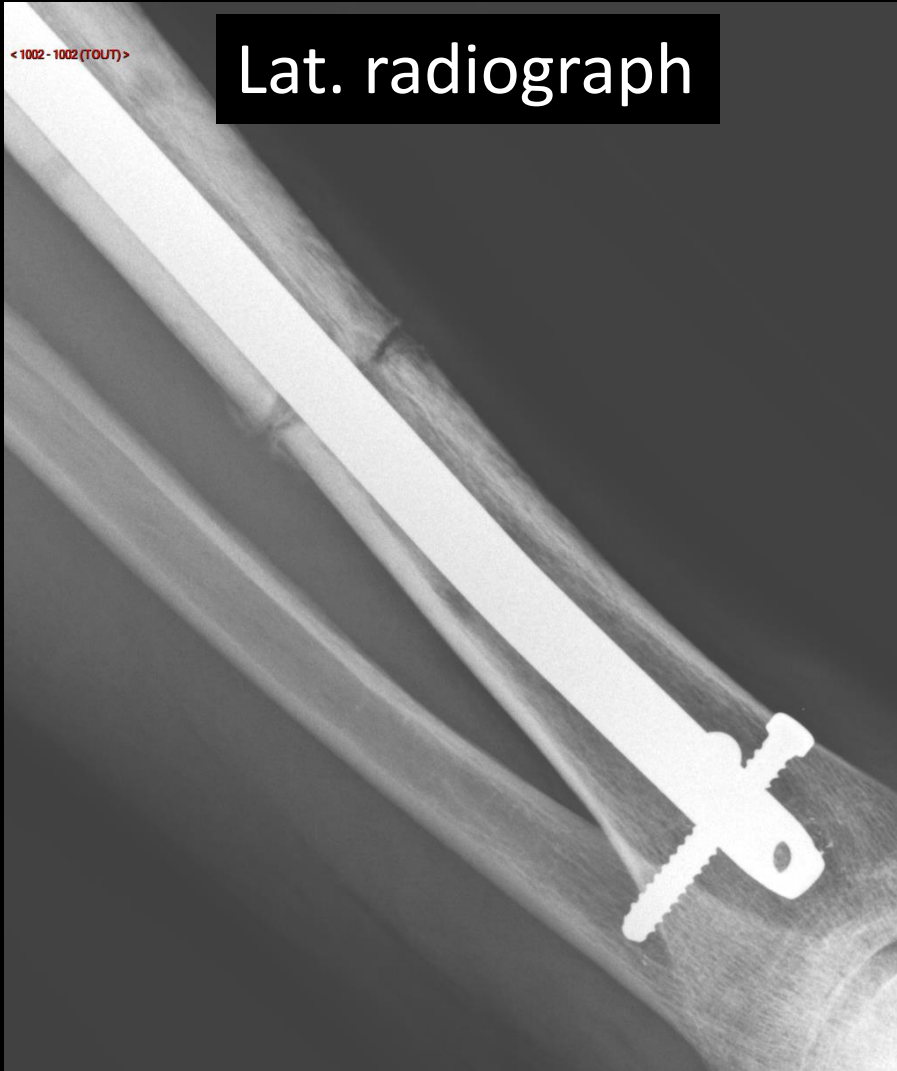


mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1

Lat. radiograph

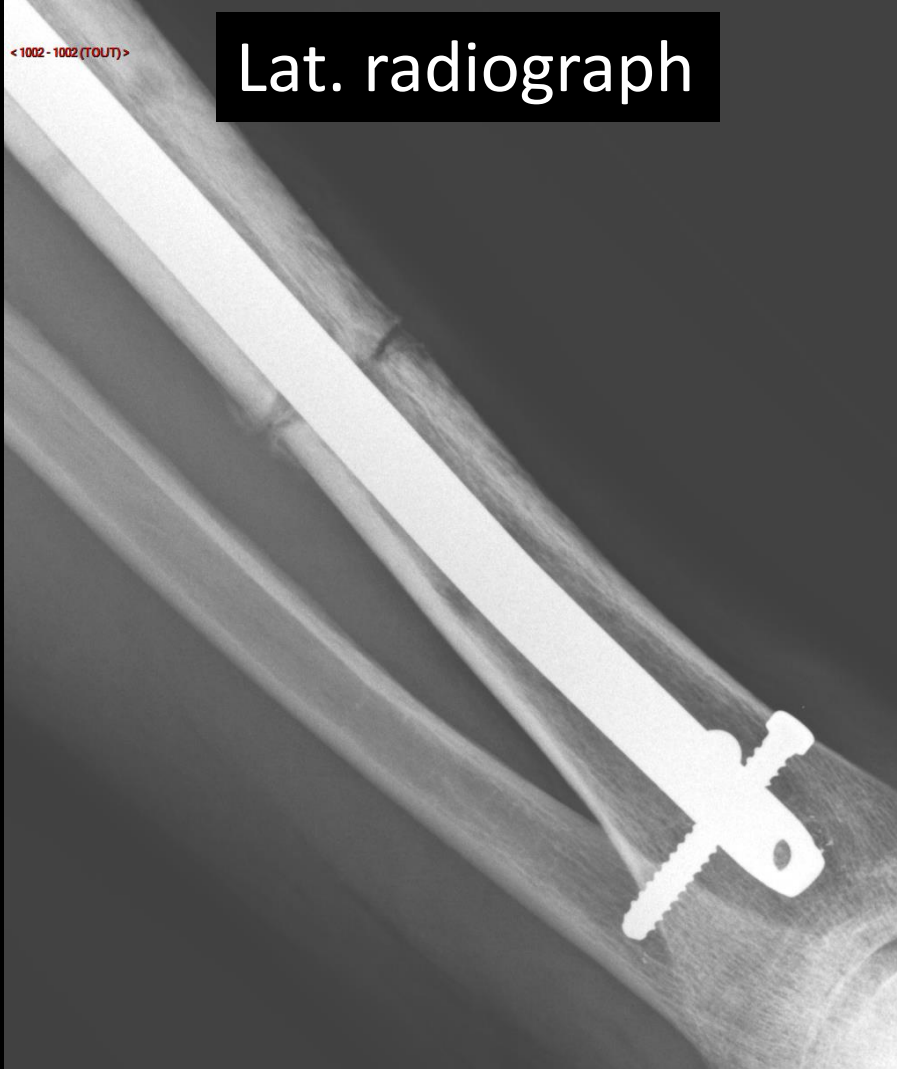


mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 1

Lat. radiograph



Sagittal CT reformat



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 2

AP radiograph



Frontal CT reformat



mRUS :

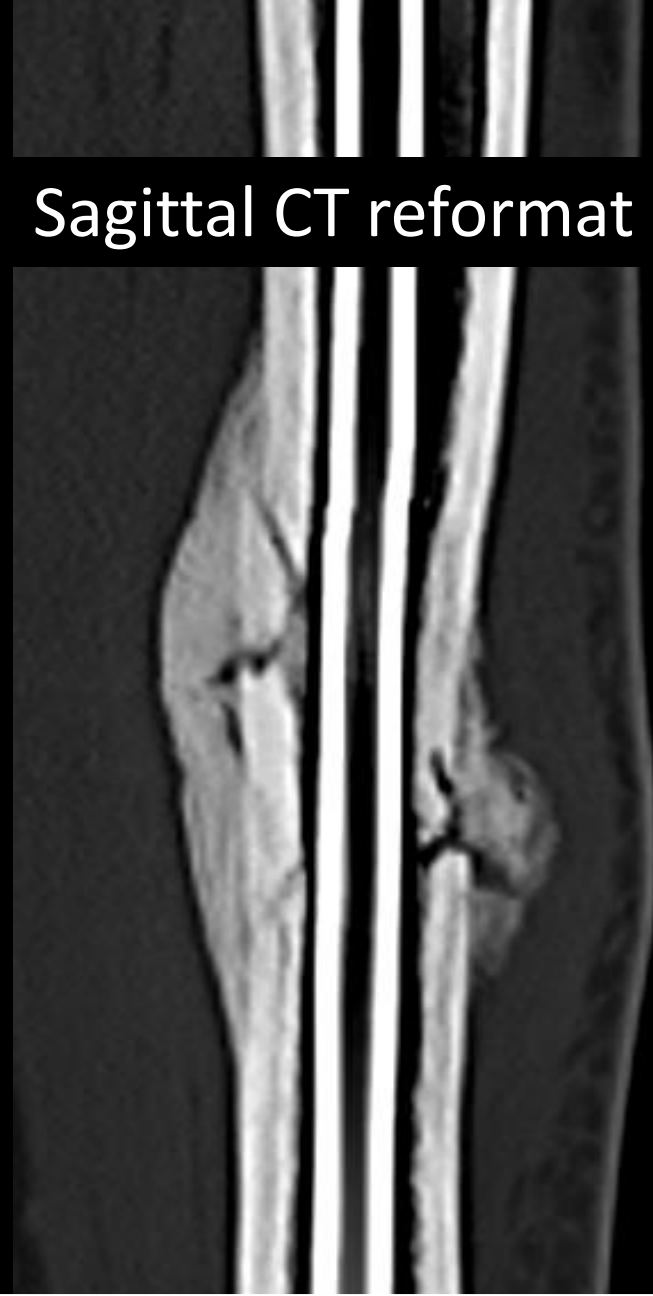
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 2

Lat. radiograph

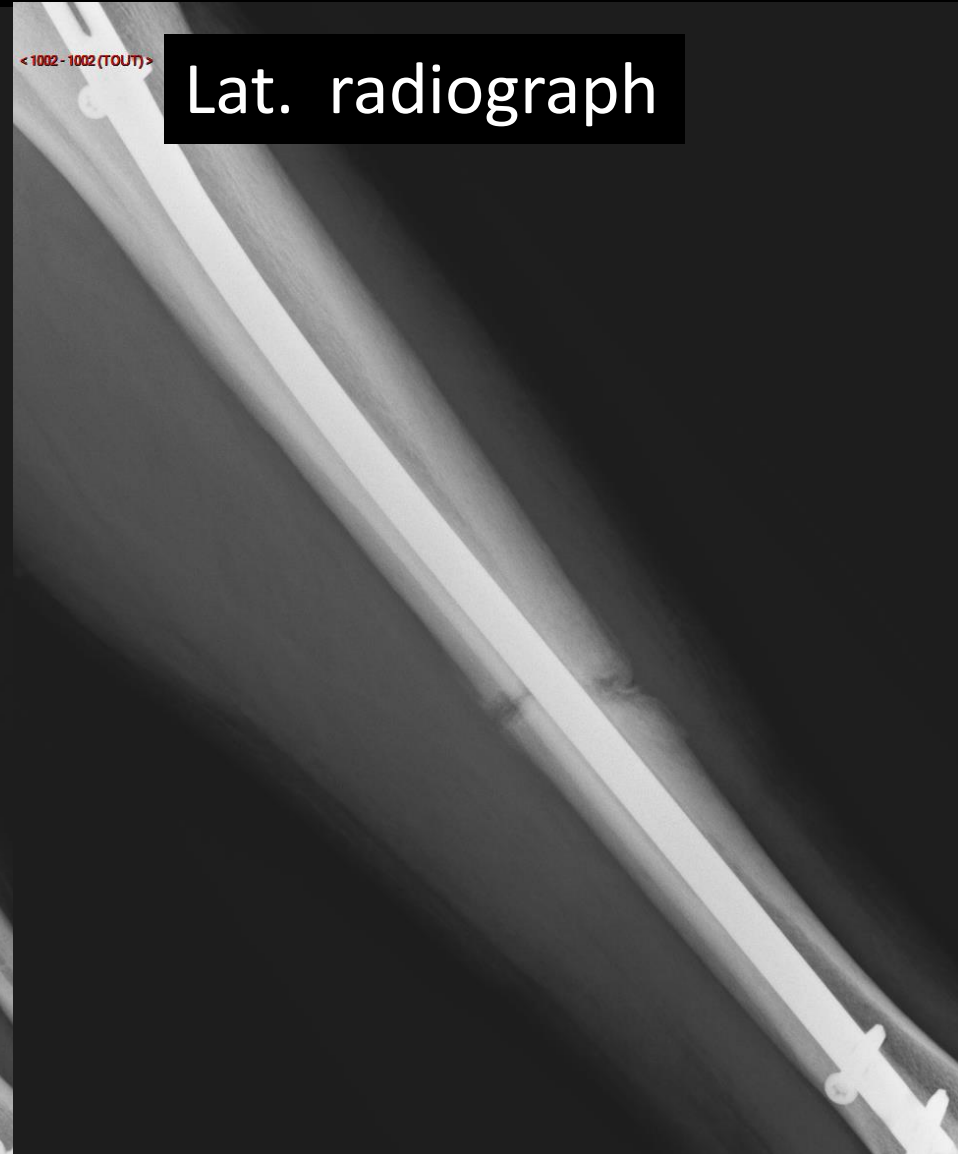
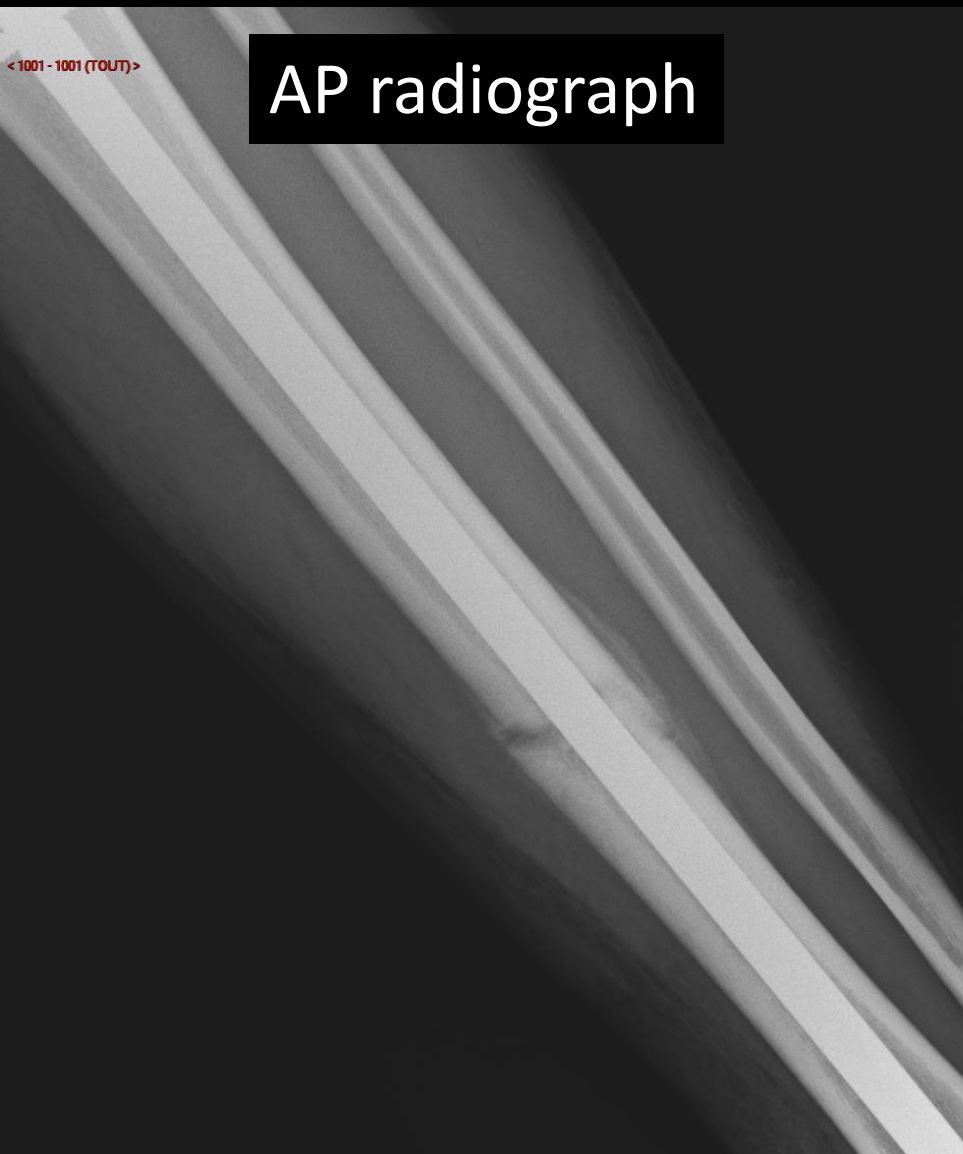


Sagittal CT reformat



mRUS :
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

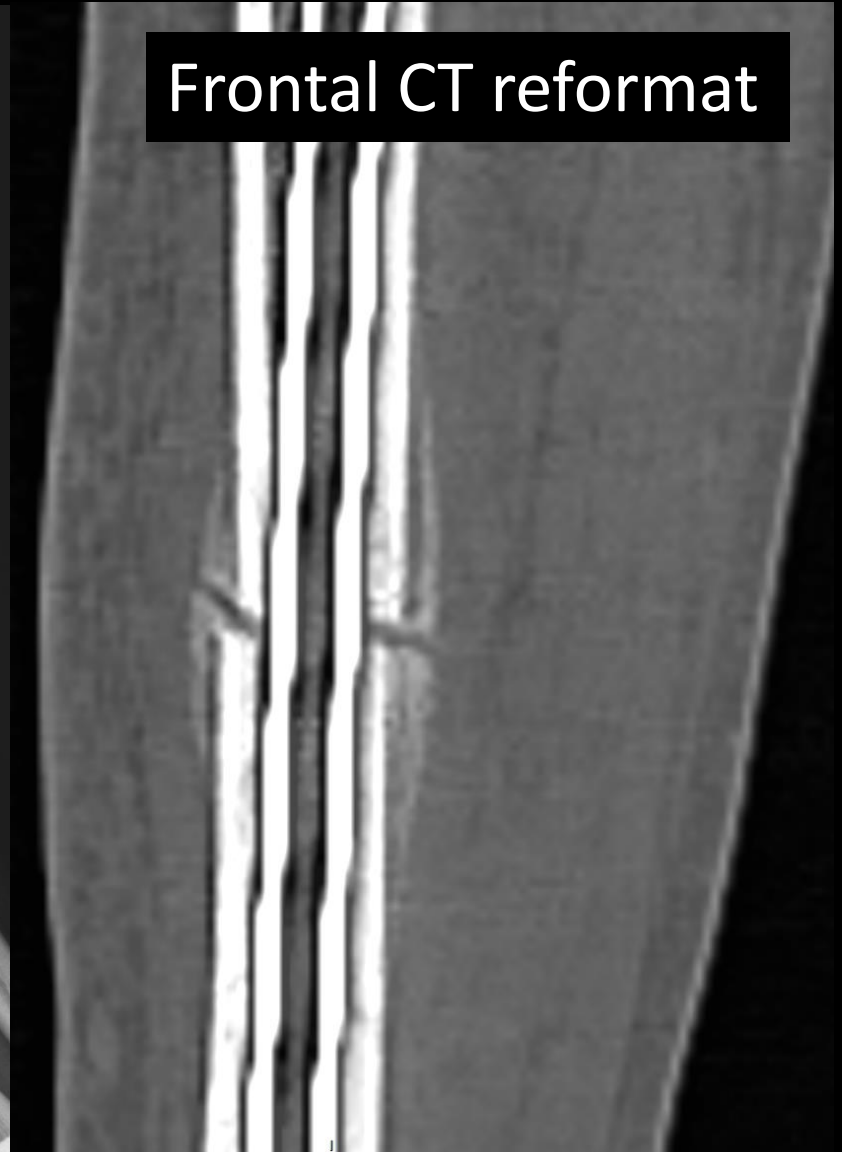
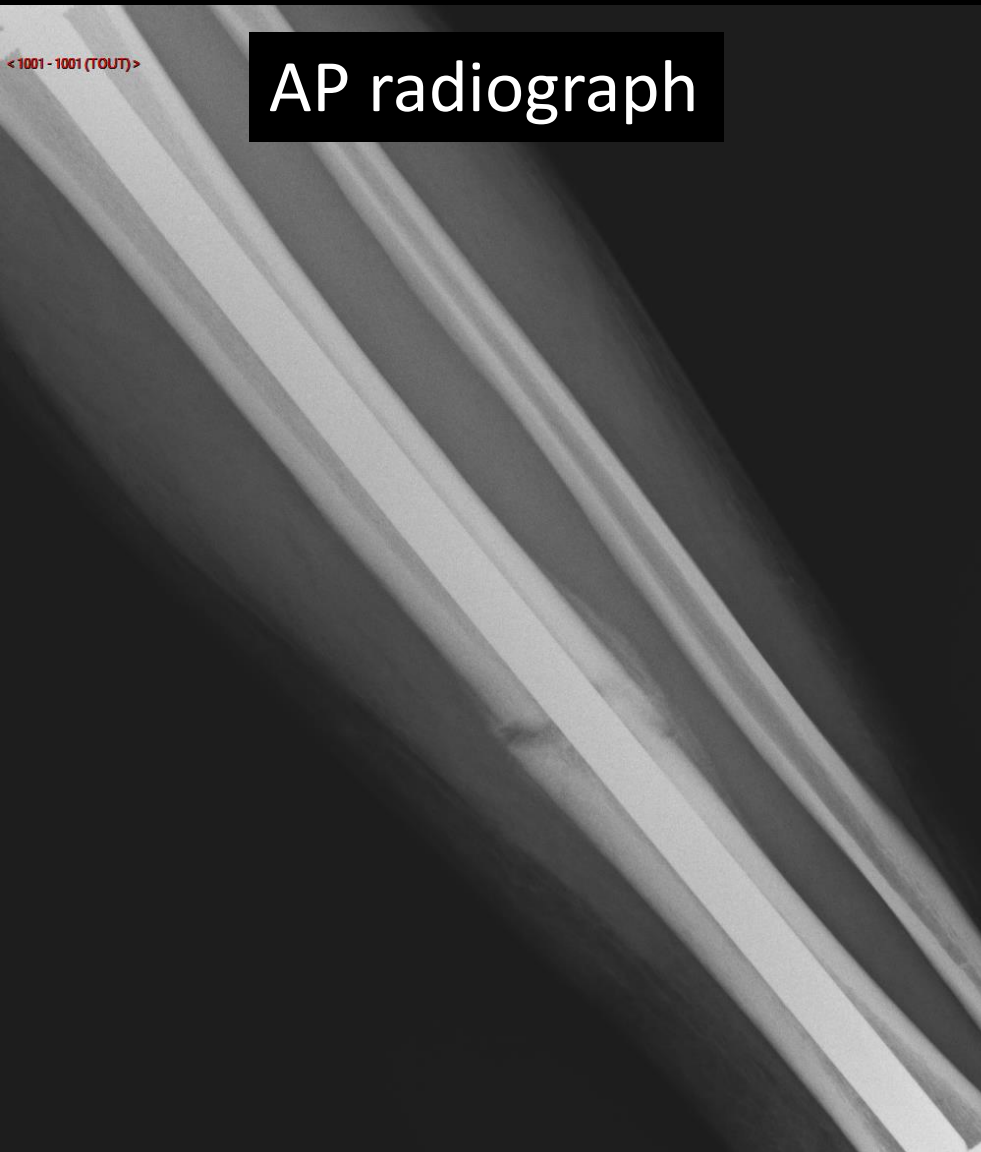
Case 3



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

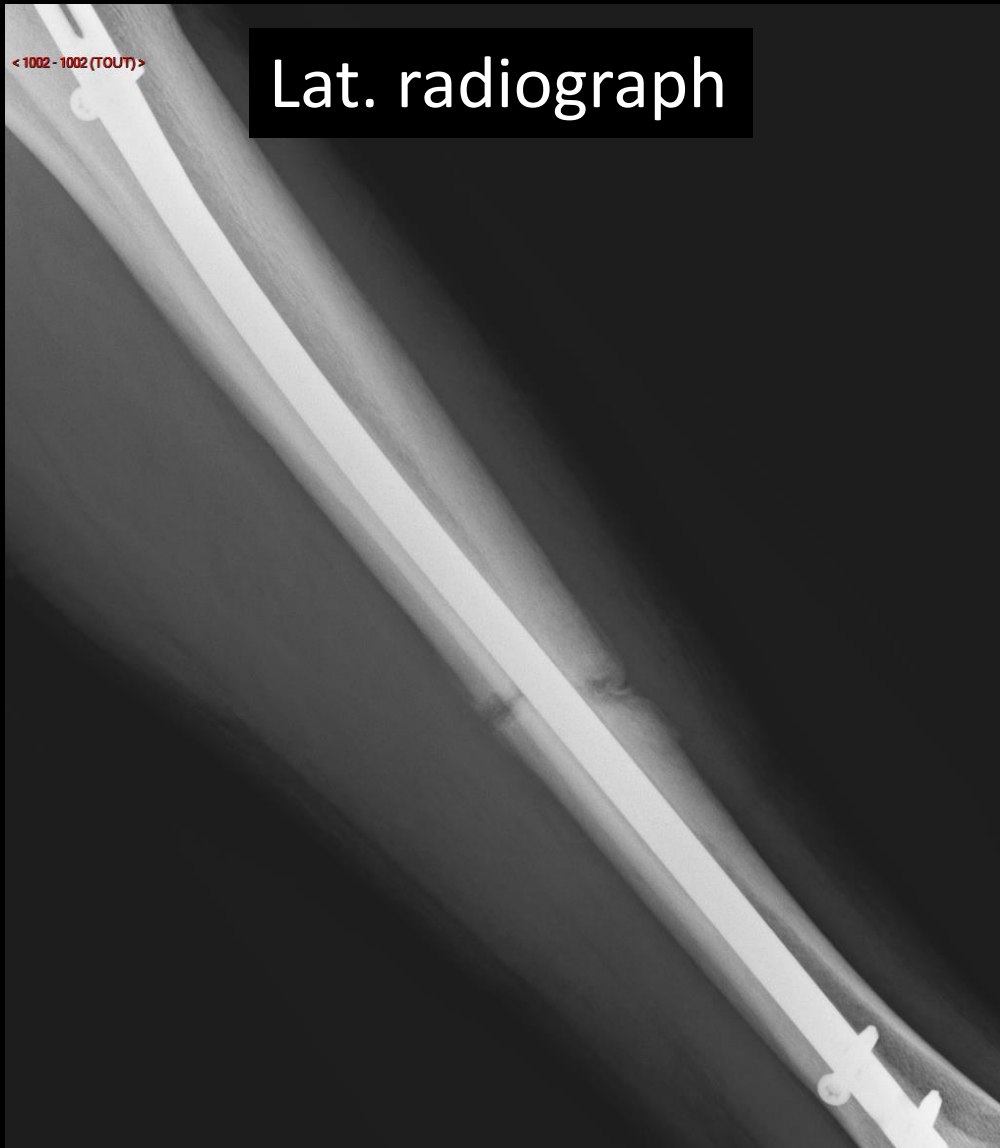
Case 3



mRUS :

1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

Case 3

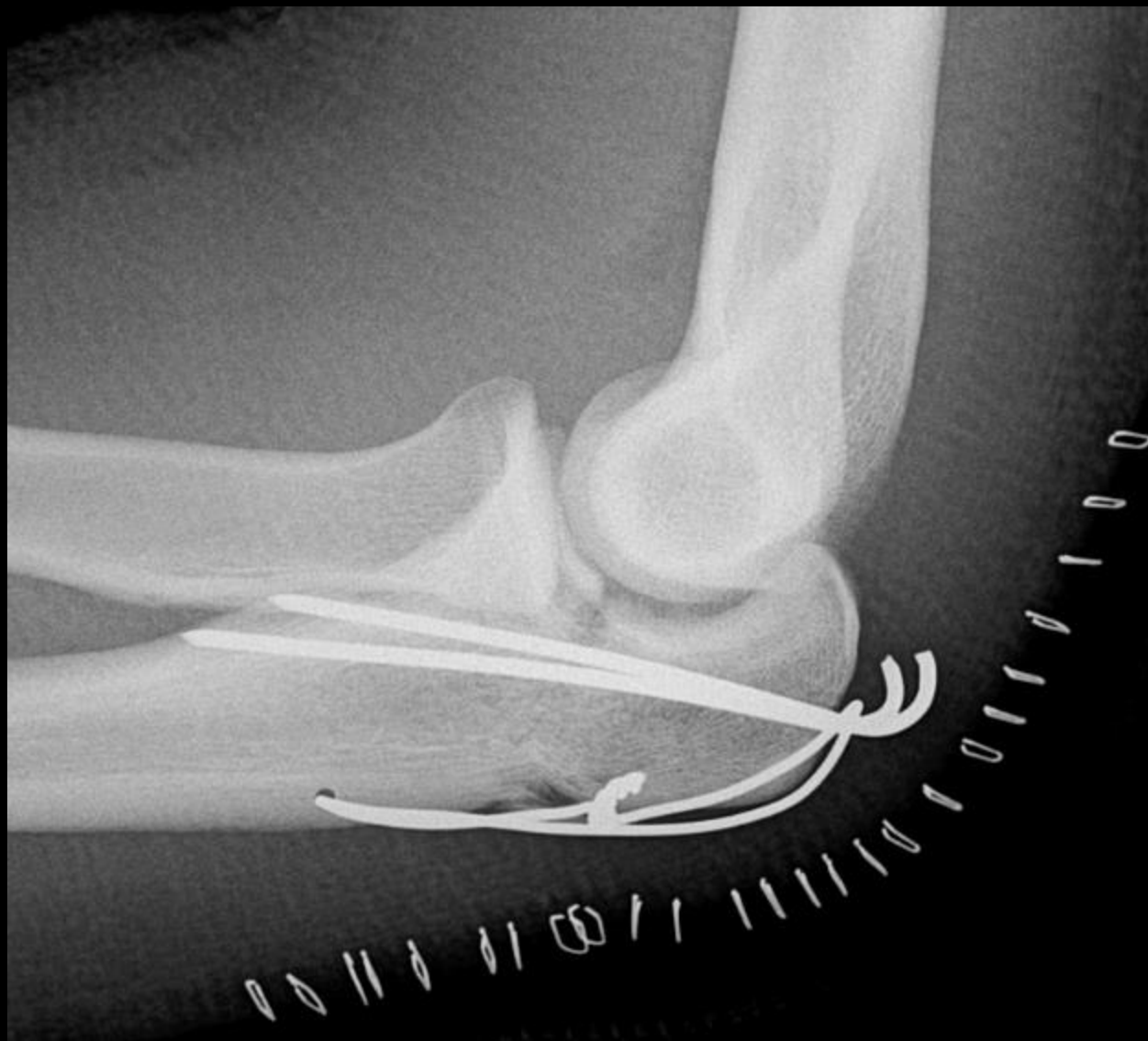


mRUS :

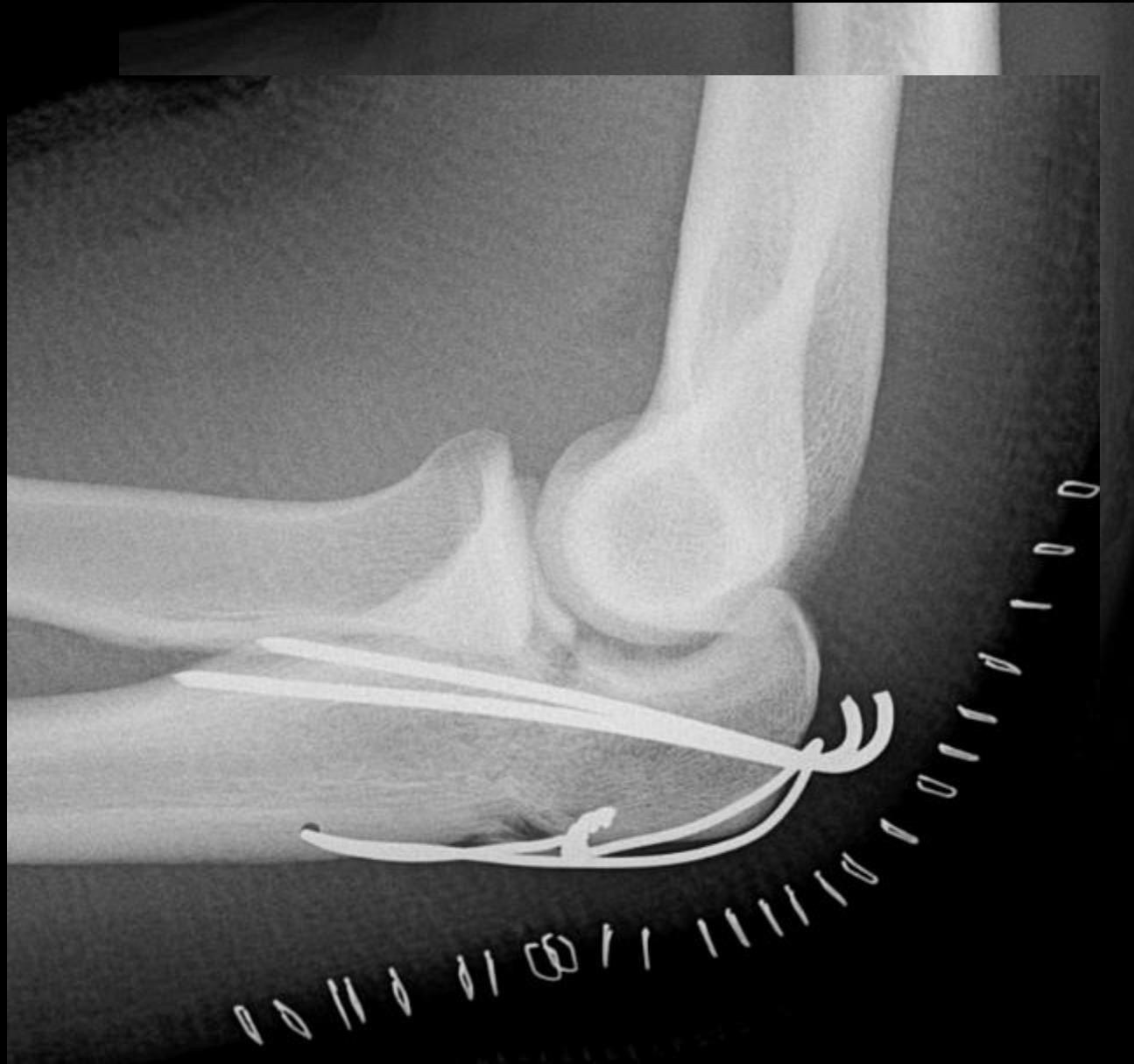
1: No callus / 2: callus, not continuous / 3 : Continuous, immature / 4: continuous, remodelled

TUS scoring

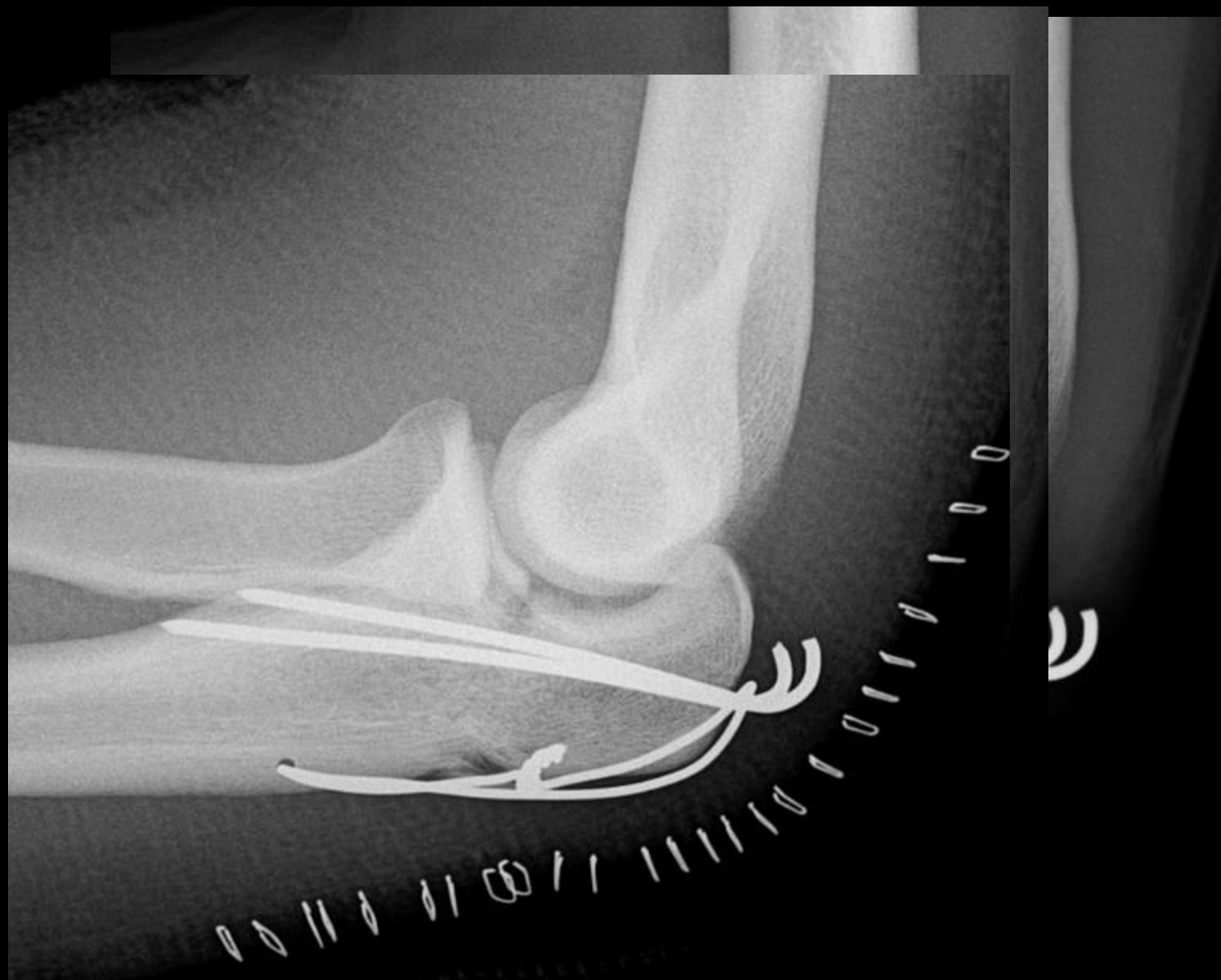
- Which and how many reformatted images to score ?
- Inter- and intra-observer agreement ?
- TUS value in normal/abnormal healing ?

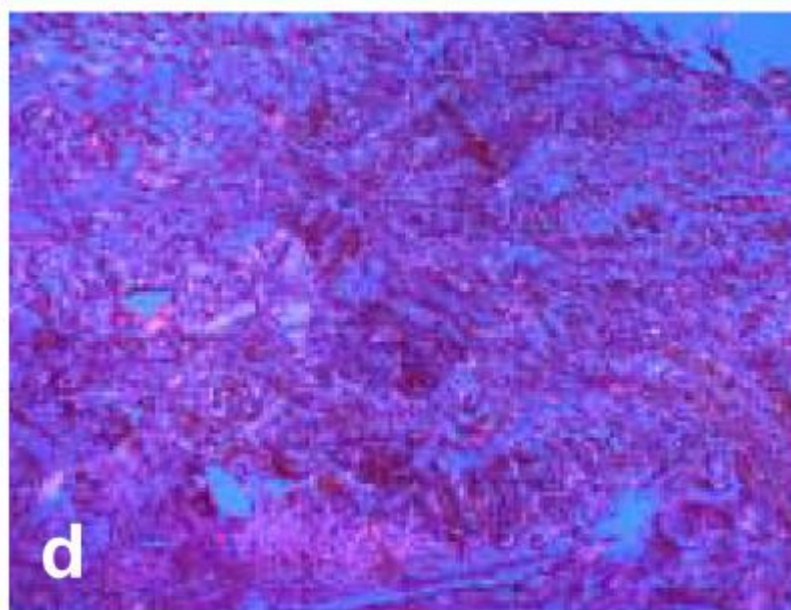
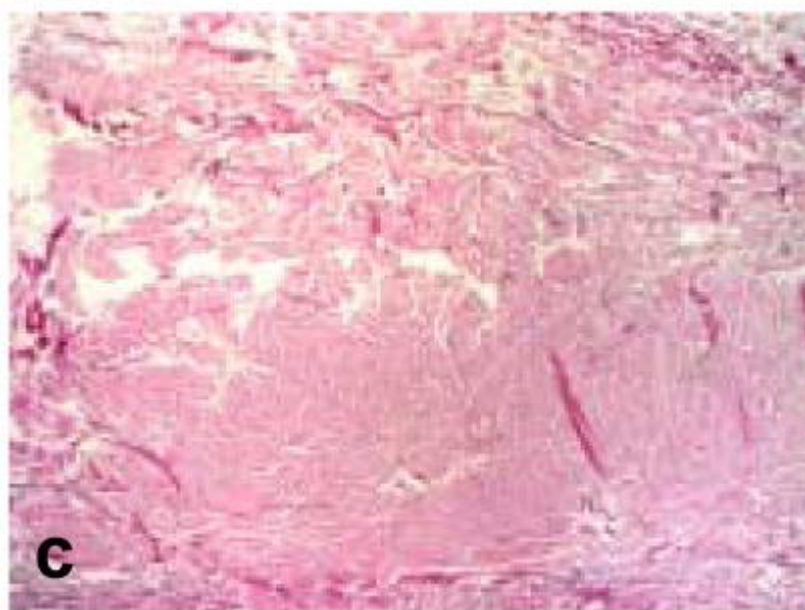
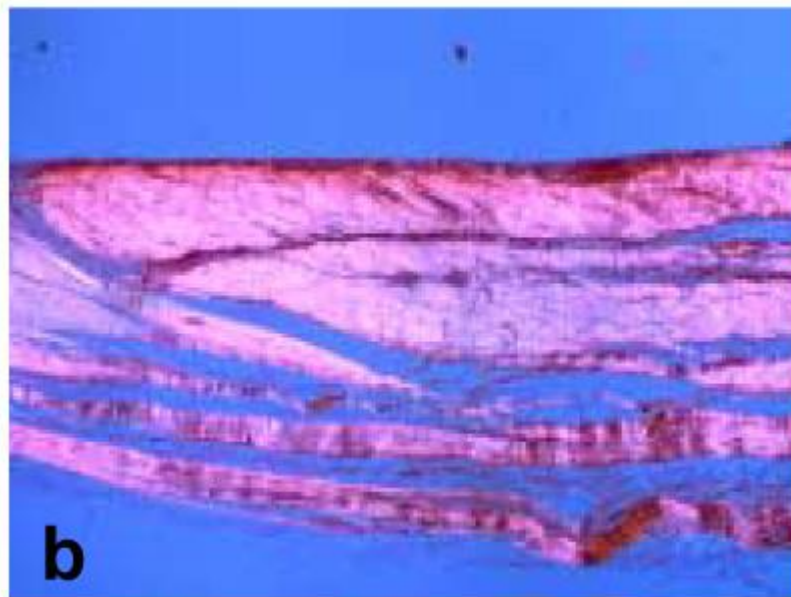
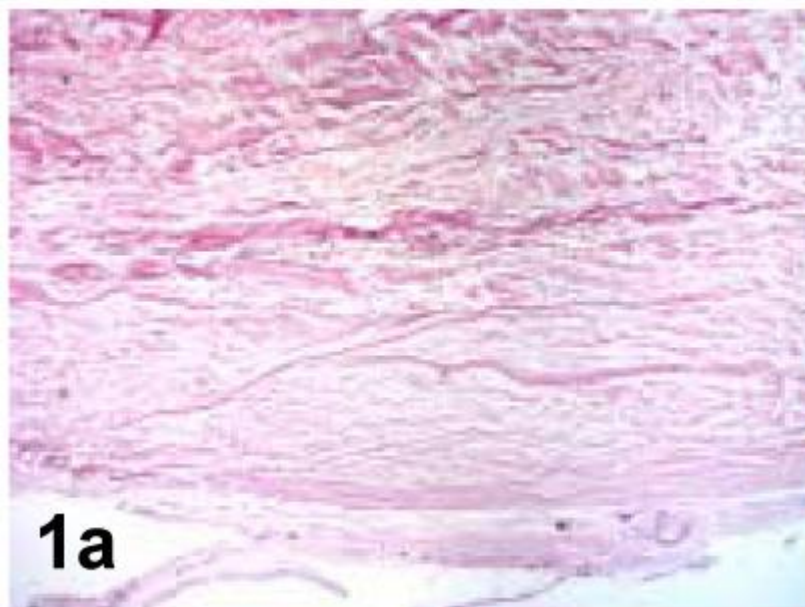


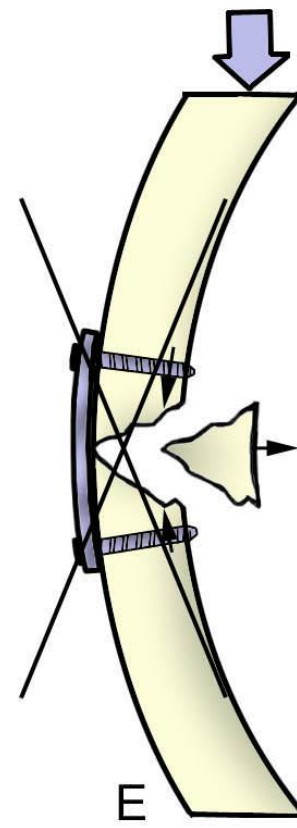
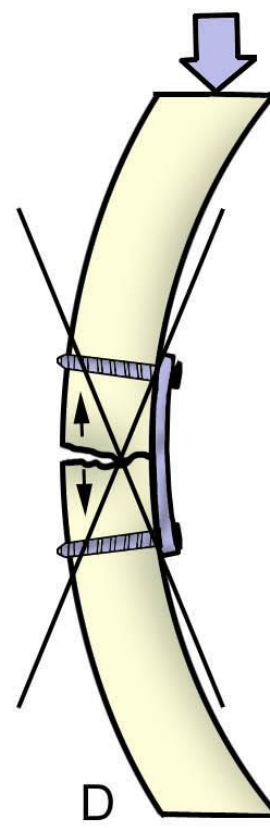
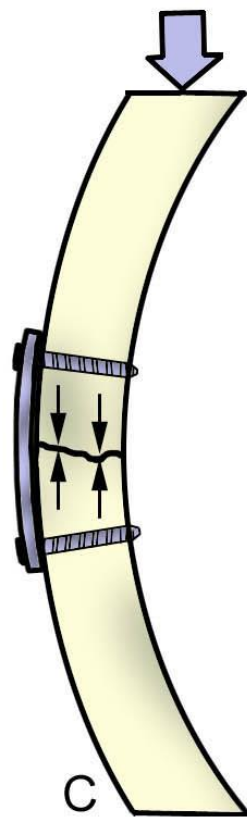
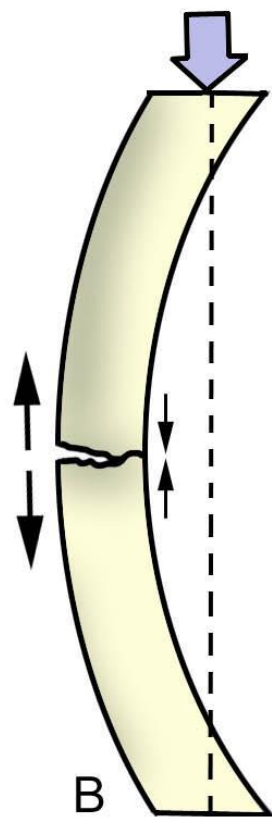
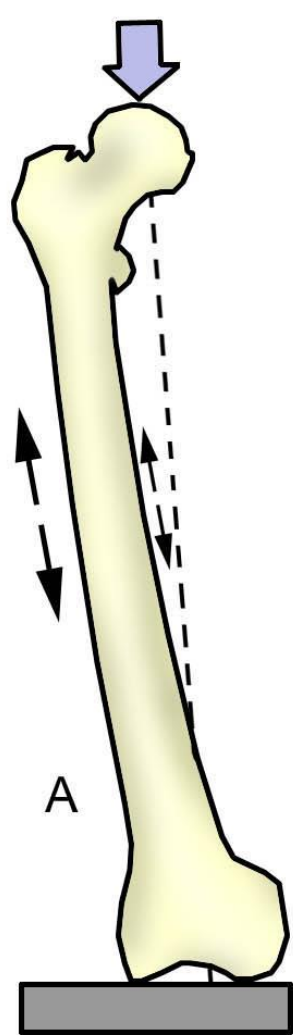
123

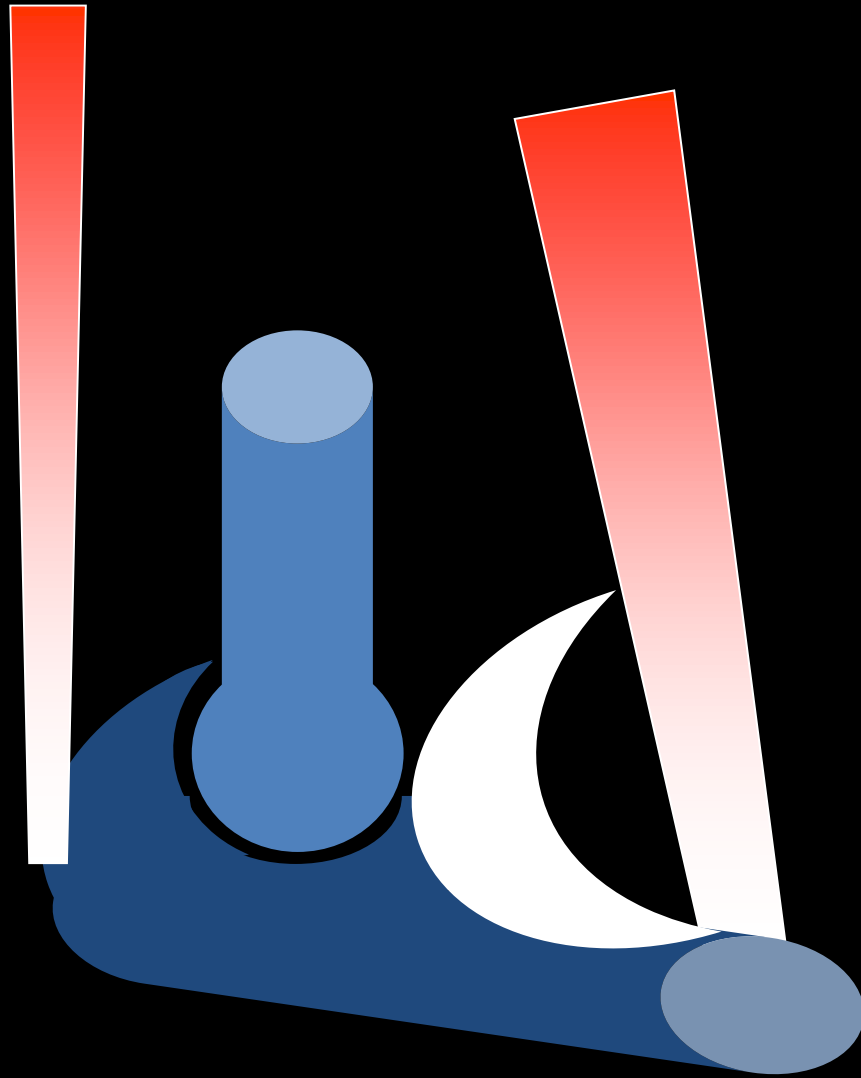


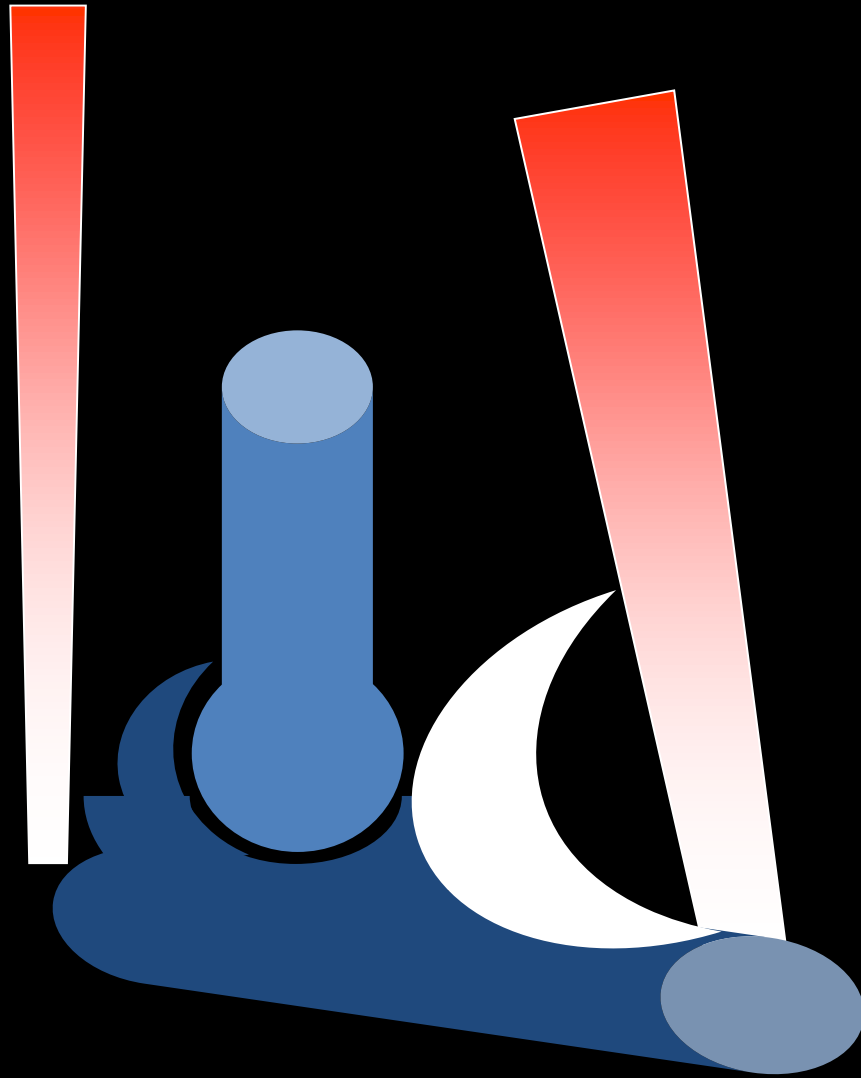
123

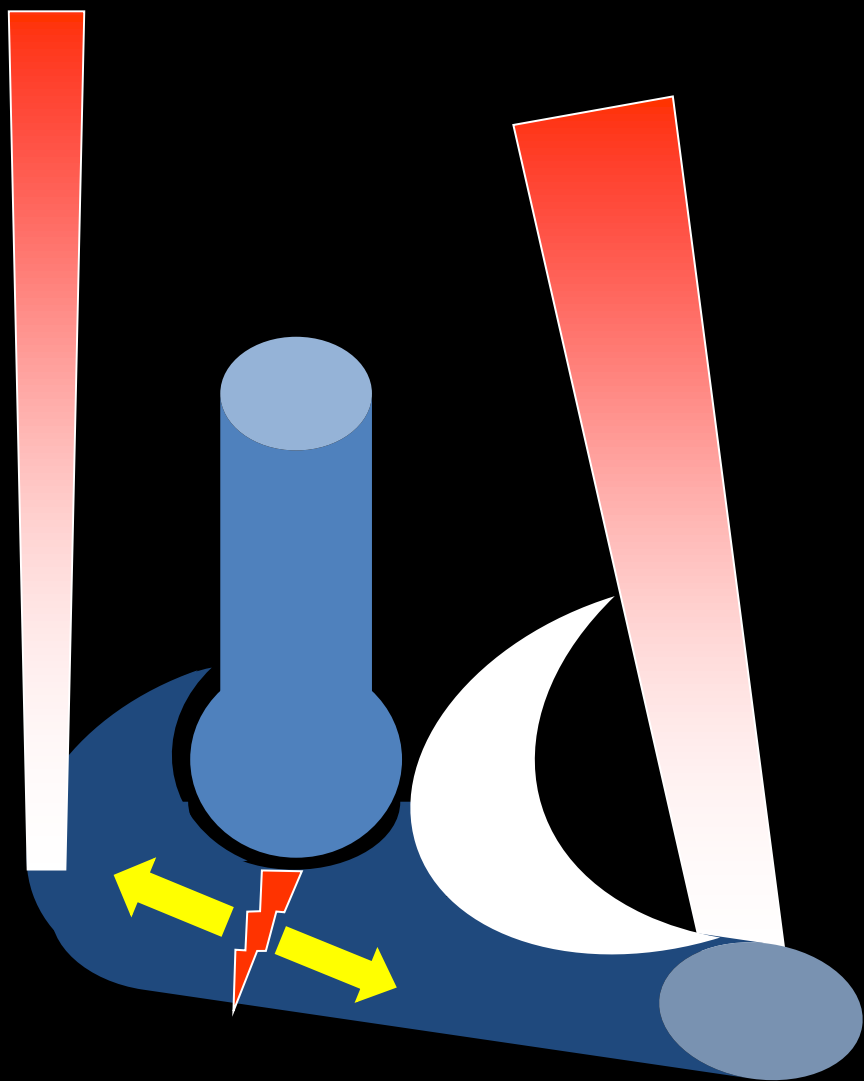


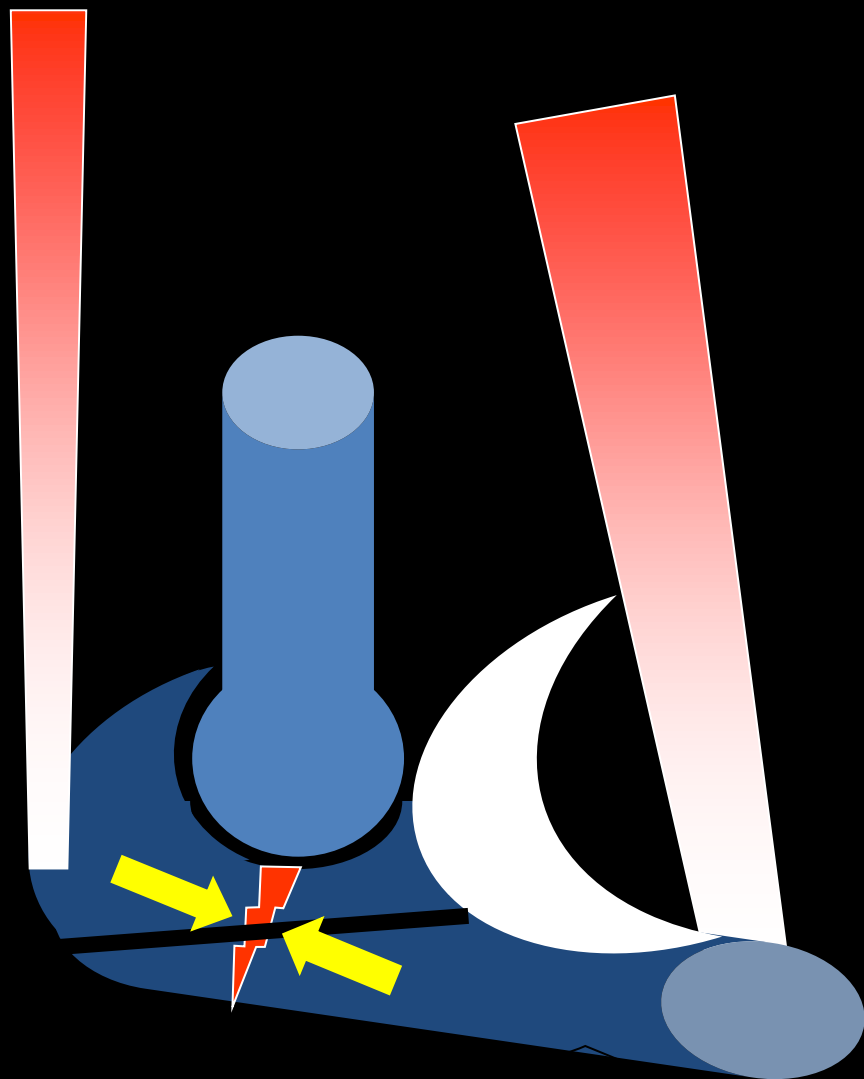




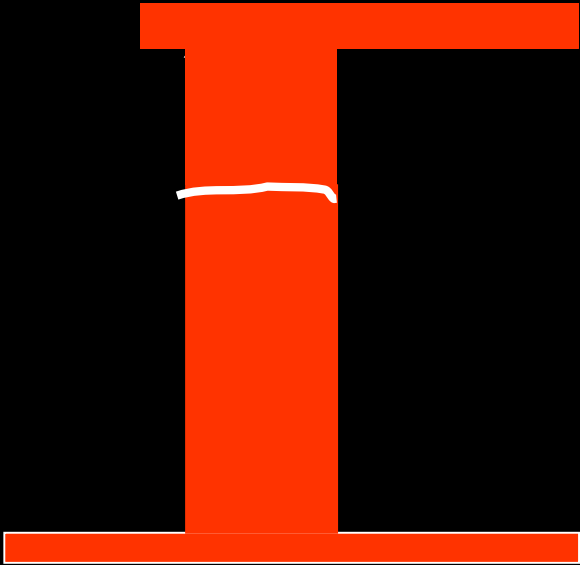




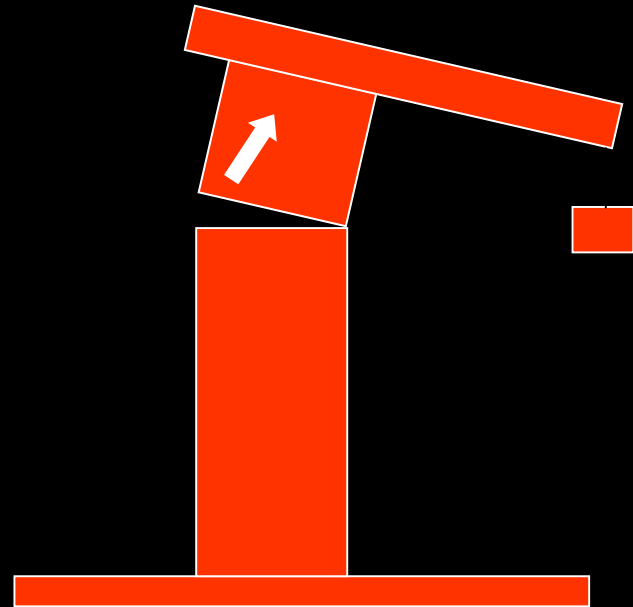




Fracture instable
non déplacée



Fracture instable
déplacée



123



Hauban age externe
Sélection de cas
Trait fracturaire simple
Centré en regard de l'humérus



Fractures articulaires - Objectifs

- Définition
- Retard de consolidation
- Fragment ostéo-chondral
- Nécrose
- Capsulite

Fragment ostéo-chondral

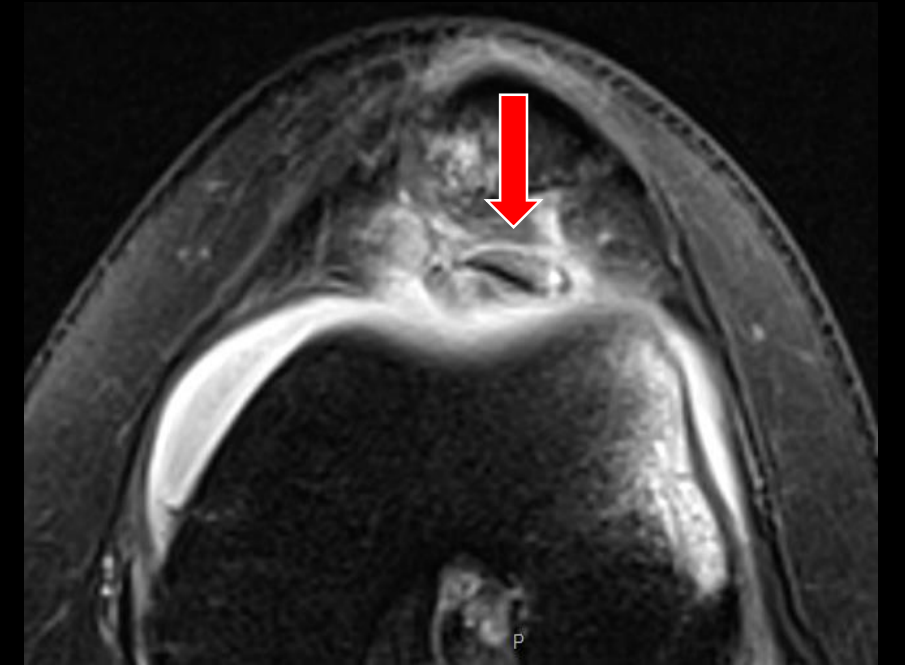
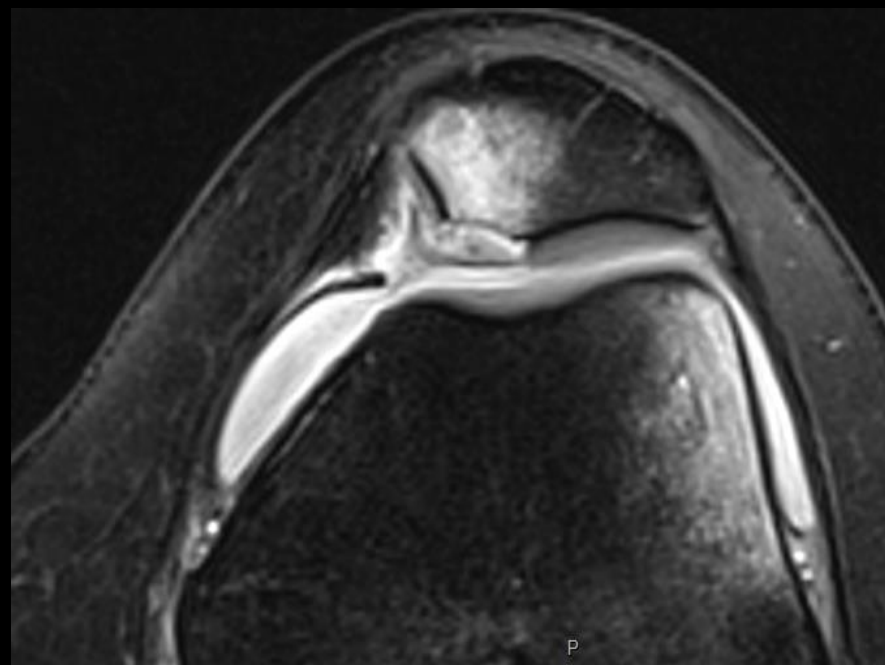
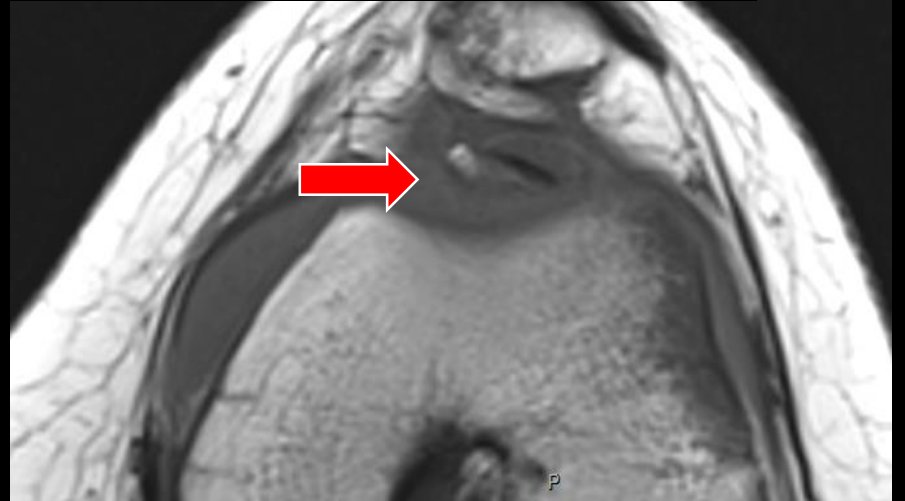
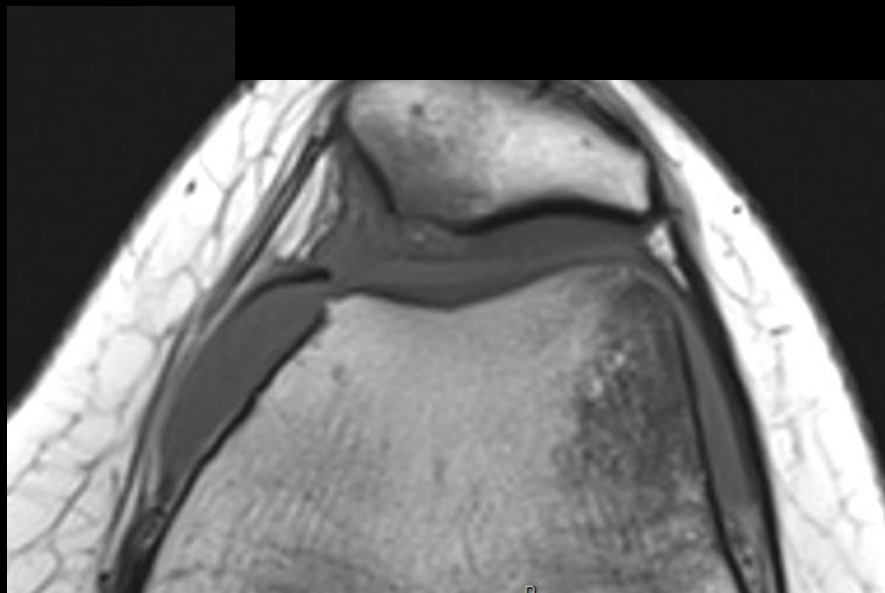
- Contraintes importantes
- En cisaillement
- Formation de fragment
 - de cartilage uniquement
 - de cartilage et d'os sous-chondral
- in situ
- déplacé
- basculé

Fragment ostéo-chondral

- Luxation patellaire
- Fragment ostéo-chondral



Fragment ostéo-chondral





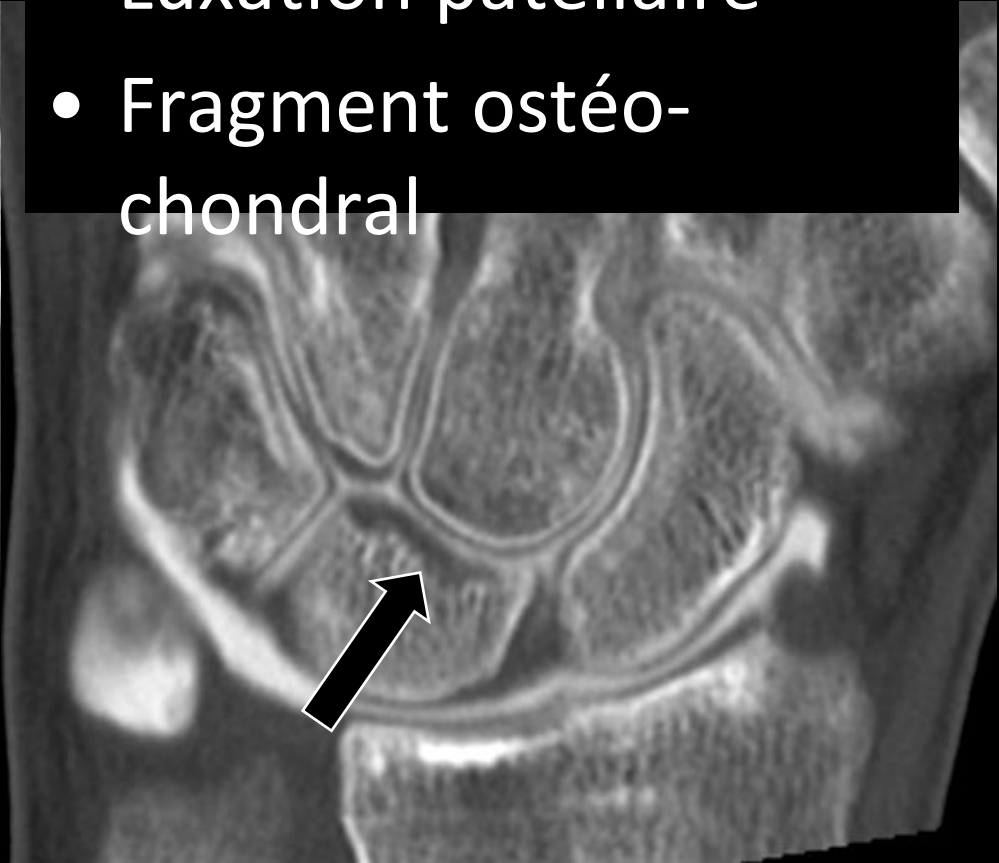






Fragment ostéo-chondral

- Luxation patellaire
- Fragment ostéo-chondral



Fragment ostéo-chondral inversé



Objectifs

- A. Biomécanique des fractures
- B. Consolidation osseuse
- C. Biomécanique du traitement chirurgical
- D. Complications des fractures