 ACTA CHIRURGIAE ORTHOPAEDICAE
ET TRAUMATOLOGIAE ČECHOSL., 73, 2006, p. 45–59

Fractures of the Femoral Neck: A Rewiew and Personal Statement

Zlomenina krčku stehenní kosti – osobní zkušenosti autora

ERNST L.F.B. RAAYMAKERS

Surgical Clinic, Section Traumatology,
Academisch Medish Centrum, Amsterdam, Netherlands

SUMMARY

EPIDEMIOLOGY

The number of hip fractures will increase enormously in the decades to come as will the cost of treatment of these patients do. In the USA the annual cost has estimated to be nearly $10 billion.

Hip fractures, therefore, represent an enormous socio-economic and medical problem and challenge (orthopaedic) surgeons an anaesthetists to find the cheapest and most effective way to treat them. At the same time the search for preventive measures should be continued. Biphosphonates and hip protectors seem to be able to decrease the risk of suffering a hip fracture with 50%.

CLASSIFICATION

The first classification of femoral neck fractures, proposed by Abraham Colles, in displaced and non-displaced (impacted) fractures appears to be still the most useful one. The Pauwels classification cannot be applied to the preoperative x-ray, because the fractured leg is always in external rotation. The Garden classification is not reproducible and does not lead us to the right treatment.

TREATMENT

Stability and healing chances of *impacted fractures* depend especially on age and general condition. In patients under 70 years of age without co-morbidity, the secondary instability rate after non-operative treatment is very low: 5%. In elderly people with multiple co-morbidity secondary instability can go up to 80%. These patients are better served with primary operative treatment. Although the majority of surgeons feel good with a strategy of prophylactical internal fixation in all patients, this author pleads for non-operative (early mobilization) treatment of all patients, who are healthy or have only one serious co-morbidity.

There is consensus about the treatment of *displaced fractures* in patients under 65 years of age: *closed reduction and internal fixation*. The best treatment for patients over 80 years of age is *prosthetic replacement*. In the (large) group of patients between 65 and 80 years of age calendar age is not a reliable guide to the right treatment. There is a growing conviction that the choice between internal fixation and prosthetic replacement in these patients should be made on the basis of the biological age (ASA-score, habitat, the activity level, the need for walking aids and cognitive function). Bone density does not seem to play an important role.

If internal fixation is the preferred treatment, the choice of implant is controversial. It is the author's experience that fractures with a steep fracture line (Pauwels 3) should be anatomically reduced and stabililized with a *sliding hip screw*. The less steep fractures (Pauwels 1 and 2) can be slightly overreduced in valgus and anteversion, which provides a bony support against shearing forces, and fixed with *parallel screws* according to the 3-point-fixation principle.

The *timing of surgery* continues to be a controversial subject. From a recent study in our own institution we concluded that no significant association could be found between delay to surgery and the clinical outcomes. However, considering the trends towards less complications and shorter length of hospital stay, early surgery (within 1 day from admission) is likely to be beneficial for hip fracture patients who are able to undergo operation.

There is agreement about the use of the *cemented* arthroplasty. If a hemiarthroplasty is chosen, the *bipolar* type is to be preferred to the unipolar type. The difference in *price* between both prostheses is negligible because the overall cost of the treatment have gone up so immensely. Futhermore, a basic advantage of the bipolar system is the relatively small operation, needed for conversion to a total hip replacement, because the stem can stay in place.

As to the question *hemiarthroplasty* or *total hip replacement*, the discussion has not yet been closed. We studied the natural history of the cemented bipolar hemiarthroplasty by evaluating 307 patients, operated between 1975 and 1989 in our institution. Only 3 patients, who not have been revised, were alive at the end of the observation period (2004). A striking difference was found in the occurrence of late mechanical complications (aseptic loosening and acetabular wear) between patients under 75 years of age (22%) and the older group of patients (6%). As to the patient's overall satisfaction 56% suffered no impairment from their sustained fracture, 36% were slightly impaired. We concluded that the use of the cemented bipolar prosthesis is justified in patients over 75 years of age. Patients between 65 and 75 years of age should either be treated with internal fixation or with a total hip replacement.

NONUNION OF THE FEMORAL NECK

Nowadays in cases of nonunions of the femoral neck the surgeon is tempted to perform prosthetic replacement of the hip, the more so if there is also evidence of a disturbed vascularisation of the head. This will provide rapid pain relief and mobilization. However, long-term results of hip arthroplasties, especially in younger people and in presence of bone atrophy, are not always as expected and a less radical approach is worth considering. The intertrochanteric valgisation osteotomy, described by Pauwels is an excellent alternative for patients up to 65 years of age with a non-union of the femoral neck. A union rate of 80-90% is described by most authors. Leg length, rotational and angular deformities can be corrected at the same time. Between 65 and 80 years a total hip replacement is probably the best option for fit patients. For elderly patients a cemented bipolar hemiarthroplasty is an adequate treatment.

A. EPIDEMIOLGY

About half of the fractures of the proximal femur are located in the femoral neck. The frequency of this "sickness of the aged" will increase enormously in the wealthy parts of the world, where the number of old people is growing very fast. Melton (1) estimated the global incidence of hip fractures to be 1.6 million in 1990. This figure is expected to rise to 4 million in 2025 and to 6.3 million in 2050 per year! In the late seventies of the last century it became obvious that the increasing number of hip fractures could not be explained by the increase of elderly people only. Hoogendoorn (2) amongst other authors pointed out that there was a rise of the age-specific incidence as well, possibly caused by osteoporosis, diminished muscle volume and neuromuscular response. Moreover, many frail patients are kept going, even after serious illnesses, operations and fracture treatment. Consequently they are exposed (again) to falls. Suzuki (3) showed that co-morbidity is frequent in these patients. He registered in 525 patients with a femoral neck fracture respiratory problems (29%), dementia (55%) and cardiovascular pathology (68%).

In Sweden, the cost of treatment during the first year following hip fractures has been calculated to be around $ 420 million annually (4). In the USA the annual cost has estimated to be nearly $ 10 billion (5). Hip fractures, therefore, represent an enormous socio-economic and medical problem and challenge (orthopaedic) surgeons an anaesthetists to find the cheapest and most effective way to treat them.

It is unclear up to now if **preventive** measures are effective in limiting the "orthopaedic epidemic", as it has been described in the United Kingdom. Several prevention strategies are available, the most effective being bisphosphonates. Bisphosphonates may prevent up to 50% of hip fractures, especially in postmenopausal women with established osteoporosis (6). A potential alternative or additional preventive method is the hip protector: special underpants with two protecting shells at the level of the major trochanter. According to the randomized controlled trial, performed by Lauritzen (7), hip protectors may prevent about 50% of hip fractures in a nursing home population. Disadvantage of the method is the low compliance: less than 25% of the patients is wearing the protector at the moment of the fracture (7,8). Absorbtion of forces acting on the major trochanter could take place as well at the other end of the line: the resilient floor (9). Special attention should be given to people with a limited visual power and those with sedative medication.

B. CLASSIFICATION

Classification of fractures should provide a guide-line for treatment strategies and give insight in the prognosis. Colles (10) diagnosed for the first time an impacted (non-displaced) femoral neck fracture and realised that the pathology of this stable type of fracture differed essentially from the unstable displaced fracture, that was well known since the description by Ambroise Paré. So, Colles was the first who created a classification of femoral neck fractures in what he called "incomplete" and "complete" fractures. This classification makes sense because the treatment and prognosis of these two fracture types are different: the incomplete (nondisplaced or impacted) fracture can be treated either nonoperatively (11) or with internal fixation (12) with good results and a low rate of avascular necrosis. The complete (displaced) fracture needs either internal fixation, complicated by non-union and avascular necrosis, requiring reoperation in up to 47% of the patients (13), or prosthetic replacement.

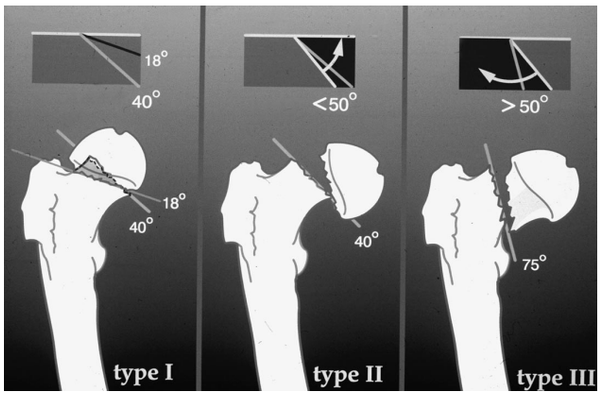

Fig. 1. Pauwels classification

Pauwels (14) extended Colles' classification by dividing the displaced fractures, depending of the inclination of the fracture, in two types (fig. 1), each with their own operative technique and implant. Unfortunately, Pauwels' classification is not helpful for the decision-making for internal fixation or prosthetic replacement. On the preoperative x-ray is the inclination of the fracture line not visible. On the other hand, in the operating theatre the difference between Pauwels type 2 and 3 can easily be made as soon as the fracture has been reduced. Like Pauwels we use that part of his classification in order to make our choice for the right implant (15). Other authors have abandonned the Pauwels classification completely (16, 17).

Garden (18) claimed the existence of a "non-displaced" fracture (Stage 2) that should be distinguished from the impacted fracture (Stage 1). However, he never showed a lateral x-ray in his publications, where the – almost always present – impaction in retroversion would have been visible (19).The idea that, in addition to the Garden stage1 and Pauwels type 1 fractures, the Garden stage 2 fracture should be considered as an impacted femoral neck fracture (IFN) as well, has been supported by several authors (20, 21, 22). Probably, the really non-displaced femoral neck fracture doesn't exist.

The Garden classification is based on the assumption that the more displaced the fracture is, the more harm has been done to the vascularization with a higher rate of avascular necrosis.

This might be true, but a significant difference in avascular necrosis rate between Garden stages 3 and 4 has not been described. Even the famous and frequently quoted paper of Barnes (23) – Garden was co-author of this paper! – shows no significant differences in the chances of healing between de stages 3 and 4. Therefore, the Garden classification does not help the preoperative decision-making more than the simple distinction between non-displaced and displaced fractures.

Finally, the inter-observer variation in classifying femoral neck fractures according to Garden is unacceptable (24, 25). It will be clear that the far more detailed AO-classification is even less reproducible (26) and therefore not useful.

In conclusion, the only useful classification of femoral neck fractures is: non-displaced and displaced fractures (17, 27).

The lateral femoral neck fracture is relatively rare. Moreover, this fracture type shows so much similarity with the trochanteric fractures qua pathology, treatment and prognosis (28), that discussion in the framework of this article does not seem to be appropriate.

The advised classification: distinguish only displaced fractures from non-displaced (impacted) femoral neck fractures. For the choice of implant the Pauwels classification has proved to be useful.

C. IMPACTED FRACTURES

C.1 Pathology

Looking at a cadaver specimen of a typical impacted fracture with the femoral head in valgus and retroversion (fig.2), the resemblance with a greenstick fracture suggests intrinsic stability. Pauwels (14) stated that impaction could only take place in fractures with minimal inclination (≤ 30°) of the fracture line (Pauwels type 1 fracture). However, 50% of all impacted fractures are of the Pauwels types 2 and 3 (29), but as a result of impaction the new fracture line is running more horizontally.

Even if the impaction is not rigid, the almost perpendicular position of the new fracture line to the resultant force, acting on the hip, causes so much more compression than shearing that this fracture can heal in most cases without operative stabilization. Although this phenomenon is well known, we also know from the literature that 10–40% secondary instability (SI) is observed following functional treatment. Many possible causes of this instability have been described: posterior tilting, valgus of more than 20, Pauwels 3 type fracture, pain, early weight-bearing, gap in the anterior cortex and bad physical and/or mental condition. Up to now no specific risk factor was generally accepted. Most surgeons are of the opinion that SI is unpredictable and, if it occurs, will harm their patients. Probably the majority of them will therefore perform some kind of prophylactic internal fixation of all impacted fractures.

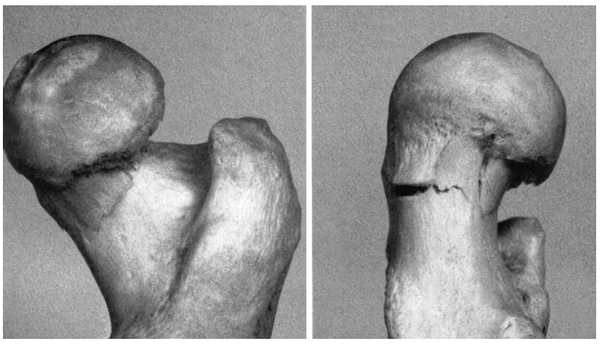

Fig. 2. Cadaver specimen of an impacted femoral neck fracture

C.2 Treatment

Opinions in the literature

Recumbency (20) and *traction* (30) have been practiced in the Netherlands until recently. These methods require a long period of bedrest with a high rate of complications like decubitus, thromboembolic complications and mental deterioration). Because of this as well as for economical and psychological reasons these treatment options cannot longer be advocated. Furthermore, it does not seem too logical to pull at a nicely impacted fracture!

Crawford (31) was the first, who reported good results of *early mobilization*: 8% SI. More recent papers report 20% (22) and 47% (32) SI. This enormous increase of SI in about half a century is not fully understood, but in line with our findings, described below.

Of course, primary *internal fixation* is able to reduce the SI-rate dramatically, but can nevertheless go up to 9% (33). The papers of Cserhati (22) and Conn (12) represent de main recent contribution to the discussion on treatment of the IFN. Both authors are strong supporters of operative treatment of the IFN, although they know that the operation is unnecessary in about half of their patients. Surgeons decide easily to perform an operation, but emotion, pain and other discomfort of an operation are never counted in cost-effectiveness studies, if operative and non-operative treatment are compared.

In the discussion on IFN's the supposed increased risk of avascular necrosis after SI in younger patients continues to be the main controversy. Several authors (23, 34, 35, 36, 37) suggested (without any statistical evidence) that the risk of avascular necrosis was increased by SI, and, therefore, recommended primary internal fixation of all patients, especially those under 60 years of age. Calandruccio and Anderson (38) emphasized that, in IFN's, the main damage is to the vessels in the bone at the level of the fracture, whereas, in displaced fractures, there may also be damage to the retinacular vessels. SI is characteristically a process of slow sliding, which may not cause additional damage to the retinacular vessels. The rate of avascular necrosis is accordingly low.

Fig. 3a–d. Impacted fracture in a 72-years old male. Valgus (a) and retroversion (b); the fracture has healed in the same position after non-operative treatment (c and d)

The author's opinion

is based on a prospective study, we started in 1980 in our institution, treating these fractures non-operatively, after we had observed that IFN's were very stable in the majority of the patients we treated with open reduction and internal fixation.The patients were admitted to the ward and rested in bed with the injured leg in a gutter splint until the pain subsided. By the end of the first week 93% of the patients could be mobilized with the help of crutches or any other support. Partial weight-bearing was preferable in the first eight weeks but if this was not possible, full weight-bearing was accepted. Until January 2000 a consecutive series of 341 IFN's was treated in our hospital. Twenty-two of them were wrongly classified as displaced fractures and primarily treated with internal fixation or arthroplasty. The remaining 319 fractures were included in the study and treated non-operatively. Their mean age was 72 years (13 to 98). We recorded the patients'age, general condition (number of serious concomitant diseases), weight-bearing immediately after the accident and after the fracture had been diagnosed. Weight-bearing was described as "early" if it took place within four weeks of the date of fracture. The amount of valgus of the capital fragment was expressed as the anteroposterior Garden index (fig 3a) and the amount of retroversion or (seldom) anteversion, as the lateral Garden index (fig. 3b). We noted the presence of a gap in the anterior cortex on the axial view (fig. 3b, arrow) and the inclination of the fracture line, expressed as the Pauwels type 1 (0° to 30°), type 2 (30° to 50°) or type 3 (> 50°). All these variables were analysed in a linear stepwise logistic regression analysis to estimate the significance of each of them for the occurrence of SI. The overall mortality at one year was 19%. Of the 311 fractures which were followed up until healing or secondary instability (SI), 216 fractures (69 %) united. Instability occurred mainly in patients over 70 years of age, and in younger patients with a short life expectancy or disabling neurological disease. Only 5 % of the healthy younger patients suffered SI. Stepwise logistic regression analysis indicated that poor general health ($p < 0.0001$) and age over 70 years ($p = 0.0002$) were highly significant risk factors. None of the other variables, such as Garden index, Pauwels type had significant influence on the development of SI (11). A huge difference ($p = < 0.0001$) in SI was found between our patients in the first decade (15% in 1980–1989) and second decade (51% in 1990–1999) of the prospective study. Although the patients were significantly ($p = < 0.001$) older in the second decade (76 years) than in the first decade (69 years), age alone can only partly explain the difference. Nevertheless is Helbig (32) supporting our point of view that we should give the patient with an IFN the benefit of doubt and treat the fracture non-operatively.

Avascular necrosis was observed in 18 (11%) of the 160 fractures, which healed after non-operative treatment and could be followed for at least 2 years after the accident (2–18 years, average follow up 5.2 years). Every change of the shape of the femoral head was considered as such. Functional treatment of all IFN's, except in patients over 70 year of age with multiple co-morbidity, seems therefore to be justified.

After SI, internal fixation was chosen as treatment of patients under 70 years of age, without co-morbidity. All other secondarily unstable IFN's were treated with partial or total hip replacement. Delayed operation after SI caused no increase in mortality, nonunion or avascular necrosis.

The advised treatment for an IFN

All healthy patients – independant of age – can be treated non-operatively with early mobilization. In patients over 70 years of age with more than one co-morbidity the SI-rate can go up to 80 %. A primary operative treatment is advocated.

D. DISPLACED FRACTURES

D.1 Pathology

Two conditions determine the biomechanics of a displaced femoral neck fracture (DFN):

a. The inclination of the fracture line, that produces shearing and/or distracting forces. These forces have to be neutralized, if possible, by bony support, and if not,

Fig. 4a, b. Pauwels 1-2 type fracture (a), Pauwels 3 type fracture (b)

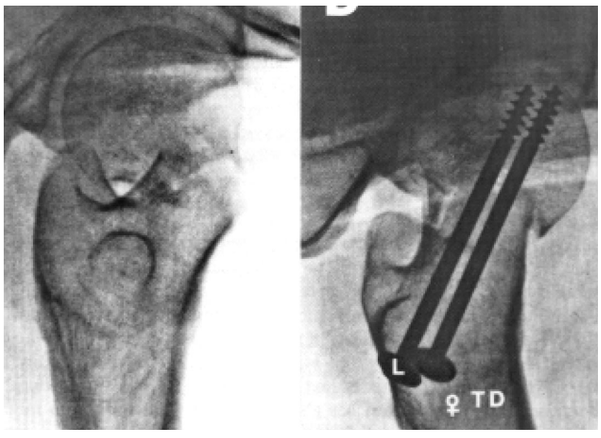

Fig. 5. Axial view of a DFN with considerable retroversion and after overreduction in slight anteversion

by a hefty implant. If the inclination is less than 50°, consequently the fracture line is running subcapitally, that is in cancellous bone (fig. 4a). Slight overreduction of the femoral head in valgus with impaction of the hard cortical bone of the neck into the softer cancellus bone of the head provides a strong bony support and stability of the fracture, which needs only simple and elegant fixation (screws, pins). On the other hand, overreduction in valgus in **vertical** fractures results in loss of contact in the distal half of the fracture and loss of stability (fig.4b). Anatomical reduction is here indicated to assure a full bony contact. The resulting lack of bony support should be compensated by a strong implant like a sliding hip screw.

b. The presence of a fractured posterior cortex of the neck, caused by a forced retroversion of the femoral head at the moment of the fracture. Anatomical reduction would produce a posterior defect and consequently a limited stability. Slight overcorrection in anteversion (fig. 5) and impaction of the neck into the head closes the defect and provides stability.

Avascular necrosis remains the main complication after internal fixation of a DFN. This fracture has a devastating effect on the blood supply to the femoral head. According to Calandruccio (38) 78 % of the femoral heads are partially (46 %) or totally (32 %) avascular after a DFN. Yet, "only" 20–30 % of the internally fixed fractures show signs of avascular necrosis. Probably, the majority of these femoral heads are revascularized in time under protection of a stable fixation (5).

D.2. Treatment

Since 1945 the literature is unanimous regarding the need for operative treatment of DFN's. Non-operative treatment perhaps remains a desirable option for truly non-ambulatory, demented, aged patients (39), who rather stay in their trusted nursing homes with adequate analgetic medication. If these patients are nevertheless are admitted to the hospital, van Dortmont suggests that canulated screw fixation is as successful as arthroplasty and therefore preferable (40).

D.2.1 Internal fixation or prosthetic replacement?

Opinions in the literature

Three meta-analyses (41, 42, 43) pooling the data of 17 prospective randomised studies on IF versus arthroplasty for displaced femoral neck fractures identified a trend towards lower early mortality in IF patients. Duration of the operation, perioperative blood loss and risk of deep wound infection were significantly lower in patients treated with IF. These benefits, however, came at the cost of significantly higher rates of operative revision: 28–36 % for IF and 10–16 % for arthroplasty. The meta-analysis results are of limited use when considering management of individual patients. For meta-analysis purposes all patients were included as being equal, but in daily practice it is unclear which type of patient may benefit from either treatment modality. The drawback of randomized trials is illustrated by the papers of – among others – Rogmark (44) and Parker (45). They conclude from their studies that the failure rate of IF in patients over 70 years of age was so high that these patients were best served with a primary arthroplasty. Such a strategy does not appreciate the significance of the **biological** age. **Calendar** age should not longer determine the fate of the femoral head: to be fixed or removed (5, 46, 47). Larger randomised trials may solve the issues of early mortality and functional outcome by

subgroup analysis of the involved factors (41, 43). In the meantime, there is a need for studies to define which patient groups are better served by the different treatment methods (42). Some crucial factors may be independent of the type of implant and instead depend on individual conditions. Swintkowski (48) proposed pleaded for internal fixation in patients between 65 and 75 years of age "with high finctional demands and good bone density". Bray stated that "the preinjury functional status may play a stronger role Robinson (46) developed an interesting scoring system to quantify the true physiologic status of individual elderly patients. Five individual qualities were quantified: mobility, accommodation, osteoporosis, cognition and medical condition. The developed Physiologic Status Score (PSS) could be a useful guide for selection of the appropriate treatment. Patients with a high PSS received IF and patients with a lower PSS arthroplasty, resulting in very low 2-year revision rates: 5 % for IF and 2 % for arthroplasty. These revision rates were much lower than the meta-analysis results stated above. This selection based on a quantification of individual patient factors appeared to be a promising strategic refinement in decision-making between IF and arthroplasty and possibly beneficial to the cost of hip fracture treatment for society.

The author's opinion

Until the late nineties of the last century the treatment of the DFN in our institution was based on the calendar age. In patients under 70 years of age an internal fixation was performed. The remaining patients got a prosthesis, although fractures in very vital, elderly patients were internally fixed as well. We were impressed by the findings of Robinson (46), who selected his patients for IF or arthroplasty on the basis of a scoring (PSS) of mobility (5 points), accommodation (5), bone density (6), cognitive (5) and medical condition (5). We decided to start a multicentre study in order to verify his promising pre-operative selection protocol.

In 10 participating hospitals 224 patients aged 60–90 years were included. If PSS ≥ 20 points, IF was performed and if PSS < 20, hemiarthroplasty. Bone density was measured preoperatively with gold standard Dual Energy X-ray Absorptiometry (DXA). The sample size was powered to demonstrate an expected 10 % reduction of IF revision (35 % to 25 %) and hemiarthroplasty revision (16 % to 6 %) compared to meta-analysis results. End points were revision, mortality and function. IF (PSS ≥ 20) was performed in 115 and hemiarthroplasty (PSS < 20) in 109 patients. The realized outcome after 2 years was a 40 % revision rate after IF and 3 % after hemiarthroplasty. Two year mortality was 16 % in IF and 50 % in hemiarthroplasty patients. After 2 years, functional outcome was comparable in successful and revised IF patients and both these groups demonstrated higher functional outcome than hemiarthroplasty patients. Technical failures of IF were identified by independent experts in 15 (14 %) patients. In this verification study, application of the PSS did not improve decision-making in a substantial way, which was not in line with the results, reported by Robinson. The PSS protocol did realize a very low risk of HA revision within 2 years in more frail patients when compared to meta-analysis data, but did not realize a decrease of IF revisions in more healthy and ambulatory patients. However, revision of appropriate IF is tolerated by active patients (PSS 20) aged 60–79 years. In the latter group revision (risk of 1 in 4) did not affect mortality or functional outcome after 2 years. Above 80 years, even in patients with a high functional demand, IF cannot be recommended as the revision risk is nearly 1 in 2. Although we are disappointed by the outcome of our study, we strongly believe in the significance of individual factors for the prognosis of an internally fixed DFN (49, 50). A better selection for internal fixation is probably possible by excluding patients over 80 years of age and by further refinement of the PSS. Preparations of a worldwide, randomized multicenter study, involving about 5000 patients are in full swing.

D.2.2 Internal fixation: choice of implant

Opinions in the literature

The literature on this subject is abundant and confusing. Confusing, because many studies compare implants without taking the patient-related factors (general condition, bone quality, fracture type) into account. For instance, papers which do not report separately about the results in impacted and displaced fractures, are worthless. Results in patients under 70 years of age cannot be compared with the outcome in elderly patients. It is therefore not surprising that on one hand contradictory results are reported in the literature and on the other hand Parker (51) on the basis of a meta-analysis (25 randomized trials, concerning 5000 patients) concluded that no difference could me made between the results of screws only and the sliding hip screw. However, in this study the inclination of the fracture line (Pauwels type 2 or 3) was not taken into account.

Cut-out of the Uppsala-screw, the Ullevaal-screw, the screw of the gammanail and the screw of the sliding hip screw was tested in the cadaveric femur. The hold of these four implants in the bone did not differ (52, 53). Rehnberg (53) advocated Uppsala-screw fixation in all DFN's and reports a low failure rate, which unfortunately could not be reproduced by others: 25% nonunion (54). Other authors prefer the use of AO-cancellous screws for all fractures, irrespective the fracture type, because they consider the sliding hip screw a too bulky implant for the femoral head (48, 55, 56). Another reason for these authors to reject the sliding hip screw was the supposed lack of rotational stability. This is a remarkable argument, because they reported only about patients under 65 years of age. Any surgeon who ever tried to drive a sliding hip screw home in a younger patient, knows how much power is needed for this action. It is therefore that the temporary use of an antirotational cancellous screw is so important in order to

avoid turning of the femoral head together with the sliding hip screw. Asnis (57) reported an unlikely low failure rate of 6 % after screw fixation of DFN's in all age groups.

He respects very strictly the 3-point-fixation principle (fig. 6) and converts intraoperatively to arthroplasty if no satisfactory reduction can be achieved. However, the high survival rate of his patients (77 % after a mean follow-up of 8 years!) suggests that his patients did not represent the average population. We all know that in an unselected group of patients over 70 years of age with a hip fracture the survival rate after 5 years is only 40 %!

The sliding hip screw has it's success story as well: 1 % non-union (58). For routine use of the sliding hip screw one has apparently to pay a price: 37% avascular necrosis (59). Some authors use both screws and sliding hip screws dependant on age: below 40 years of age screw fixation is performed, between 40 and 70 years the sliding hip screw is applied (60).

The AO 130° – angled blade plate is a nowadays almost abandoned implant, although Broos (61) still reported about good results in patients up to 50 years of age.

The author's opinion

We have in Amsterdam screws and sliding hip screws in our armamentarium but the indication for the use of one or the other is not age-related. In 1990 we performed a retrospective study of 263 DFN's in patients under 70 years of age, fixed with cancellous screws, 130° – angled blade plate or sliding hip screw after **open** reduction. The main finding of this study was a dramatically high failure rate of screw fixation for vertical fractures (Pauwels 3): 50 %! After adequate reduction the failure rate of screw fixation in Pauwels 2 fractures was 7%. A possible explanation of this enormous difference is described in paragraph D.1.a. (*Pathology*). On the other hand, Pauwels 2 fractures did better with screws than with an angled blade plate. In the early nineties of the last century we changed our treatment strategy: a DFN, which is considered for internal fixation, is reduced on the orthopaedic table with the help of an image intensifier. Than the Pauwels type is established.

For a Pauwels 2 fracture screw fixation is chosen; a Pauwels type 3 fracture is stabilized with a sliding hip screw. With protocol we were able to reduce the nonunion rate to < 10%. There is support in the literature for this treatment strategy on clinical (62) and experimental (63, 64) grounds. One could put the question: why do we not use a mechanically superior implant like de sliding hip screw in all DFN's? Fuglesang (59) described 37% avascular necrosis in his patients after 3 years. Unfortunately he did not distinguish Pauwels 2 and 3 fractures. As long there is uncertainty about what a bulky implant like the sliding hip screw brings about in the relatively small femoral head fragment of the Pauwels 2 fracture, we advise to limit the use of the sliding hip screw to Pauwels 3 fractures.

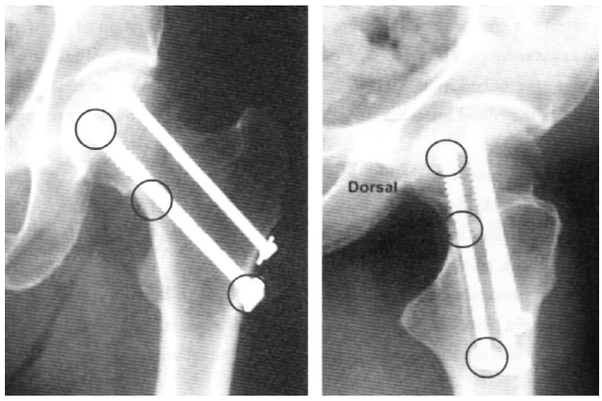

Fig. 6a, b. Technically optimal placement of canulated screws according to the 3-point-fixation principle. ***First*** *point: screw tip within the femoral head.* ***Second*** *point: the shaft of the lower dorsal screw rests on the cortex of the dorsal femoral neck (b, arrow); the shaft of the lower ventral screw rests on the calcar (a, arrow).* ***Third*** *point: the screw head within the lateral femur cortex.*

D 2.3 Significance of bone density

Opinions in the literature

The displaced femoral neck (DFN) fracture is associated with osteoporosis (65), defined as a bone density of more than 2.5 standard deviations below the peak value) is prevalent in 16 %–18 % of women and 3%–6 % of men in the United States. Osteopenia (defined as a bone density between one and 2.5 standard deviations below the normal peak value) is prevalent in 37 %–50 % of women and 28 %–47 % of U.S. men (66). Data from The Netherlands are similar.(67). In vitro studies on cadaveric bone have found a correlation (r = 0.69 – 0.78) between bone density and the intrinsic stability of fracture fixation (52, 68). Two retrospective cohort studies without controls involving 139 and 47 patients, in whom IF was performed with multiple cancellous screws, also reported a relationship between bone density and clinical outcome (69, 70). In 1994 it has been suggested that bone densitometry may aid in the selection of patients for IF (46, 48).

The author's opinion

We hypothesized that active patients over 60 years with normal bone density or osteopenia would require less revisions to arthroplasty after IF of a DFN fracture compared to similar patients with osteoporosis. Therefore the aim of this prospective study was to analyse clinical outcome of IF in osteopenic and osteoporotic patients. As a branch of the already described PSS-trial, a prospective, multi-center study of 111 active patients above 60 years with a DFN fracture eligible for IF was performed (50). Bone density of the femoral neck was measured pre-operatively with gold standard Dual energy X-ray Absorptiometry (DXA). Patients were

divided into 2 groups: osteopenia (66 %, mean T-score –1.6) and osteoporosis (34 %, mean T-score –3.0). Age (p = 0.47), sex (p = 0.67), delay to surgery (p = 0.07), fracture angle (p = 0.33) and type of implant (p = 0.48) were similar in both groups. Revision to arthroplasty was performed in 41% of osteopenic and 42 % of osteoporotic patients (p = 0.87); morbidity (p = 0.60) and mortality were similar in both groups (p = 0.65). Clinical outcome of IF for DFN fractures does not depend on bone density. Pre-operative DXA is not useful. For the same reason we don't think there is an indication for a primary valgisation osteotomy for a fresh DFN in osteoporotic patients, as suggested by Magu (71).

D 2.4 Timing of surgery in hip fractures

Opinions in the literature

As well as causing distress to the patient, delay before surgical treatment of hip fracturepatients is associated with an increase in postoperative complications (72, 73, 74), length of hospital stay (74, 75, 76) and mortality (75, 77). In a large prospective study an association (p = 0.04) between fewer major postoperative complications and operation within 24 hours was found in a subgroup of medically stable patients (78).

Better functional results at three months have been shown when the mean delay to surgery was 29 hours compared to 57 hours (79). Surgery within 24 hours reduces the risk of deep vein thrombosis (80) and of fatal pulmonary embolism (81) after hip fracture.

As to the **local** complications (delayed/non-union, avascular necrosis), caused by delay of operative treatment, the literature is less helpful. Some authors report a deleterious effect on the fracture healing (79, 82, 83). These findings are not confirmed in more recent papers. A connection between delay of treatment and the occurrence of avascular necrosis is supposed by Manninger (84) and Bonnaire (58) and denied by others (23, 85, 86). Parker (87) stated that there is no acute indication for surgery in patients older than 65 years of age in view of avascular necrosis or poor functional outcome.

The author's opinion

To determine the association between delay to surgery and the development of postoperative complications, length of hospital stay (LOS) and 1-year mortality a retrospective study was performed. The medical records of intra – and extracapsular hip fracture patients in 2000 and 2001 admitted to our institution were reviewed. Uni- and multivariate regression analysis was performed to determine an association between the time interval to surgery and morbidity, LOS and 1-year mortality. Of the 192 patients managed operatively for a hip fracture, 39 (20 %) patients developed 50 postoperative complications (23 infections). The mean LOS was 17 days and 1-year mortality was 25 %. There was a trend towards less postoperative complications (p = 0.06, multivariate regression, MR) and shorter LOS (p = 0.09, MR) in patients with a delay of less than 1 day from the time of admission to surgery. No association between surgical delay and 1-year mortality was found (p = 0.632, univariate regression, UR). Age over 80 years (complications: p = 0.001 MR, LOS: p = 0.05 UR, mortality: p = 0.04 MR) and ASA class (complications: p = 0.29 UR, LOS: p = 0.07 UR, mortality: p = 0.03 MR) had stronger associations with the clinical outcomes than the time interval to surgery. In ASA I and II class patients, operation beyond 1 day from the time of injury was associated with more infectious complications (p = 0,02, UR), but low 1-year mortality (p = 0.03, MR). We concluded that no significant association could be found between delay to surgery and the clinical outcomes. However, considering the trends towards less complications and shorter LOS, early surgery (within 1 day from admission) is likely to be beneficial for hip fracture patients who are able to undergo operation (49). Delay to surgery is common, and when it is due to inadequate facilities or poor organisation rather than any medical reason, the underlying problems should be addressed, and solutions identified by the clinicians and hospital management.

D 2.5 Prosthetic replacement

Opinions in the literature

The hemiarthroplasty is still the most frequently used type of replacement surgery in DFN patients, because the majority of them is (very) old and has a limited life expectancy. Once a hemiarthroplasty has been chosen, further controversy surrounds the selection of either a unipolar or a bipolar bearing, a cemented or uncemented stem.

Although even in a recent paper a lance was broken for the **uncemented** stem insertion (88), the results of **cemented** hemi-prosthesis are more favourable when regarding pain relief and functional outcome (89).

In many hospitals the **unipolar** prosthesis has been replaced by the **bipolar** type because patients are more mobile (90) and have less pain and better mobility (91), although radiological studies have suggested that, in many patients, bipolar prostheses move almost entirely on their outer articulation (92, 93). Probably that is the reason why erosion of the acetabulum is observed in bipolar prostheses as well. When reviewing the literature comparing bipolar and unipolar hemiarthroplasties, patient age, mobility and length of follow-up are important considerations because acetabular wear is a time- and activity-dependent phenomenon. In this context, two papers meet these conditions and describe follow-up periods of minimally 7 years (41) and 10 years (94). Lu-Yao (41) observed a 20 % revision rate after a unipolar prosthesis, 10 % after a bipolar prosthesis. Haidukewych (94) did not compare both types of prosthesis but reviewed a series of 212 bipolar prostheses. Only 10 (4.7 %) of the surviving patients underwent revision and only one of them had this operation because of acetabular wear! The most common reason for revision was loosening of the stem, a complication which could occurr in all types of prosthesis.

Historically, **total hip arthroplasty** (THA) has been reserved for patients with a DFN in combination with osteoarthritis of the hip (extremely rare), rheumatoid arthritis or with a pathological fracture. Since the results of THA became substantially better, the indications have been broadened to include active elderly patients with an acute DFN with encouraging outcome without an increase of morbidity or mortality (95, 96). Pain relief is more predictable after THA. However, postoperative dislocations are the main concern. Their rates have averaged approximately 10 % across multiple studies (95, 97, 98), with approximately 25% of those dislocations becoming recurrent and chronic. If we could solve this serious problem, in the opinion of Schmidt (5) there would be an indication to treat everey active elderly patient with a DFN with THA. Hopefully, several prospective randomized trials, comparing THA with hemiarthroplasty, which are running at the moment, will show us the way to the best treatment.

The author's opinion

The surgical technique, chosen for the treatment of a DFN in elderly patients, should allow immediate, full and painless weightbearing. Up to now, only the **cemented** prosthesis meets these conditions. Although it may be so that **bipolar** prostheses move mainly at the outer articulation, the long-term results (41, 94) suggest that this prosthesis should be given preference to the unipolar type. Furthermore, the difference in **price** between both prostheses is negligible because the overall cost of the treatment have gone up so immensely. Finally, a basic advantage of the bipolar system is the relatively small operation, needed for conversion to a total hip replacement (fig.7), because the stem can stay in place.

As to the question **hemiarthroplasty** or **total hip replacement,** the discussion has not yet been closed. We studied the natural history of the cemented bipolar hemiarthroplasty (Weber trunnion-type) by evaluating 307 patients, operated between 1975 and 1989 in our institution.

Only 3 patients, who not have been revised, were alive at the end of the observation period (2004). A striking difference was found in the occurrence of late mechanical complications (aseptic loosening and acetabular wear) between patients under 75 years of age (22 %) and the older group of patients (6 %). As to the patient's overall satisfaction 56 % suffered no impairment from their sustained fracture, 36 % were slightly impaired. We concluded that the use of the cemented bipolar prosthesis is justified in patients over 75 years of age. We hope to confirm this opinion after finishing a prospective randomized trial, comparing hemiarthroplasty and total hip replacement for displaced femoral neck fractures, that was started in 1995.

The advised treatment of a DFN

Patients up to 65 years of age are selected for internal fixation. Patients over 80 years of age can safely be treated with a cemented bipolar hemiarthroplasty.

The biological age (co-morbidity, activity level etc.) of patients between 65 and 80 years of age should be estimated. The PSS-score, designed by Robinson (1994) did work in selecting patients for prosthetic replacement. In our hands this scoring-system was not reliable enough to select the right patients for internal fixation. If internal fixation does not seem the proper treatment or cannot be done properly, total hip replacement is probably the best option in this age group.

If internal fixation is the chosen treatment, closed reduction on the orthopaedic table is performed with help of an image intensifier. The inclination of the fracture line is calculated. In Pauwels 2 fractures two or three parallel screws are inserted after slight overreduction in valgus and anteversion (fig.5). The positioning of the screws respects the 3-point fixation principle (fig.6). In Pauwels 3 fractures an anatomical reduction is accepted. The fracture is stabilized with a sliding hip screw.

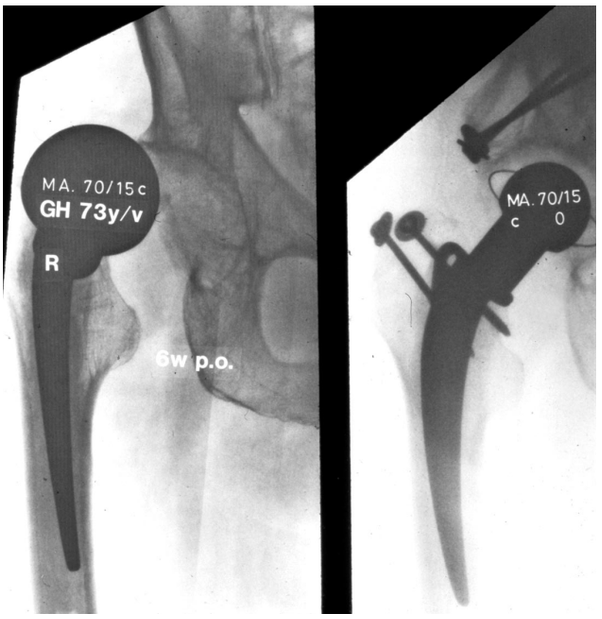

Fig. 7a, b. Three weeks after insertion of a cemented bipolar hemi-prosthesis in a demented patient. Missed dislocation of the prosthesis (a). Closed reduction appeared to be unstable. Intraoperatively a damaged acetabular roof was observed. With the help of an acetabular shelf plasty (autologeous iliac crest) an acetebular prosthesis was inserted. The ball-head of the hemi-prosthesis was replaced by smaller one. The stem could stay in place (b).

E. NONUNION OF THE FEMORAL NECK

Opinions in the literature

Nowadays in cases of nonunions of the femoral neck the surgeon is tempted to perform prosthetic replacement of the hip, the more so if there is also evidence of a disturbed vascularisation of the head. This will provide rapid pain relief and mobilization. However, long-term results of hip arthroplasties, especially in younger people and in presence of bone atrophy, are not always

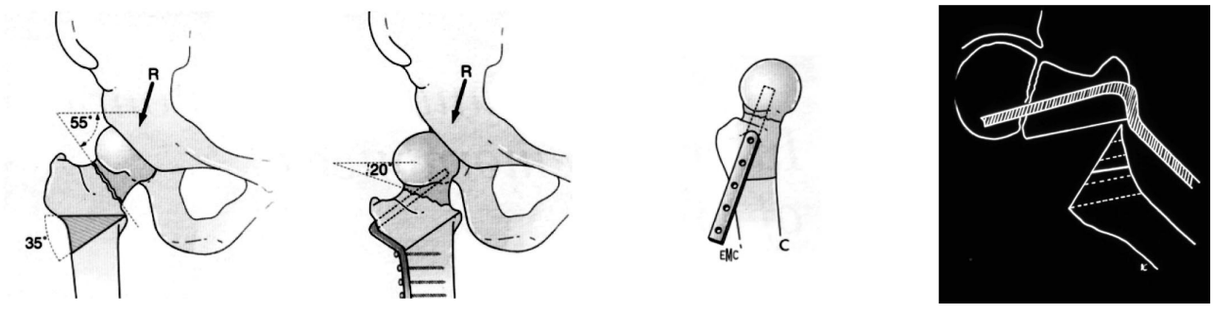

Fig. 8a–d. Preoperative drawing of a valgization osteotomy for femoral neck nonunion.
a: *The inclination of the nonunion is the angle between the perpendicular to the femoral shaft and the fracture line. In this example the angle is 55. The resultant (arrow) of the forces, acting on the hip joint, is a shearing force. In order to transform shearing into compressing forces, the fracture line should be brought in a more horizontal position. Ideally the new inclination angle would be 20. Therefore a lateral wedge of 35 must be taken out.*
b: *Result of the preoperative planning. The inclination of the nonunion is now 20. Mainly compressing forces are acting on the nonunion and will promote healing. The position of plate and screws is included in the drawing.*
c: *Retrotorsion of more than 15 should be corrected and the position of the plate in the lateral view has to be included in the preoperative planning. Correction of these retrotorsion is mandatory in order to obtain an ideal position of the tip of the blade of the plate in the centre of the femoral head, to correct a flexion contracture and avoid impingement.*
d: *Loss of leg length is usual in femoral neck nonunions. If the preoperative planning reveals that removal of a complete lateral wedge fails to restore leg length, a partial lateral wedge can be taken out, leaving enough contact between the cancellous surfaces of the fragments for undisturbed healing of the osteotomy. The removed wedge can be used as a graft on the medial side.*

as expected and a less radical approach is worth considering.

Usually nonunions of the femoral neck are grossly displaced by shortening and rotation. If not, a simple (re)fixation of the initial fracture without complementary osteotomy can be successful (99), as long as the original fracture line corresponds to the Pauwels types 1 and 2. However, in our small group of 6 patients with such a procedure 3 of them developed serious avascular necrosis. Hou (100) reports a small series of neglected fractures with shortening up to 5 cms. He was able to cure these nonunions with a pedicled autologeous bone graft and restore leg length in 4 of his 5 patients. The use of these grafts has been popularized by Meyers (101).The initially reported success has not been reproduced in large series, and the procedure has been considered unreliable (102).

The valgisation osteotomy, designed by Pauwels (14), represents a masterly mechanical concept, with which not only healing of the nonunion and osteotomy can be achieved. Leg length discrepancy, rotational and angular deformity (fig. 8) can be corrected at the same time (103). Osteotomies on subtrochanteric level (104, 105) are less capable to correct the inclination of the fracture line adequately; no more is it possible to restore leg length and secondary THR gets more difficult. Finally, the cancellous bone of the intertrochanteric region offers better healing qualities than the cortical bone at the subtrochanteric level (106).

Reports on HA or THR as the treatment of nonunion are not frequently published. However, these reports are without exception in favour of THR as the treatment for femoral neck nonunion. Mehlhoff (107) described the results of THR for femoral neck and trochanteric nonunion. He observed postoperative dislocations exclusively in de trochanteric group. The results in de femoral neck group were comparable to those of THR for fresh fractures. Johnsson (108) compared HA and THR and focussed on postoperative dislocations. Dislocations were mainly seen after HA ! Franzen (108) reported THR in 84 patients with femoral neck non-union did better than reported results of THR for acute femoral neck fracture. Secondary THR after failed internal fixation had a similar outcome to primary THR, except for a higher incidence of mechanical failure of the prosthesis in older patients. Other reports confirm the 1.5 to 2.5 times higher risk of secondary THR than primary THR for osteoarthritis (99, 110, 111). Therefore, these authors plead for the choice of joint-saving procedures (refixation, valgisation osteotomy) in younger patients, if the local situation permits such a choice (absence of complete collapse) and if the surgical skill is available.

The author's opinion

During the period 1973–1995 in our institution valgisation osteotomy according to Pauwels was performed in 66 patients, 18–72 years old (mean age 49.5 years). There was no hospital mortality. During the observation period 24 (37 %) of our patients died 4 months to 24 years (mean: 9.5 years) after the operation. Early complications were: one postoperative haematoma was debrided. Four times the angled blade plate had to be exchanged because the blade penetrated into the hip joint. Union of the femoral neck was achieved in 58 of the 66 patients (88 %), union of the osteotomy in 65 patients (99 %).

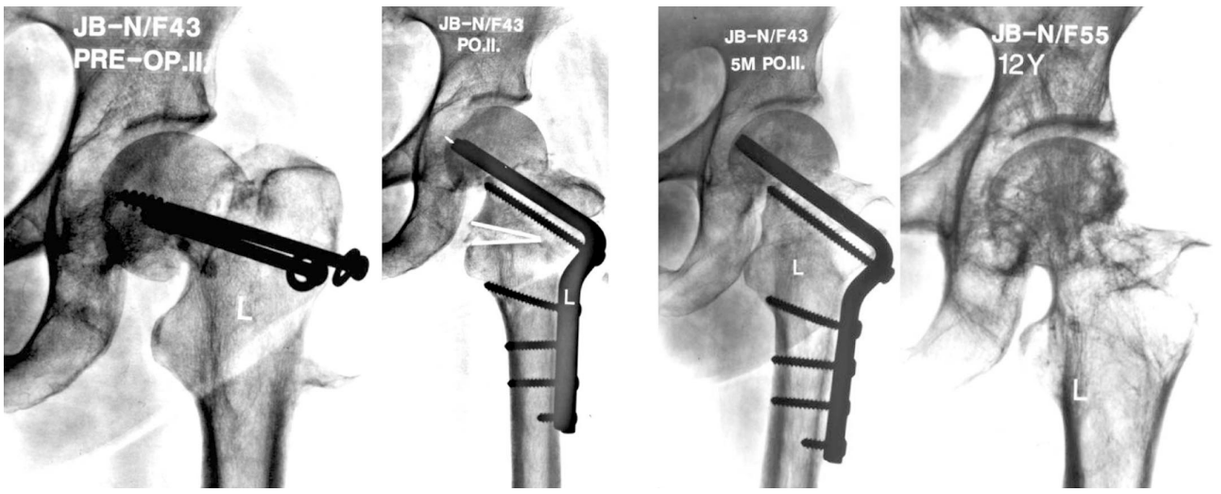

Fig. 9a–d.
***a:** Female, 43 years, femoral neck non-union with very steep fracture line. Gross valgisation is needed.*
***b:** The Y-shaped osteotomy allows a high valgisation degree and the medial displacement leads to direct support of the femoral head by the calcar femoris.*
***c:** Five months postoperative. The aspect of the femoral head is avascular/sclerotic. Note the screw through the plate in the proximal fragment, which improves the hold of the plate in the proximal fragment.*
***d:** At 12 years after valgisation the femoral head shows the irregular pattern, resulting from an intensive revascularization process. However, there is no deformity of the head; the hip joint is congruent. Avascularity of the femoral head is no contra-indication for a joint-saving procedure like the valgisation osteotomy.*

A good or excellent result was achieved in 62% (23 x uneventful + 13 x healed, necrosis/artrosis without need for further treatment) of our patients (fig. 9). The method has it's limits. If there is too little bone stock inside the femoral head, a valgisation osteotomy is prospectless (fig. 10).

Walcher (112) considered radiographic signs of avascular necrosis in patients over 30 years of age as a contra-indication for an osteotomy. Our results show that it is worthwhile trying to save the joint of young patients even in case of a segmental collapse (fig.11). In the competition between revascularization and collapse often revascularization will be the winner. We deliberately give nature it's chance and don't rely on the result of bleeding from drillholes in the head (113), nuclear scans and other methods to measure vascularity.

A total hip replacement is considerably postponed and better conditions for hip replacement can be achieved by the development of sclerotic bone in the subchondral areas of the actabulum and femoral head. The results of the valgisation osteotomy related to age are listed in table 1. It is obvious that patients in their sixties should not be excluded from having a joint saving operation.

It is our strategy to treat fresh femoral neck fractures with a hemiarthroplasty (HA) in patients over the bio-

Table 1. Age-related results in terms of nonunion, avascular necrosis, interval between valgisation osteotomy and total hip replacement (THR), mean follow-up and Harris Hip Score (HHS).

age group (mean age)	nonunion/ necrosis	THR/interval osteot-reop	mean FU/HHS (no reoperation)
< 40 y (28)	0 % / 54 %	23 % / 12 y	11 y / 88
40 – 49 y	25 % / 54 %	15 % / 7 y	9 y / 79
50 – 59 y	4 % / 54 %	44 % / 9 y	11 y / 93
> 60 y (65)	33 % / 25 %	25 % / 2 y	5 y / 89

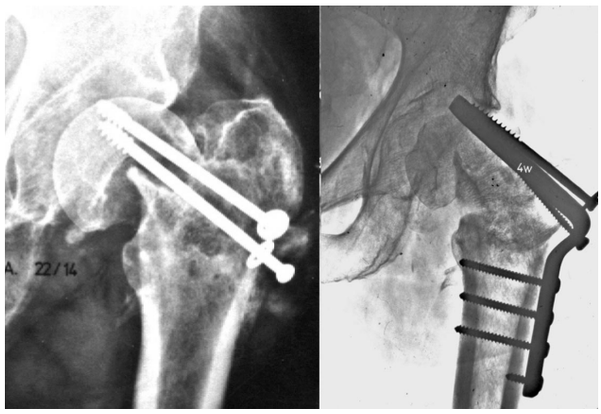

*Fig. 10a, b. Wrong indication for valgisation osteotomy. **a:** Male, 50 years. Seven months after internal fixation. Nonunion. The screw tips have continuously been turning around in the femoral head and have scraped away the cancellous bone. An empty eggshell-like situation resulted, but was not appreciated. **b:** Four weeks after a valgisation osteotomy; implants have not enough hold in this excavated femoral head. Cut-out of the blade and screw. In this case a primary prosthetic replacement would have been a better choice than a valgisation osteotomy.*

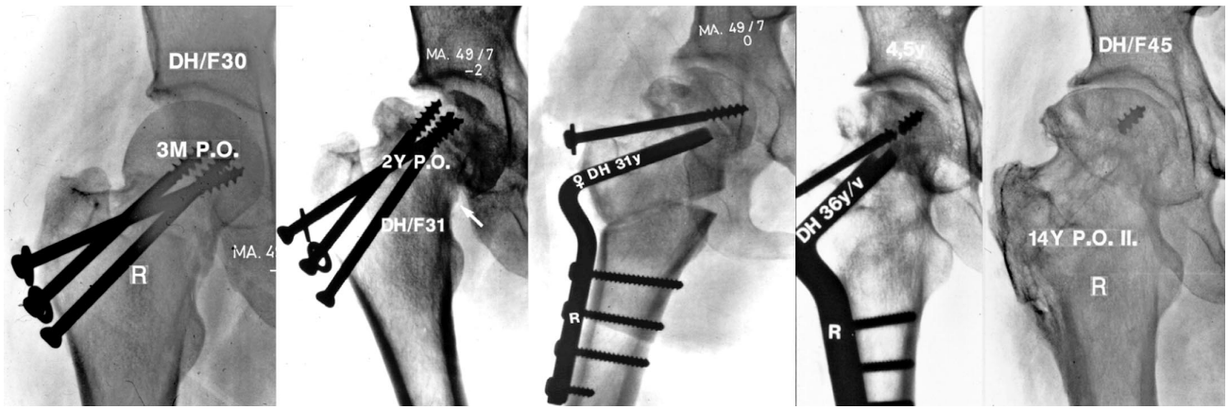

Fig. 11a–e. ***a:*** *Female, 30 years. Three months after screw fixation of a displaced femoral neck fracture. Healed fracture. The patient refused further controls.* ***b:*** *Two years after the primary fracture the patient was readmitted after a fall. She now seems to have a pathological fracture in the necrotic femoral head rather than a nonunion of the former fracture.* ***c:*** *Postoperative x-ray: open reduction of the fracture was performed. The fracture was stabilized only by a screw. Valgisation osteotomy. The blade of the plate did not cross the fracture line in order to avoid additional violation of the already deformed femoral head fragment.* ***d:*** *Healed osteotomy and fracture, 4.5 years postoperative.* ***e:*** *Fourteen years after the osteotomy. There is little trochanter pain, the patient walks one hour without any support. There is no limp, a satisfying ROM and a HHS of 81.*

logical age of 80 years. Logically the same choice will be made for patients with a non-union. During the period 1973–1995 we performed 34 times a HA in the least vital group of patients. Their mean age was 79 years. The average survival in these patients was less than 3 years and that explains probably the low late complication rate: one aseptic loosening and one deep infection with chronic fistula.

Total hip replacement (THR) was performed in 37 younger patients with a mean age of 69 years. They were not considered for a valgisation osteotomy because of age over 70 years, severe osteoporosis or a total collapse of the femoral head. In this group we observed 1 aseptic cup revision and 2 extractions of the prosthesis because of a deep infection.

The advised treatment

Patients up to 65 years of age with a non-union of the femoral neck are candidates for a valgisation osteotomy. Between 65 and 80 years a total hip replacement is probably the best option for fit patients. For elderly patients a cemented bipolar hemiarthroplasty is an adequate treatment.

References

1. MELTON, L. J.: Hip fractures: a worldwide problem today and tomorrow. Bone, 14:S1-8, 1993.
2. HOOGENDOORN, D.: Enkele gegevens over 64.453 fracturen van het proximale uiteinde van het femur (collum plus trochantergebied), 1967–1979. Ned. Tijdschr. Gen., 126: 963–968, 1982.
3. SUZUKI, S., TABATA, M., MURAI, K., OKAZAKI, H., GOTO, T.: Pre- and postoperative complications of elderly patients with femoral neck fractures-a report of 525 cases. Masui, 48:528–533, 1999.
4. BORQVIST, L., LINDELÖW, G., THORNGREN, K-G.: Costs of hip fracture: Rehabilitation of 180 patients in primary health care. Acta orthop. scand., 62:39–48, 1991.
5. SCHMIDT, A. H., ASNIS, S. E., HAIDUKEWYCH, G. J., KOVAL, K. J., THORNGREN, K.-G.: Femoral neck fractures. AAOS Instructional Course Lectures, 54:417–445, 2005.
6. PAPAPOULOS, S. E., QUAND, S. A., LIBERMAN, U. A., HOCHBERG, M. C., THOMPSON, D. E.: Meta-analysis of the efficacy of alendronate for the prevention of hip fractures in postmenopausal women. Osteoporos Int. 15:2-8, 2004.
7. LAURITZEN, J. B., PETERSEN, M. M., LUND, B.: Effect of external hip protectors on hip fractures. Lancet, 341:11–13, 1993.
8. SCHOOR, N. M. V., SMIT, J. H., TWISK, J. W. R., BOUTER, L. M., LIPS, P.: Prevention of hip fractures by external hip protectors: a randomized controlled trial. JAMA, 289:1957–1962, 2003.
9. CASALEA, J. A., BADRE-ALAM, A., OVAERT, T. C., CAVANAGH, P. R., STREIT, D. A.: The Penn State Safety Floor: part II, Reduction of fall-related peak impact forces on the femur. J. Biomech. Eng., 120:527–532, 1998.
10. COLLES, A.: Fracture of the neck of the femur. Dublin Hospital Reports, 2:334–355, 1818.
11. RAAYMAKERS, E. L.: The non-operative treatment of impacted femoral neck fractures. Injury, 33 (suppl 3): C8-14, 2002.
12. CONN, K. S., PARKER, M. J.: Undisplaced intracapsular hip fractures. Results of internal fixation in 375 patients. Clin. Orthop. 421:249–254, 2004.
13. BLOMFELDT, R., TÖRNQVIST, H., PONZER, S., SÖDERQVIST, TIDERMARK. J. Comparison of internal fixation with total hip replacement for displaced femoral neck fractures. J. Bone Jt Surg., 87-A:1680–1688, 2005.

14. PAUWELS, F.: Der Schenkelhalsbruch. Ein mechanisches Problem. Beilageheft. Z. Orthop. Chir., 63:1–138, 1935.
15. Raaymakers ELFB, Schafroth M. Die mediale Schenkelhalsfraktur. Kontroversen in der Behandlung. Unfallchirurg, 105:178–186, 2002.
16. PARKER, M. J., DYNAN, Y.: Is Pauwels classification still valid? Injury, 29:521–523, 1999.
17. THORNGREN, K. G., HOMMEL, A., NORRMAN, P. O., THORNGREN, J., WINGSTRAND, H.: Epidemiology of femoral neck fractures. Injury, 33 (suppl 3): C1-7, 2002.
18. GARDEN, R. S.: Low-angle fixation in fractures of the femoral neck. J. Bone Jt Surg., 43-B:647–663, 1961.
19. RAAYMAKERS, E. L. F. B., MARTI, R. K.: Non-operative treatment of impacted femoral neck fractures. J. Bone Jt Surg., 73-B: 950–954, 1991.
20. EKLUND, J., ERIKSSON, F.: Fractures of the femoral neck: with special regard to the treatment of stable abduction fractures. Acta chir. scand., 127: 315–337, 1964.
21. RZESACZ, E. H., WEINBERG, A.-M., REILMANN, H.: Gedeckte Osteosynthese durch kanülierte Schrauben bei medialen Schenkelhalsfrakturen Typ Garden I und II. Unfallchirurg, 98:478–482, 1995.
22. CSERHÁTI, P., KAZÁR, G., MANNINGER, J., FEKETE, K., FRENYÓ, S.: Non-operative treatment for undisplaced femoral neck fractures: a comparative study of 122 non-operative and 125 operatively treated cases. Injury, 27: 583–588, 1996.
23. BARNES, R., GARDSEN, R. S., et al.: Subcapital fractures of the femur. J. Bone Jt Surg., 58-B: 2–24, 1976.
24. FRANDSEN, P. A., ANDERSEN, E., MADSEN, F., SKJODT, T.: Garden's classification of femoral neck fractures. J. Bone Jt Surg., 70-B: 588–590, 1988.
25. ZLOWODZKI, M., BHANDARI, M., KEEL, M., HANSON, B., SCHEMITSCH, E.: Perception of Garden's classification for femoral neck fractures: an international survey of 298 orthopaedic trauma surgeons. Arch. orthop. trauma Surg., 2005; aug 2 (Epub ahead of print).
26. BLUNDELL, C. M., PARKER, M. J., PRYOR, G. A., HOPKINSON-WOOLLEY, J., BHONSLE, S. S.: Assessment of the AO classification of intracapsular fractures of the proximal femur. J. Bone Jt Surg., 80-B: 697–683, 1998.
27. PARKER, M. J.: Garden grading of intracapsular fractures: meaningful or misleading? Injury, 24: 241–242, 1993.
28. PARKER, M. J., PRYOR, G. A., THORNGREN, K.-G.: In Handbook of Hip Fracture Surgery. Oxford, Butterworth Heinemann, 1997.
29. RAAYMAKERS, E. L. F. B.: Functional treatment of impacted femoral neck fractures. Thesis. University of Amsterdam 1988.
30. WALDENSTRÖM, J.: Fractures récentes du col fémoral. J. Chir., 2:129–162, 1924.
31. CRAWFORD, H. B.: Conservative treatment of impacted fractures of the femoral neck. J. Bone Jt Surg., 42-A: 471–479, 1960.
32. HELBIG, L., WERNER, M., SCHNEIDER, S., SIMANK, H. G.: Die mediale Schenkelhalsfraktur Typ 1 nach Garden : konservative vs. operative Therapie. Ergebnisse einer retrospektiven Studie. Orthopäde, 34: 1040–1045, 2005.
33. HIGGINS, G. A., SADIQ, S., WASEEM, M., HIRS, P., PAUL, A. S.: Success of cannulated screw fixation of subcapital neck of the femur fractures. Hip International, 14: 244–248, 2004.
34. DAHL E.: Treatment of impacted fractures of the femoral neck. T. norske Laegeforen, 11: 98–101, 1978.
35. BENTLEY, G.: Impacted fractures of the neck of the femur. Clin. Orthop., 152: 93–99, 1980.
36. JEANNERET, B., JAKOB, R. P.: Konservative versus operative Therapie der Abduktions- Schenkelhalsfrakturen. Resultate einer klinischen Nachkontrolle. Unfallchirurg, 88: 270–273, 1985.
37. PHILIPS, J. E., CHRISTIE, J.: Undisplaced fracture of the neck of the femur: results of treatment of 100 patients treated by single Watson-Jones nail fixation. Injury, 19:93–96, 1988.
38. CALANDRUCCIO, R. A., ANDERSON, W. E.: Post-fracture avascular necrosis of the femoral head: correlation of experimental and clinical studies. Clin. Orthop. 152: 49–84, 1980.
39. LYON, L. J., NEVINE, M. A.: Management of hip fractures in nursing home patients:to treat or not to treat? J. Amer. Geriatr. Soc., 32:391–394, 1984.
40. Van DORTMONT, L. M., DOUW, C. M., Van BREUKELEN, A. M., LAURENS, D. R., MULDER, P. G., WERELDSMA, J. C., Van VUGT, A. B.: Cannulated screwsversus hemiarthroplasty for displaced intracapsular femoral neck fractures demented patients. Ann. Chir. Gynaecol., 89:132–137, 2000.
41. Lu Yao G. L., KELLER, R. B., LITTENBERG B., WENNBERG J. E.: Outcomes after displaced fractures of the femoral neck. A meta-analysis of 106 published reports. J. Bone Jt Surg., 76-A:15–25, 1994.
42. MASSON, M., PARKER, M. J., FLEISCHER, S.: Internal fixation versus arthroplasty for intracapsular proximal femoral fractures in adults (Cochrane Review). In: The Cochrane Library, Issue 4. Chichester, John Wiley & sons Ltd. 2003.
43. BHANDARI, M., DEVEREAUX, P. J., SWIONTKOWSKI, M. F., TORNETTA, P., OBREMSKY, W., KOVAL, K. J., NORK, S., SPRAGUE, S., SCHEMITSCH EH, GUYATT, G. H.: Internal fixation compared with arthroplasty for displaced fractures of the femoral neck – a meta-analysis. J. Bone Jt Surg., 85-A: 1673–1681, 2003.
44. ROGMARK, C., CARLSSON, A., JOHNELL, O., SERNBO, I.: A prospective randomied trial of internal fixation versus arthroplasty for displaced fractures of the neck of the femur. J. Bone Jt Surg., 84-B: 183–187, 2002.
45. PARKER, M. J., KHAN, R. J., CRAWFORD, J., PRYOR, G. A.: Hemiarthroplasty versus internal fixation for displaced intracapsular fractures in the elderly. J. Bone Jt Surg., 84-B:1150–1155, 2002.
46. ROBINSON, C. M., SARAN, D., ANNAN, I. H.: Intracapsular hip fractures. Results of management adopting a treatment protocol. Clin. Orthop., 302: 83–91, 1994.
47. BRAY, T. J.: Femoral neck fracture fixation. Clinical decision making. Clin. Orthop, 339:20–31, 1997.
48. SWIONTKOWSKI, M. F.: Current concepts review. Intracapsular fractures of the hip. J. Bone Jt Surg, 76-A:129–138, 1994.
49. HEETVELD, M. J.: Displaced femoral neck fractures. Towards better practice. Thesis University of Amsterdam, 2005.
50. HEETVELD, M. J., RAAYMAKERS, E. L., VECK-SMIT, B. L., VWALSUM, A. D., LUITSE JS. Internal fixation for displaced femoral neck fractures: does bone density affect clinical outcome? A prospective, multicenter study of 111 active, elderly patients. J. Bone Jt Surg., 87-B: 367–373, 2005.
51. PARKER, M. J., BLUNDELL, C.: Choice of implant for internal fixation of femoral neck fractures. Acta orthop. scand., 69: 138–143, 1998.
52. JENNY, J.-Y., RAPP E, CORDEY, J.: Type of screw does not influence holding power in the femoral head. Acta orthop. scand., 70:435–438, 1999.
53. REHNBERG, L., OLERUD, C.: Fixation of femoral neck fractures. Comparison of the Uppsala and von Bahr screws. Acta orthop. scand., 60:759–784, 1989.
54. LAGERBY, M., ASPLUND, S., RINGQVIST, I.: Cannulated screws for fixation of femoral neck fractures. Acta orthop. scand., 69: 387–391, 1998.
55. DAVID, A., RICHTER, J. et al.: Mediale Schenkelhalsfraktur-Kopferhaltende Therapiekonzept. Zbl. Chir., 120841-9, 1995.
56. BRAUN, W., RÜTER, A., WIEDEMANN, M., KISSING, F.: Kopferhaltende Therapie bei medialen Schenkelhalsfrakturen. Unfallchirurg, 94:325–230, 1991.
57. ASNIS, S., WANEK-SGAGLIONI, L., Intracapsular fractures of the femoral neck. Results of cannulated screw fixation. J. Bone Jt Surg., 76-A:1793–1803, 1994.
58. BONNAIRE, F., KUNER, E. H., LORZ, W.: Schenkelhalsfrakturen beim Erwachsenen: gelenkerhaltende Operationen. Die Bedeutung des Operationszeitpunkts und des Implantats für die Genese der aseptischen Hüftkopfnekrose. Unfallchirurg, 98:259–264, 1995.
59. FUGLESANG, P. N., EDNA, T. H., HATLINGHUS, S., SVINSÅS, M., BJERKESET, T.: Femoral neck fractures treated with the hip compression screw. A follow-up study of 311 cases. Acta orthop. scand., suppl. 247:6, 1992.

60. RENZ, N., BILAT, C., BEREITER, H., RÜDI TH, LEUTENEGGER, A.: Dynamische Hüftschraube (DHS) bei Schenkelhalsfrakturen. Helv. Chir. Acta, 59:543–546, 1992.
61. BROOS, P., VERCRUYSSE, R., DRIESEN, R., STAPPAERTS, K. H.: De 130°-hoekplaat, de oplossing voor de "unsolved fractures" bij jonge volwassenen? Ned. Tijdschr. Traum. 6:29–34, 1998.
62. HERTZ, H., POIGENFÜRST, J.: Der Einfluss der primären Reposition auf die Kopfnekrose nach Schenkelhalsbruch. Unfallchirurg, 8:41–47, 1982.
63. HAMMER, A. J.: Nonunion of subcapital femoral neck fractures. Orthop. Trauma, 6:73–77, 1992.
64. BAITNER, A. C., MAURER, S. G., HICKEY, D. G., JAZRAWI, L. M., KUMMER, F. J., JAMAL, J., GOLDMAN, S., KOVAL, K.: Vertical shear fractures of the femoral neck. A biomechanical study. Clin. Orthop., 367:300–305, 1999.
65. GARDNER, M. J., FLIK, K. R., MOOAR, P. K., LANE, J. M.: Improvement in the undertreatment of osteoporosis following hip fracture. J Bone Jt Surg., 84-A:1342–1348, 2002.
66. LOOKER, A. C., JOHNSON, C. C. Jr., WAHNER, H. W., DUNN, W. L., CALVO, M. S., HARRIS, T. B., HEYSE, S. P., LINDSAY, R. L.: Prevalence of low femoral bone density in older U.S. women from NHANES III. J. Bone Miner. Res., 10:796–802, 1995.
67. Kwaliteitsinstituut voor de Gezondheidszorg CBO. Osteoporose: tweede herziene richtlijn. Alphen a/d Rijn: Van Zuiden Communications BV, 2002.
68. STROMSOE, K., KOK, W. L., HOISETH, A., ALHO, A.: Holding power of the 4.5 mm AO/ASIF cortex screw in cortical bone in relation to bone mineral. Injury, 24:656–659, 1993.
69. WEINROBE, M., STANKEWICH, C. J., MUELLER, B., TENCER, A. F.: Predicting the mechanical outcome of femoral neck fractures fixed with cancellous bone screws: an in vivo study. J. Orthop. Trauma, 12:27–36, 1998.
70. SPANGLER, L., CUMMINGS, P., TENCER, A. F., MUELLER, B. A., MOCK, C.: Biomechanical factors and failure of transcervical repair. Injury, 32:223–228, 2001.
71. MAGU, N. K., SINGH, R., MITTAL, R., GARG, R., WOKLU, A., SHARMA, A. K. Osteosynthesis and primary valgus intertrochanteric osteotomy in displaced intracapsular fracture neck of femur with osteoporosis in adults. Injury, 36:110–122, 2005.
72. ZUCKERMAN, J. D., SKOVRIN, M. L., KOVAL, K. J.: Postoperative complications and mortality associated with operative delay in older patients who have a fracture of the hip. J. Bone Jt Surg., 77-A: 1551–1556, 1995.
73. GRIMES, J. P., GREGORY, P. M., NOVECK, H.: The effects of time-to-surgery on mortality and morbidity in patients following hip fracture. Amer. J. Med., 112: 702–709, 2002.
74. DOROTKA, R., SCHOECHTNER, H., BUCHINGER, W.: The influence of immediate surgical treatment of proximal femoral fractures on mortality and quality of life operation within six hours of the fracture versus later than six hours. J. Bone Jt Surg., 85-B:1107–1113, 2003.
75. ROGERS, F. B., SHACKFORD, S. R., KELLER, M. S.: Early fixation reduces morbidity and mortality in elderly patients with hip fractures from low-impact falls. J. Trauma, 39:261–265, 1995.
76. KITAMURA, S., HASEGAWI, Y., SUZUKI, S.: Functional outcome after hip fracture in Japan. Clin. Orthop., 348:29–36, 1998.
77. CASALETTO, J. A., GATT, R.: Post-operative mortality related to waiting time for hip fracture surgery. Injury, 35:114–120, 2004.
78. OROSZ, G. M., MAGAZINER, J., HANNAN, E. L.: Association of timing of surgery for hip fracture and patient outcomes. JAMA, 291:1738–1743, 2004.
79. VILLAR, R. N., ALLEN, S. M., BARNES, S. J.: Hip fractures in healthy patients: operative delay versus prognosis. Brit. Med. J. (Clin. Res. Ed.), 293:1203–1204, 1986.
80. HEFLEY, F. G. J. R., NELSON, C. L., PUSKARICH-MAY, C. L.: Effect of delayed admission to the hospital on the preoperative prevalence of deep-vein-thrombosis, associated with fractures about the hip. J. Bone Jt Surg., 78-A: 581–583, 1996.
81. PEREZ, J. V., WARWICK, D. J., CASE, C. P., BANNISTER, G. C.: Death after proximal femoral fracture – an autopsy study. Injury, 26:237–240, 1995.
82. BROWN, T. T., ABRAMI, G.: Transcervical femoral fracture: review of 195 patients, treated by sliding nail-plate. J. Bone Jt Surg., 46-A:648–655, 1964.
83. DAVIS, F. M., WOOLNER, T., FRAMPTON, C., et al.: Prospective multi-centre trial of mortality, following general or spinal anaesthesia for hip fracture surgery in the elderly. Brit. J. Anaesthesia, 59: 1080–1088, 1987.
84. MANNINGER, J., KAZAR, C., FEKETE, C. et al.: Significance of urgent (within 6h) internal fixation in the management of fractures of the neck of the femur. Injury, 20:101–105, 1989.
85. HOLMBERG, S., KALÉN, R., THORNGREN, K-G.: Treatment and outcome of femoral neck fractures. Clin. Orthop., 218: 42–52, 1986.
86. TONETTI, J., COUTURIER, P., REMY, A., NICOLAS, L., MERLOZ, P., FRANCO, A.: Proximal femoral fractures in patients over 75 years. Vital and functional prognosis of a cohort of 78 patients followed during 2.5 years. Rev. Chir. Orthop. Rep. Appar. Mot., 83:636–644, 1997.
87. PARKER, M. J., STOCKTON, G.: Internal fixation implants for intracapsular proximal femoral fractures in adults. Cochrane Database Syst. Rev., 2003, issue 2.
88. BEZWADA, H. P., SHAH, A. R., HARDING, S. H., BAKER, J., JOHANSON, N. A., MONT, M. A. Cementless bipolar hemiarthroplasty for displaced femoral neck fractures in the elderly. J. Arthroplasty, 19; suppl 2:73–77, 2004.
89. PARKER, M. J., RAJAN, D.: Arthroplasties (with and without bone cement) for proximal femoral fractures in adults (Cochrane review). In The Cochrane Library, Issue 4, 2003. Chichester, UK; John Wiley & Sons, Ltd. 2003.
90. CORNELL, C. N., LEVINE, D., O'DOHERTY, J., LYDEN, J.: Unipolar versus bipolar hemiarthroplasty for the treatment of femoral neck fractures in the elderly. Clin. Orthop., 348:67–71, 1998.
91. KENZORA, J., MAGAZINER, J., HUDSON, J., HEBEL, J. R., YOUNG Y, HAWKES, W., FELSENTHAL, G., ZIMMERERMAN, S. I., PROVENZANO, G.: Outcome after hemiarthroplasty for femoral neck fractures Clin. Orthop., 348:51–58, 1998.
92. CHEN, S. C., SARKAR, S., PELL, L. H.: A radiological study of the movements of the two components of the Monk prosthesis (hard-top "duo-pleet") in patients. Injury, 12:243–249, 1981.
93. EISKJAER, S., GELINECK, J., SOBALLE, K.: Fractures of the femoral neck treated with cemented bipolar hemiarthroplasty. Orthopaedics, 12:1545–1550, 1989.
94. HAIDUKEWYCH, G. J., ISRAEL, T. A., BERRY, D. J.: Long-term survivorship of cemented bipolar hemiarthroplastyfor fracture of the femoral neck. Clin. Orthop., 403:118–126, 2002.
95. Lee, B. P., BERRY, D. J., HARMSEN, W. S., SIM, F. H.: Total hip arthroplasty for the treatment of an acute fracture of the femoral neck: long-term results. J. Bone Jt Surg., 80-A: 70–75, 1998.
96. KEATING, J. F., MASSON, M., SCOTT, N., FORBES, J, GRANT, A.: Randomized trial of reduction and fixation versus bipolar hemiarthroplasty versus total hip arthroplasty for displaced subcapital fractures in the fit older patient. 70th Annual Meeting Proceedings. Rosemont, IL, American Academy of Orthopaedic Surgeons 2003, 582–583.
97. DORR, L. F., GLOUSNMAN, R., SEW, A. L., VANIS, R., CHANDLER, R.: Treatment of femoral neck fractures with total hip replacement versus cemented and uncemented hemiarthroplasty. J. Arthroplasty, 1:21–28, 1986.
98. GEBHARD, J. S., AMSTUTZ, H. C., ZINAR, D. M., DOREY, F. J.: A comparison of total hip arthroplasty and hemiarthroplasty for treatment of acute fracture of the femoral neck. Clin. Orthop., 282: 123–131, 1992.
99. MATHEWS, V., CABANELA, M. E.: Femoral neck nonunion treatment. Clin. Orthop., 419:57–64, 2004.
100. HOU, S. M., HANG, Y. S., LIU, T. K.: Ununited femoral neck fractures by open reduction and vascularized iliac bone graft. Clin. Orthop., 294:176–180, 1993.

101. MEYERS, M. H.: The role of posterior bone grafts (muscle pedicle) in femoral neck fracture. Clin. Orthop., 152: 143–146, 1980.
102. ANGLEN, J. O.: Intertrochanteric osteotomy for failed internal fixation of femoral neck fracture. Clin. Orthop. 341: 175–182, 1997.
103. WEBER, B. G., ČECH, O.: Pseudarthrosen. Bern, Verlag Hans Huber 1973.
104. HUANG, C. H.: Treatment of neglected femoral neck fractures in young adults. Clin. Orthop., 206: 117–126, 1986.
105. ZINGHI, G. F., SPECCHIA, L., RUGGIERI, N., GALLI. G. The role of osteotomy in the treatment of pseudarthrosis of the neck of the femur in younger patients. Ital. J. Orthop. Traum., 11:341–348, 1985.
106. BALLMER, F. T., BALLMER, P. M., BAUMGARTEL, F., GANZ, R., MAST, J. W.: Pauwels osteotomy for nonunions of the femoral neck. Orthop. Clin. N. Amer., 21:759–767, 1990.
107. MEHLHOFF, T. H., LANDON, G. C., TULLOS, H. S.: Total hip arthroplasty following failed fixation of hip fractures. Clin. Orthop., 269: 32–37, 1991,
108. JOHNSSON, R., BENDJELLOUL, H., EKELUND, L., PERSSON, B. M., LIDGREN, L.: Comparison between hemiarthroplasty and total hip replacement following failure of nailed femoral neck fractures, focused on dislocations. Arch. Orthop. Traum. Surg., 102: 187–190, 1984.
109. FRANZEN, H., NILSSON, L. T., STRÖMQVIST, B., TORNGREN, K-H.: Secondary total hip replacement after fracture of the femoral neck. J. Bone Jt Surg., 72-B:784–787, 1990.
110. SKEIDE, B. I., LIE, S. A., HAVELIN, L. I., ENGESAETER, L. B.: Total hip arthroplasty after femoral neck fractures: Results from the national registry on joint prostheses. T. norske Laegeforen, 116: 1449–1451, 1996.
111. JACKSON, M., LEARMONTH, I. D.: The treatment of nonunion after intracapsular fracture of the proximal femur. Clin. Orthop., 399: 119–128, 2002.
112. WALCHER, K., WIESINGER, H.: Aufrichtungsosteotomie nach Pauwels oder Alloplastik bei der Schenkelhalspseudarthrose? Aktuel Traumatol., 13: 34–41, 1983.
113. GILL, T. J., SLEDGE, J. B., EKKERNKAMP, A., GANZ, R.: Intraoperative assessment of femoral head vascularity after femoral neck fracture. J. Orthop. Traum., 12:474–478, 1998.

Ernst Raaymakers, MD. PhD.,
Assoc. Prof./Leitender Arzt Traumat.
Surgical Clinic, Section Traumatology,
Academisch Medisch Centrum
Meibergdreef 9,
1105 AZ Amsterdam
Netherlands