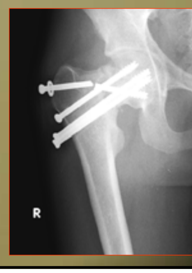
Femoral Neck Fractures in Young Adults:
What is the Evidence?



Cory Collinge, MD
Vanderbilt University
Nashville, TN

We accept….

Femoral neck fracture in young adults
- Difficult injuries
- Early, skilled treatment essential
- Complications are potentially catastrophic
- Salvage Rx are common

FAILED

Summary

- Describe injury pattern
- What is the standard?
- Optimal care
- Expectations

Who Risks Failure?

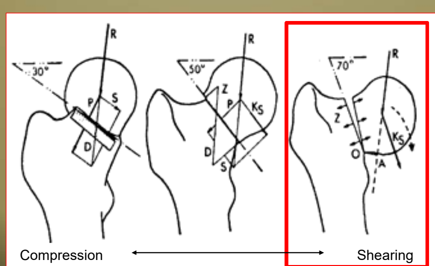
What is likely to affect union?

- Host factors (hormones, smoking, etc.…)
- Intra-articular injury (synovial fluid)
- Vascularity
- Fracture configuration
- Reduction
- Fixation

Affected by surgeon

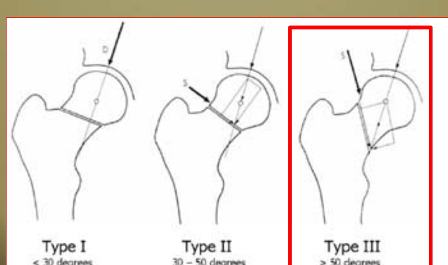
Friedrich Pauwels (1920's)

- Mechanical approach



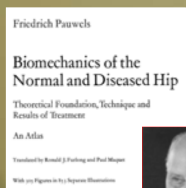
Friedrich Pauwels (1920's)

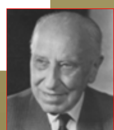
- Classification system

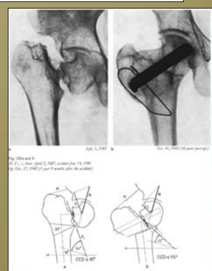


Friedrich Pauwels (1920's)

"The Fracture of the Femoral Neck. A Mechanical Problem", Biomechanics of the Locomotor Apparatus, 1935







Early Surgical Rx

Protzman and Burkhalter. Femoral neck fractures in young adults. JBJS-Am, 1976.

- 22 patients aged 20-40 (Army recruits)
- Mostly CRIF

- 59% nonunions
- 86% AVN

Modern Treatment

Liporace et al. Results of internal fixation of Pauwels' III vertical femoral neck fractures. JBJS-Am, 2008.

- 56 patients young patients with Pauwels' III
- 17% nonunions 12% AVN

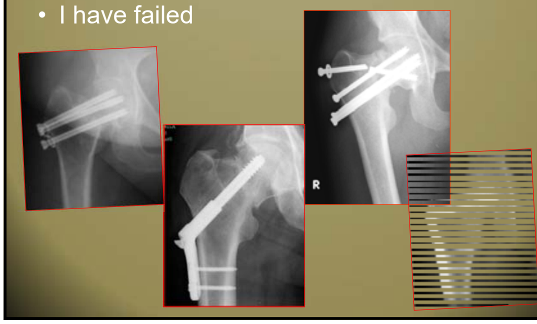
30% failure rate

– 12% AVN




Modern Treatment

- I have failed



Modern Treatment

- Failure is costly for the young patient

Shortening

Zielinski et al. Femoral Neck Shortening After Internal Fixation of a Femoral Neck Fracture. Orthopedics, 2013; 36(7) 138-147.

- Results

"IF of femoral neck fractures and femoral neck shortening affect patient VAS scores and functional outcomes."

Table 2

Data on Femoral Neck Shortening, Gait Parameters, Muscle Strength, and Self-reported Patient Functioning

Variable	Total (N=76)	Little or No FNS[a] (n=25)	Moderate FNS[b] (n=26)	Severe FNS[c] (n=25)	P
Femoral neck shortening, cm[d]	1.1 (0.5 to 1.7)	0.4 (0.1 to 0.5)	1.1 (0.9 to 1.3)	2.0 (1.7 to 2.3)	<.001
Feeling of LLD[e]	31 (40.8)	5 (20.0)	7 (26.9)	19 (76.0)	<.001
VAS score complaints of LLD[d,f]	4.0 (1.5 to 7.2)	2.1 (0.5 to 7.1)	4.9 (4.8 to 8.0)	3.9 (1.9 to 7.0)	.242
Heel lift use[e]	23 (30.3)	3 (12.0)	4 (15.4)	16 (64.0)	<.001
VAS score satisfaction with gait pattern[d]	7.5 (5.1 to 8.7)	8.0 (6.5 to 9.0)	7.3 (5.3 to 8.3)	7.3 (4.3 to 8.0)	.006
SF-12 score[d]	102.1 (92.3 to 108.0)	102.4 (98.3 to 108.8)	101.7 (92.9 to 106.2)	99.8 (83.9 to 108.2)	.439
WOMAC score[d]	86.5 (72.9 to 97.4)	95.6 (80.2 to 99.0)	88.3 (73.8 to 97.9)	81.2 (58.9 to 92.4)	.059
Foot axis, deg[g,h]	0.5 (−5.5 to 4.6)	2.4 (−1.2 to 7.4)	−2.8 (−7.3 to 3.9)	−1.8 (−6.5 to 4.8)	.034

Shortening

Zielinski et al. Femoral Neck Shortening After Internal Fixation of a Femoral Neck Fracture. Orthopedics, 2013; 36(7) 138-147.

- Results

"Displaced fractures and Pauwels 3 fractures shorten the most."

Patient and Fracture Characteristics

Characteristic	Total (N=76)	Little or No FNS (n=25)	Moderate FNS (n=26)	Severe FNS (n=25)	P
Age, y	68.3 (61.6-78.4)	70.5 (62.4-79.5)	69.4 (61.7-77.2)	67.1 (60.6-78.7)	.882
Male sex	37 (48.7)	8 (32.0)	11 (42.3)	18 (72.0)	.013
Weight, kg	75.0 (63.0-83.0)	65.0 (56.5-76.5)	72.5 (62.3-83.0)	80.0 (73.5-90.0)	.001
BMI, kg/m²	24.3 (21.9-26.0)	23.6 (21.3-25.5)	24.0 (21.4-25.3)	25.8 (23.5-28.4)	.021
ASA score >2	5 (6.6)	1 (4.0)	1 (3.8)	3 (12.0)	.465
Institutionalized prefracture	1 (1.3)	0 (0.0)	0 (0.0)	1 (4.0)	.336
Prefracture use of aids	6 (7.9)	1 (4.0)	2 (7.7)	3 (12.0)	.576
Subcapital fracture	36 (47.4)	15 (60.0)	12 (46.2)	9 (36.0)	.246
Displaced fracture (Garden III-IV)	27 (35.5)	3 (12.0)	11 (42.3)	13 (52.0)	.009
Pauwels class 3	22 (28.9)	1 (4.0)	7 (26.9)	14 (56.0)	.001
Time FNS measurements since surgery, mo	11.7 (11.2-12.4)	11.7 (11.3-12.3)	11.5 (10.5-12.3)	11.8 (11.2-12.9)	.448
Time gait measurements since surgery, mo	22.3 (18.9-24.3)	22.9 (20.0-27.0)	22.0 (18.2-23.7)	21.5 (17.8-23.2)	.187

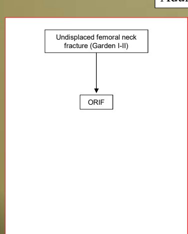
Modern Treatment

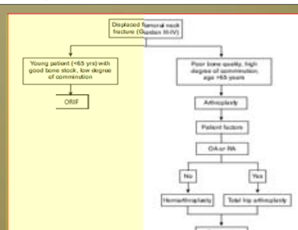
- Pauwels
- …….
- …….
- …….
- …….
- Swiontkowski et al.
- …….
- …….
- ?

Treatment Decisions

- Algorithms

Macauley et al.. Femoral Neck Fractures in the Young Adult. JAAOS, 2006

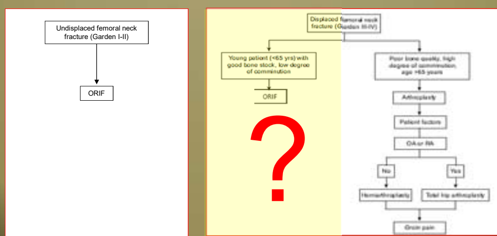




Treatment Decisions

- Algorithms

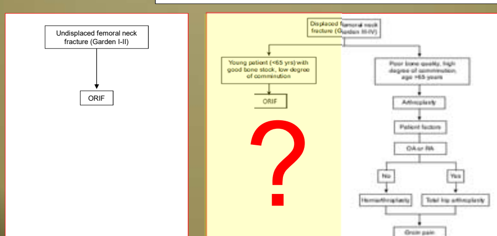
Macauley et al.. Femoral Neck Fractures in the Young Adult. JAAOS, 2006



Treatment Decisions

- Algorithms

Macauley et al.. Femoral Neck Fractures in the Young Adult. JAAOS, 2006



Treatment Decisions

AAOS

Treatment of Femoral Neck Fractures in Young Adults

- Algorithm provided

an axially loaded, high-energy force applied to an abducted hip) result in a basicervical or more distal neck fracture. The fracture pattern has a tendency to be more vertically oriented and, thus, biomechanically more unstable[42-46]. These characteristics have important implications with regard to obtaining and maintaining stable fixation, both of which are necessary for healing to occur.

Treatment Decisions

AAOS
American Academy of Orthopaedic Surgeons

Treatment of Femoral Neck Fractures in Young Adults

imaging, a Weber clamp or 2.0-mm Kirschner wires can provisionally hold the reduction. Definitive fixation can be obtained with three cannulated or noncannulated cancellous screws (Fig. 3). Closure is routine. Another approach, with use of a modified Smith-Petersen sur... as been described[62]. ... t access to and visualiza... ral neck fracture, espe... capital region. How... ncision is required for ... n.

The postoperative regimen that

?

- Algorithm provided

Treatment Decisions

- ICL Example

Fig. 4-A

Figs. 4-A through 4-E A twenty-two-year-old man with a displaced right femoral neck fracture sustained in a motor-vehicle collision.

Treatment Decisions

Fig. 4-B Fig. 4-C

Fig. 4-B Anteroposterior radiograph after open reduction and internal fixation with three cannulated cancellous screws. **Fig. 4-C** Lateral hip radiograph after open reduction and internal fixation.

Treatment Decisions

Fig. 4-D
Anteroposterior radiograph made at eight months postoperatively. There is some settling of the fracture and a lack of complete healing at this point. The patient had no pain and was bearing full weight.

Treatment Decisions

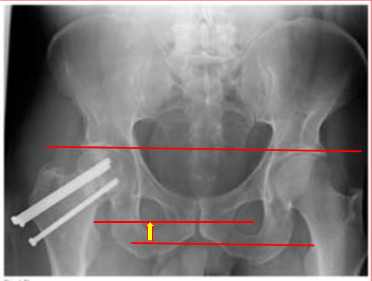


Fig. 4-D
Anteroposterior radiograph made at eight months postoperatively. There is some settling of the fracture and a lack of complete healing at this point. The patient had no pain and was bearing full weight.

Treatment Decisions

- What might have been done differently?

Treatment Decisions

- What about pre-operative planning?

Treatment Decisions

- Is evaluating this in surgery OK?

Treatment Decisions

What sort of evaluation is being done?

- 3 trauma centers
- 65 Pauwels' III vertical neck fractures in patients <50 yo undergoing repair
- Exclusion:
  - Acetabular or femoral shaft fx
  - Arthroplasty

Collinge, Beltran, Reddix, and Mir. J Ortho Trauma submitted

Treatment Decisions

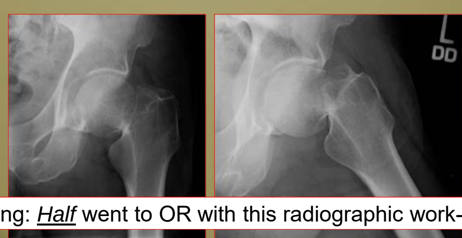
What sort of evaluation is being done?

- "AP and 'lateral'" Xrays 65/65
  - 30/65 (55%) had adequate Xray
- "Advanced" imaging
  - 2% had dynamic/ traction views
  - 55% had CT scan (25/30 trauma scans)

Collinge, Beltran, Reddix, and Mir. J Ortho Trauma, 2014

Treatment Decisions

- Radiography: 52 yo rancher

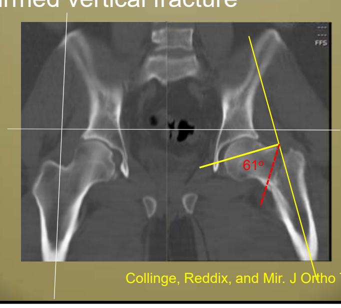


Finding: *Half* went to OR with this radiographic work-up

Collinge, Beltran, Reddix, and Mir. J Ortho Trauma, 2014

Fracture Morphology

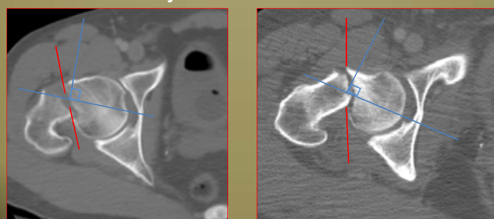
- Confirmed vertical fracture



Collinge, Reddix, and Mir. J Ortho Trauma, 2014

Fracture Morphology

- External rotation deformity
- Fracture rarely transverse



Collinge, Reddix, and Mir. J Ortho Trauma, 2014

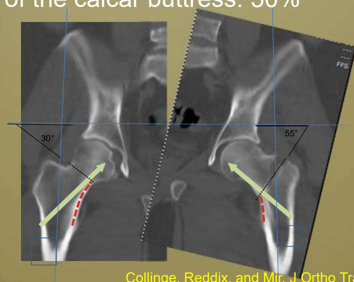
Fracture Morphology

- Comminution
  - Young 95%
- Apex inferiorly on calcar

Collinge, Reddix, and Mir. J Ortho Trauma, 2014

Fracture Morphology

- Loss of the calcar buttress: 50%



Collinge, Reddix, and Mir. J Ortho Trauma, April 2014

Fracture Morphology

Collinge, Reddix, and Mir. J Ortho Trauma, April 2014

Fracture Morphology

Understanding fracture morphology

- Oblique- Cranial shear
- Oblique- Posterior shear + comminution
- Calcar defect
- +/- osteopenic bone
- +/- segmental bone loss

Fracture Morphology

Understanding fracture morphology

- Oblique- Cranial shear
- Oblique- Posterior shear + comminution
- Calcar defect
- +/- osteopenic bone
- +/- segmental bone loss

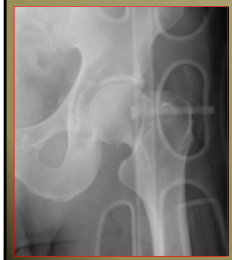
All we have to offer is 3 cannulated screws? or a SHS +/- AR screw?

Fracture Morphology

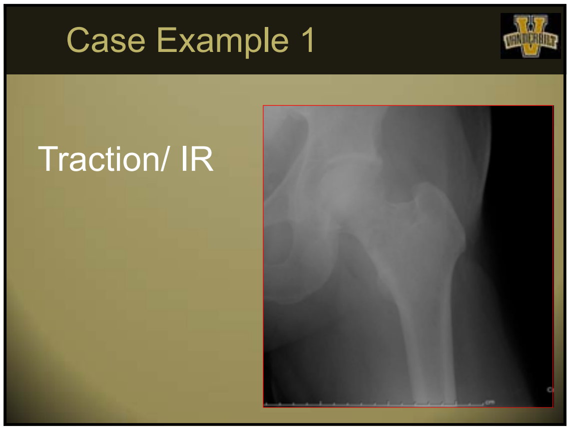
So now what?

- Better idea of obtaining reduction
  - Open (vs. closed)
- Not everyone gets the same construct (?)
  - Fixed angled devices with rotational control?
  - Buttress plating the neck?
- Modelling for Lab studies

Case Example 1



Case Example 1

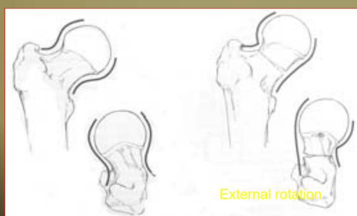

Case Example 1
Traction/ IR

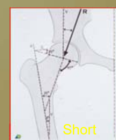

Case Example 1

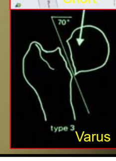

Case Example 1

Reduction

- Must overcome *deformity* and *muscle forces*







Reduction

Ideal reduction is ***<u>ANATOMIC</u>***
- Restores muscle lengths, levers
- Restores fracture stability
  - Optimizes fractures mechanics
  - Interdigitates bony interstices

- Acceptable?: $\leq$15° valgus, $\leq$10 ° AP
- NO varus is acceptable

Reduction

- Leadbetter Technique
  - Flex the hip to 90°, slight adduction
  - In-line traction with the femur
  - While maintaining traction, IR to 45°
  - Slowly move into slight abduction and full extension, while maintaining traction and internal rotation

- Lots of others

Reduction

Karanicolas et al. Interobserver Reliability of Classification Systems to Rate the Quality of Femoral Neck Fracture Reduction. JBJS-Am 2004

- Assessed inter-rater reliability of surgeons using reduction grading systems
- Reviewed series of femoral neck ORIF's
- 5 scales used vs. "clinical impression"

e.g.

TABLE 3. The Quality of Fracture Reduction, Modified from Lindquist and Tornkvist's Criteria[20]

Quality of Reduction	Criteria
Acceptable	Anteroposterior alignment 160-175 degrees Lateral angulation ≤10 degrees
Unacceptable	Anteroposterior alignment <160 degrees or >175 degrees or lateral angulation >10 degrees

TABLE 2. The Quality of Fracture Reduction, Modified from Lowell's Criteria[19]

Quality of Reduction	Criteria
Anatomic	Perfect anteroposterior and lateral alignment
Acceptable with minor concerns	<2-mm-fracture displacement Anteroposterior alignment: anatomic to 15-degree valgus Lateral alignment: anatomic ± 10 degrees
Borderline acceptable	2- to 5-mm-fracture displacement Anteroposterior alignment: <5-degree varus to <25-degree valgus Lateral alignment: 10-20 degrees from anatomic
Unacceptable	>5 mm displacement Anteroposterior alignment: >5-degree varus or >25-degree valgus Lateral alignment: >20 degrees from anatomic

Reduction

Karanicolas et al. Interobserver Reliability of Classification Systems to Rate the Quality of Femoral Neck Fracture Reduction. JBJS-Am 2004

- "Overall impression" used in practice

TABLE 6. Reviewers' Routine Use of Instruments to Rate the Quality of Femoral Neck Fracture Reduction

Instrument	Number of Reviewers (%)
Overall impression	15 (83)
Garden Index	8 (44)
Lowell's criteria	2 (11)
Lindquist and Tornkvist's criteria	1 (6)
WIG angle	0 (0)
International Hip Fracture Research Collaborative standards	0 (0)

Reduction

Karanicolas et al. Interobserver Reliability of Classification Systems to Rate the Quality of Femoral Neck Fracture Reduction. JBJS-Am 2004

- Trauma trained surgeons better reliability for assessment of quality of reduction, vs. non-trauma and trainees

J Orthop Trauma • Volume 23, Number 6, July 2009 *Reliability of Femoral Neck Fracture Reduction Quality*

TABLE 8. Interobserver Reliability for Assessment of Quality of Fracture Reduction Using Different Instruments (95% CI), Grouped by Level of Expertise

Instrument	Trauma	Nontrauma	Residents
Overall impression†	0.58 (0.46, 0.70)	0.46 (0.33, 0.62)	0.46 (0.34, 0.60)
Garden Index†	0.54 (0.41, 0.67)	0.42 (0.30, 0.56)	0.26 (0.15, 0.40)
Lowell's criteria†	0.58 (0.47, 0.70)	0.50 (0.38, 0.63)	0.42 (0.30, 0.56)
Lindquist and Tornkvist's criteria*	0.33 (0.15, 0.48)	0.32 (0.15, 0.47)	0.17 (0.05, 0.32)
WIG angle*	0.48 (0.32, 0.63)	0.34 (0.15, 0.54)	0.34 (0.21, 0.52)
International Hip Fracture Research Collaborative standards†	0.51 (0.38, 0.65)	0.36 (0.24, 0.50)	0.47 (0.34, 0.60)

*Kappa for dichotomous scales.
†ICC for polytomous scales.

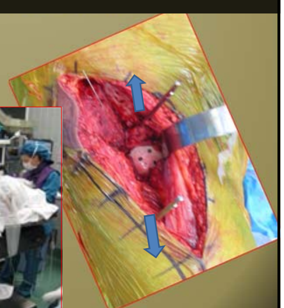
Open Reduction

Heuter/ Mini Smith-Pete

- Excellent neck exposure

Open Reduction

- Traction (or not)



Open Reduction

- Joy stick(s)
  - Rotate
  - Push/pull(?)
  - Provisional fixation
- Bone hook
  - pull (rotate)

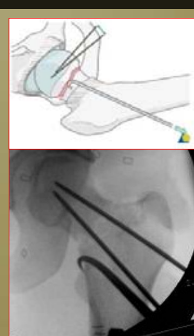


FIGURE 4. A, A 16-year-old female involved in a high-speed motor vehicle accident. The patient sustained a left external iliac artery injury requiring emergent repair. The reduction was then temporarily held with a 3.5-mm pelvic reconstruction plate (D and E). Definitive fixation was placed percutaneously using small incisions (F and G). The bone hook prevents subluxation through the acetabular fracture.

Open Reduction of Intracapsular Hip Fractures Using a Modified Smith-Petersen Surgical Exposure

Molnar, Robert B; Routt, M L (Chip) Jr
Journal of Orthopaedic Trauma. 21(7):490-494, August 2007.
doi: 10.1097/BOT.0b013e31804a7f7f

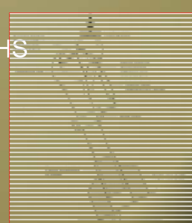
- Clamps
- Small or mini-frag plates

 52

Fixation

Baitner et al. Clin Orthop Rel Res. Vertical shear fractures of the femoral neck: a biomechanical study, 1999; 367: 300-304.

- Mechanical testing
- 3 cannulated screws vs. SHS
- Cadavers
- Pauwels 3
- Flat cut
- No comminution
- Osteoporotic specimens



Fixation

Baitner et al. Clin Orthop Rel Res. Vertical shear fractures of the femoral neck: a biomechanical study, 1999; 367: 300-304.

- Results

"The SHS outperformed 3 cannulated screws in Pauwels 3 femoral neck fractures."

Fixation Method	Femoral Head Displacement at 500N (mm)	Change in Inferior K-wires at 500N (mm)	Change in Superior K-wires at 500N (mm)	Load to Failure (N)
Cancellous lag screws	2.1 (2.3)	2.6 (1.6)	1.9 (2.2)	800 (245)
Sliding Hip Screw	0.4 (0.3)	1.3 (0.5)	0.6 (0.2)	2550 (479)
P Value	< 0.05	< 0.05	0.07	< 0.01

Fixation

Sirkin et al. J Orthop Trauma. A biomechanical analysis of fixation constructs in high angle femoral neck fractures, 2000; 14(2): 131

- Mechanical testing
- 3 cannulated screws vs SHS vs DCS vs crossed lag screws
- Young cadavers (21-58)
- Pauwels 3
- Flat cut
- No comminution

Fixation

Sirkin et al. J Orthop Trauma. A biomechanical analysis of fixation constructs in high angle femoral neck fractures, 2000; 14(2): 131

- Results

"The DCS and crossed screws outperformed 3 parallel cannulated screws and the SHS in Pauwels 3 femoral neck fractures."

	Force at 2 mm displacement (N)	Force at 4 mm displacement (N)	Force at 6 mm displacement (N)	Stiffness (N/mm)
CS	1789.93 ± 369.57	1883.79 ± 93.78	1949.09 ± 184.94	2127.41 ± 1749.10
DHS	2243.18 ± 491.29	2692.30 ± 848.97	3323.29 ± 811.15	1740.23 ± 475.75
DCS	3123.94 ± 980.92*!	3621.10 ± 1442.22!	3632.70 ± 303.10	3080.93 ± 574.60
XCS	3396.02 ± 474.68*!	3337.54 ± 161.65!	3862.14 ± 466.58!	2964.57 ± 1741.33

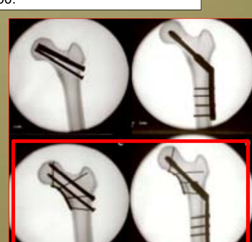
Values with an (!) indicate a significant difference with CS ($p < 0.05$). Values with an (*) indicate a significant difference with DHS ($p < 0.05$).

JOURNAL OF ORTHOPAEDIC TRAUMA

Fixation

Kunapuli et al. Biomechanical Analysis of Augmented Plate Fixation for the Treatment of Vertical Shear Femoral Neck Fractures. J Orthop Trauma. 2015 (29) 3, 144–150.

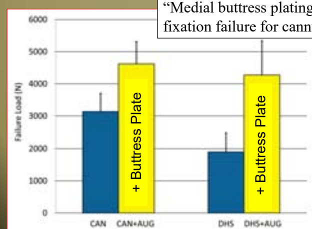
- Mechanical testing
- 4 constructs
- Sawbones IV
- Pauwels 3
- No comminution



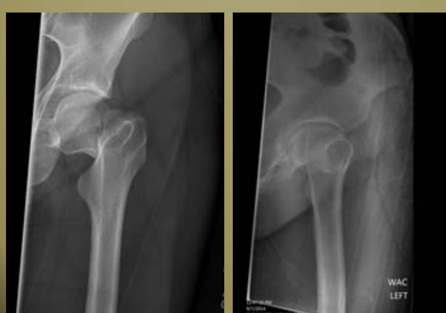
Fixation

Kunapuli et al. Biomechanical Analysis of Augmented Plate Fixation for the Treatment of Vertical Shear Femoral Neck Fractures. J Orthop Trauma. 2015 (29) 3, 144–150.

"Medial buttress plating improves resistance to vertical fixation failure for cannulated screws and SHS."

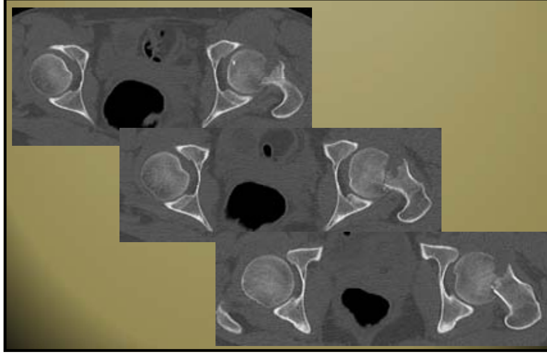


Summary: Case 2



Summary: Case 2

Summary: Case 2



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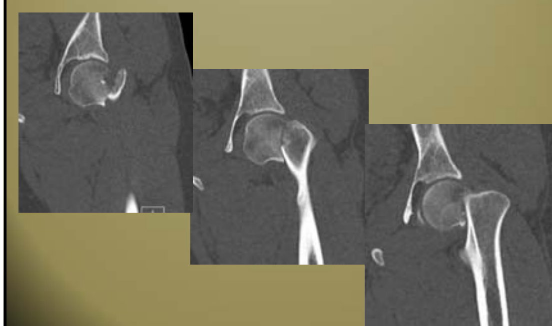
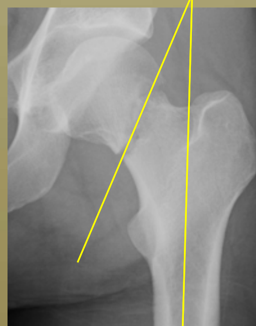


Summary: Case 2

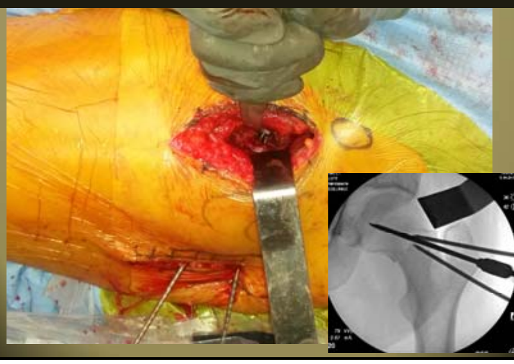
Summary: Case 2



Summary: Case 2

Summary: Case 2

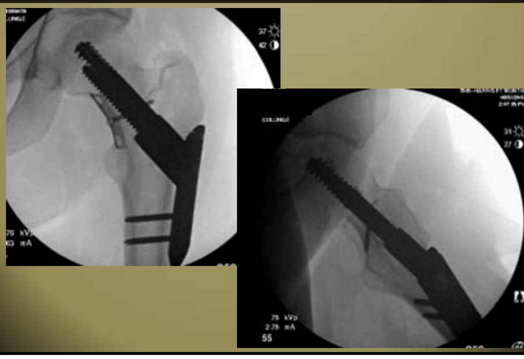
Summary: Case 2



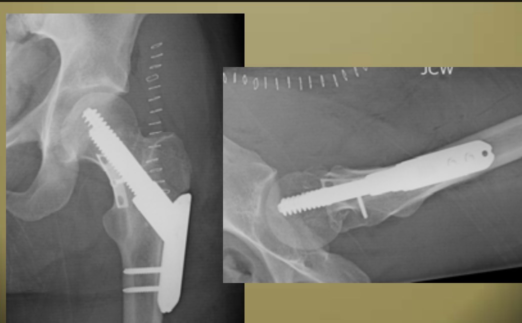
Summary: Case 2

Summary: Case 2

Summary: Case 2

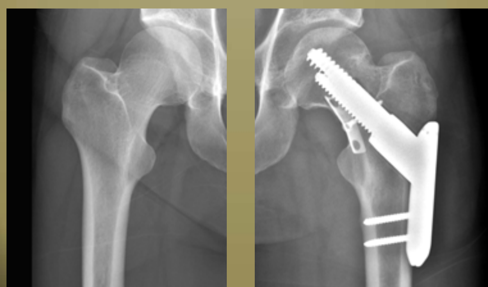


Summary: Case 2



Summary: Case 2

Summary: Case 2



Conclusions

Femoral neck Fx in young adult

- Assessment
- Pre-op planning
- Reduction
- Fixation
- Complication management

Conclusions

Pauwels III femoral neck Fx in young adult

- We need to understand the injury better

- Requires a thoughtful solution

Thank You