Chapter 4

HISTORICAL RETROSPECTION

4.1 History of the treatment of hip fractures

4.1.1 The beginnings

The first proper description of proximal femur fractures was done by **Ambroise Paré** in the 16th century. Up to this time they were thought to be dislocations (cited by Cordasco, 1938).

During the ensuing centuries many unsuccessful treatment attempts have been described. **Cooper** (1822) distinguished between extracapsular fractures having a favorable prognosis and intracapsular fractures that failed to consolidate; he attributed this failure to the poor blood supply to the femoral head. This perception prevailed during the entire century although already in 1858 **von Langenbeck** (cited by Böhler, 1996), later **Senn** (1889), and then **Nicolaysen** (1897) and **Delbet** (1919) attempted an open reduction and internal fixation with nails, screws and fibular strut grafts. **Senn** undertook investigations in animals. He was one of the few surgeons who insisted that intracapsular fractures would heal when properly reduced and stabilized. Inadequate asepsis, absent or unsatisfactory biocompatibility and insufficient mechanical stability of the implants associated with these procedures precluded a successful outcome. No wonder, therefore, that **Kocher** (1896) recommended resection of the femoral head.

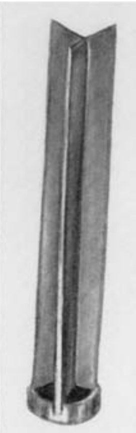
A consolidation of the fracture was achieved in some patients for the first time by **Whitman** (1925) who reduced the fracture and then placed the patient in a spica cast, a cast that included trunk, pelvis and lower limb. At the same time successful results were achieved in some instances of extracapsular fractures by **Codevilla** (1904) and later **Steinmann** (1919) who employed skeletal traction by means of a transosseous pin inserted either through the distal femur or proximal tibia. On account of the prolonged immobilization for six months, be it in the cast or in bed, most patients succumbed to an intercurrent complication. In 1936, **Hohenegg** summarized the situation as follows: "The hip fracture is an injury affecting elderly persons and is often the beginning of the end. The demise of most patients is due to pneumonia, urinary sepsis or decubitus. To avoid this bitter end, physicians should do their utmost to get patients out of the bed" (cited by Ehalt, 1967).

4.1.2 The development of internal fixation

Axhausen (cited by Manninger et al, 1960) was the first to submit a counterevidence to the assertion of Cooper. During an autopsy he could document that a fracture with a totally necrotic head consolidated. Subsequently attempts were undertaken to improve the process of consolidation. **Smith-Petersen** in 1925 undertook the first major step in this direction with his three-flanged nail (Smith-Petersen et al, 1931; Smith-Petersen, 1937). The nail was inserted after an arthrotomy. A more exact placement of the nail became possible thanks to **Johansson** (1932); he used a nail with a central bore and a guide wire that obviated an arthrotomy. The procedure gained fast acceptance in Europe and permitted surgery even in elderly persons. At the same time **Jerusalem** (cited by Manninger et al, 1960) designed a similar nail; the bore for the guide wire was placed at the base between two flanges. **Felsenreich** (1938) and **Böhler** (1996) improved the stability of fixation by broadening the flanges and by adding a small spike at the nail's neck to decrease the risk of backing out (Fig. 106).

The introduction of the **Jeschke** mesh helped to improve the placement and the control of position of the guide wire (Böhler, 1996). This technique necessitated serial radiographs and thus lengthened markedly the operating time.

Already in 1940 **Bauer** (1941) ameliorated the stability of internal fixation of non-unions by adding a second nail. The high rate of early and late complications induced several authors to look for means to enhance the design of implants and the surgical



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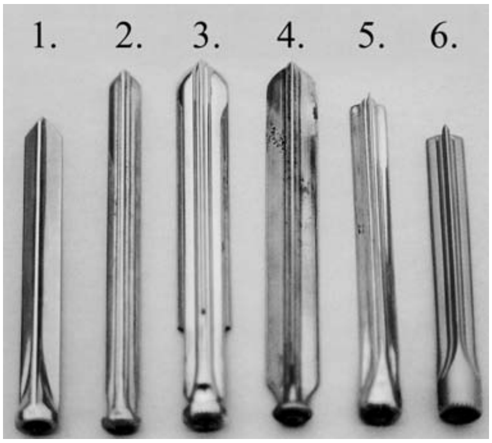

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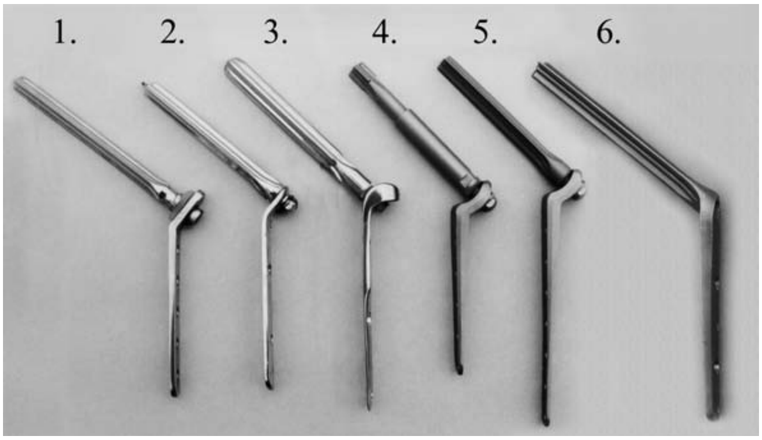
Fig. 106. Three-flanged nails.
a. Photograph of the first flanged nail taken from the publication of Smith-Petersen (1931). Nail and head were manufactured separately and then welded together. The junction gave rise to corrosion; **b.** The subsequent nails were made in one piece: (1) non-cannulated nail similar to the Smith-Petersen nail; (2) small, cannulated nail designed by Johansson in 1932; (3) broad flanged nail of L. Böhler with spikes that were supposed to prevent backing-out; (4) Felsenreich nail with broad flanges; (5) Aesculap® SP-nail with inner threads at the end; (6) Thornton nail made from vitallium



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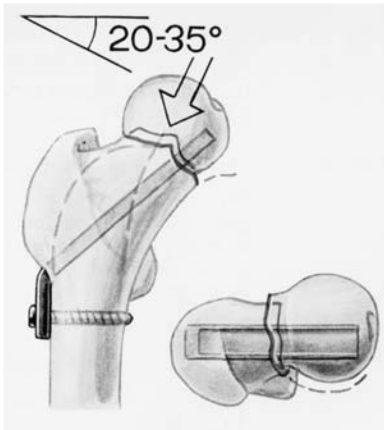

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Fig. 107. Various plate-nail systems.
a. Combined plate-nail systems: (1) Szilágyi nail made in Hungary in 1960; (2) Aesculap® nail with plate; (3) nail made in the former German Democratic Republic; (4) Pugh telescoping nail made from Vitallium allowing a settling; (5) McLaughlin nail with side plate made either from Titanium or Vitallium; (6) Jewett nail-plate; **b.** AO 130° blade-plate (Müller et al, 1977)

technique. The well-known book by **Pauwels** (1935) contributed to a better understanding of biomechanical conditions. **Böhler** (1996) was the first to describe the migrating non-union. **Freund** (1930), **Trueta and Harrison** (1953), **Judet and collaborators** (1955), **Trueta** (1957), **Sevitt** (1964), **Catto** (1965a, 1965b), **Judet and colleagues** (1981) contributed to the study and elucidation of the pathology of fractures, the investigation of the blood supply and the refinement of diagnosis. **Brittain** (1942) as well as **Küntscher** (1953) and **Maatz** (1950) advocated the vertical position of the nail.

Thornton (cit. Bonnaire, 1998) was the first to add a plate to the caudal end of the nail. Using the same principle **McLaughlin** (1947), **Massie** (1958) and **Böhler** (1996) designed side plates attached to the nail. **Jewitt** (1941) developed his nail-plate and the researchers of the **AO/ASIF** group their blade plate (Müller et al, 1977); all these designs increased considerably the stability of the implants. Further modifications were made; they improved the treatment of trochanteric fractures considerably (Fig. 107). These devices did not prove worthwhile in the treatment of neck fractures. Due to the

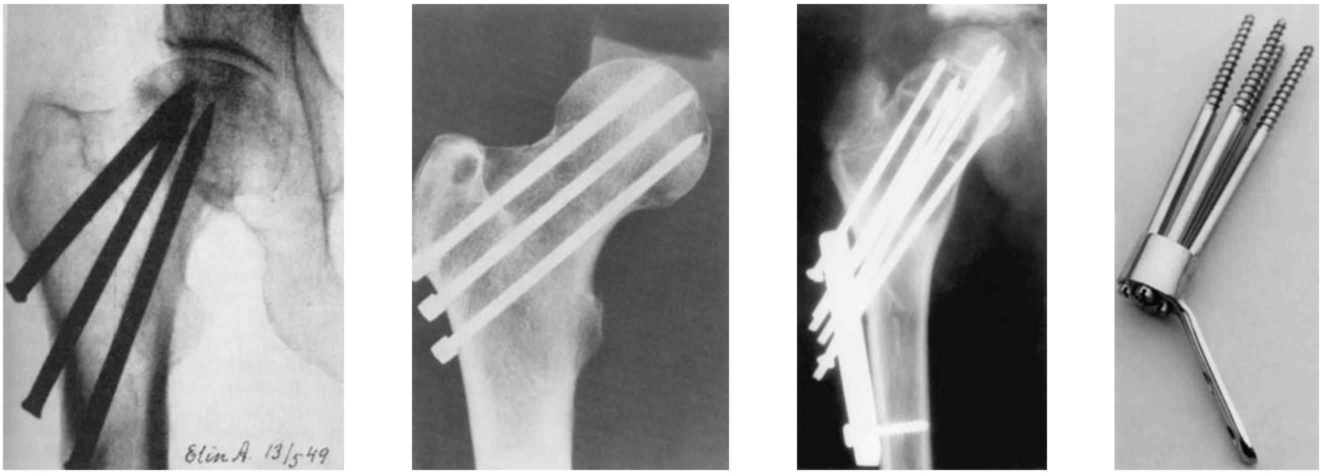

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Fig. 108. Examples of the use of multiple implants.
a. Nyström's nails; **b.** Knowles pins; **c.** Deyerle method using several 3 mm wires with thread on their tip and a strong angle-stable plate; it was used repeatedly in our institute; d. Internal fixation according to Forgon with four neck screws and an angle-stable lateral buttressing plate that allowed backing out

impaction/resorption (settling) at the fracture site and thus the shortening of the neck the nail often perforated the femoral head particularly in elderly patients. In younger patients this caused a distraction as the nail had found a solid purchase in the strong subchondral bone. This led to a non-union and then to a fatigue fracture of the nail (see Fig. 118).

To counter this problem **Pugh** (1955) designed a telescoping nail with a fixed angle side plate that permitted to compensate for impaction/resorption (settling) of the fracture (Fig. 107a). **Putti** (1942) was the first to introduce screw fixation instead of rigid nailing. In 1951, **Pohl** invented a telescoping screw (Laschenschraube) that allowed to compensate for a settling of the fracture. This sliding hip screw, later refined in U.S.A. (Schumpelick and Jantzen, 1955), permitted an auto-compression of a neck fracture. Thanks to a small compression screw the fragments were impacted (Richards compression screw). The **AO** flattened the caudal end of the screw and squared the hole in the side plate to prevent any rotation of the femoral head. This lead to the design of the **Dynamic Hip Screw (DHS)**.

The disadvantage of these methods was that a single implant did not protect sufficiently against a rotational displacement and thus did not stabilize adequately the femoral head. For this reason several authors recommended a combination of two, three or more nails, screws or pins (**Nyström**, 1959; **Knowles**, 1936). **Deyerle** (1980) introduced many thin screws through a thick plate. **Forgon** (1975) achieved dynamic internal fixation with four screws and an angulated side plate. Thus he could early on prove that a combination of several implants, settling of the fracture and lateral fixation are equally important (Fig. 108).

Other improved the purchase of the implant in the head: **Rydell** (1964) added to his four-flanged nail a spring, **Hansson** (1982) used different hook pins (Fig. 109).

The methods of internal fixation underwent internationally an enormous development.

4.1.3 The history of joint replacement

The high incidence of complications after internal fixation led already in the first half of the 20th century to ideas to replace the fractured femoral head (**Hey-Groves**, 1930). **Moore and Bohlmann** (1943) were the first to replace the proximal femur with a stainless steel prosthesis for a malignant giant cell tumor in Baltimore 1940. The **Judet**

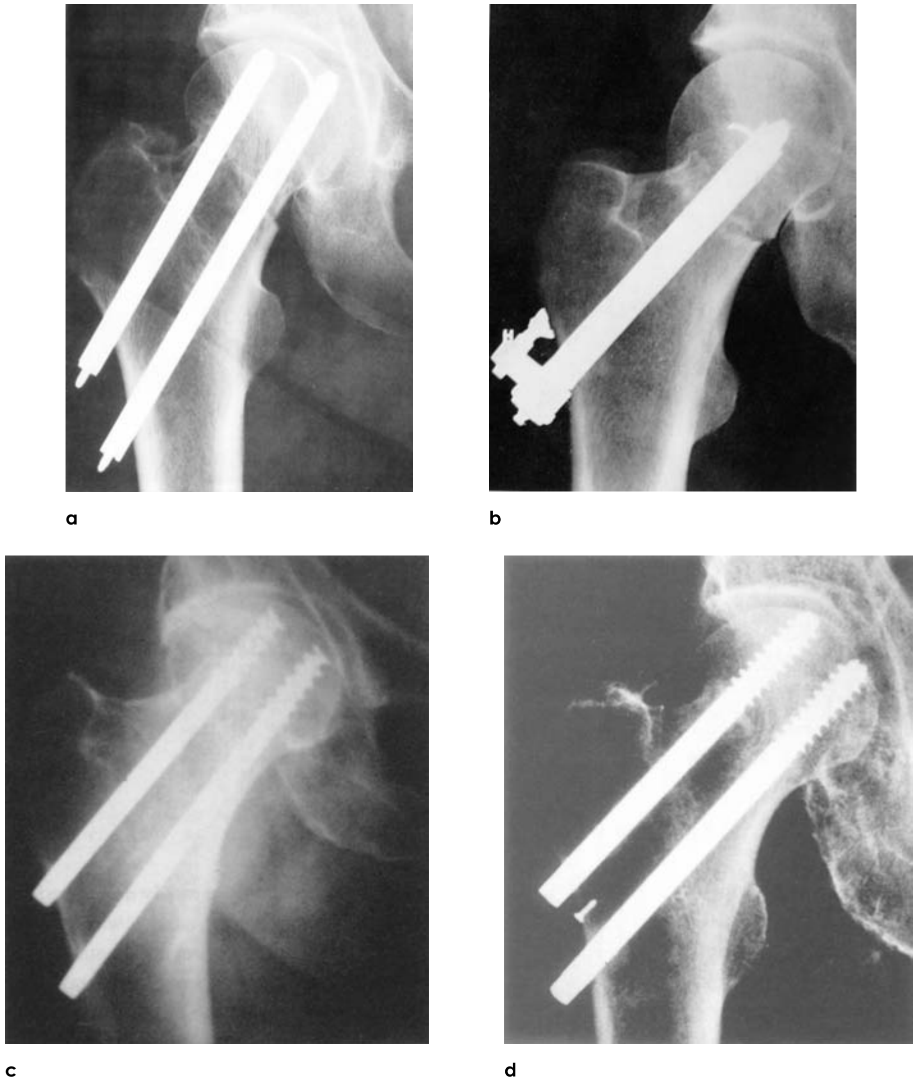

Fig. 109. Different designs of implants to improve purchase in the femoral head.
a. Double hook pin according to Hansson; **b.** Four-flanged nail with spring according to Rydell; **c.** Non-cannulated cancellous bone screws according to von Bahr; **d.** Cannulated cancellous bone screws designed by Rehnberg (1977)

brothers (1950) published a series of 300 patients that since 1947 had undergone a femoral head replacement with a short stemmed head component. **Thompson** (1954) and **Moore** (1957) implanted a head component with a longer stem for the first time in 1950. The development of a total joint replacement as an alternative for internal fixation started with **McKee and Watson-Farrar** (1966), **Charnley** (1961; 1970b) and **Müller** (1963; 1970). To improve the fixation of the components **Charnley** (1960; 1970b) was the first to use bone cement.

In countries where fresh fractures in elderly patients were treated with primary replacement, the hemiarthroplasty was the method of choice. This procedure similar to internal fixation went through major steps in the development with the goal to reduce complications (dislocation, protrusion); for example, the double cup components (Duokopf®) known for their minimal friction.

4.1.4 Beginnings of operative treatment of femoral neck fractures in Hungary

In Hungary, thanks to the influence of Lorenz Böhler who had learned the method in U.S.A. and was the first to execute it in Europe, the three-flanged nail was used to treat femoral neck fractures (**Monspart, Neuber, Dániel,** cited by Manninger et al, 1960).

Following the inauguration of the first Hungarian accident hospital (Magdalena Hospital) in 1940 the surgeons in charge – **Dániel, Elischer** and from 1945 up **Hedri** – performed hip nailing as a routine procedure. Even before the foundation of the National Institute of Traumatology in the same building (1956) we created a study group to investigate femoral neck fractures (1953). During the scientific sessions of the Hungarian surgeons in 1954 we presented for the first time an analysis of results reaching back to 1940. In 1960 we published an exhaustive study (Manninger et al, 1960) in several parts listing our experience in more than 1000 patients that had been treated in our institute between 1940 and 1955. In this study we emphasized the widening range of surgical indications, the importance of early surgery, the increasing age of patients and the improvement of results. However, at the same time we drew attention to two serious complications.

Loss of reduction was noted in one fifth of our patients that without revision surgery usually led to a nonunion. Avascular necroses of variable extent were the most frequent complication that occurred in one third of healed fractures, an observation also confirmed by other authors. This led to a search for means of achieving increased stability of internal fixation and to look for ways to preserve the vitality of the head. We hoped to prognosticate the occurrence of femoral head necrosis in order to arrive at a scientifically based decision to opt either for an internal fixation or a joint replacement. Among the known methods to investigate the circulation in the femoral head we chose the intraosseous venography as the optimal procedure, not lastly on account of our limited financial means. Already in the mid-sixties results were at our disposal justifying an international trauma congress in Hungary. Many participants from abroad presented their experiences at the symposium organized by us. With our study we were able to contribute to the elucidation of current problems of femoral neck fractures (Ehalt 1968).

4.2 The stages of development of internal fixation for femoral neck fractures at the National Institute of Traumatology (Budapest)

4.2.1 Nailing of femoral neck fractures

From the opening of the Trauma Hospital (1940) (belonging to the largest insurance company in Hungary and which preceded our institute) to the end of the fifties all displaced neck fractures were treated with the **Smith-Petersen** (1931) and the **Johansson** (1932) nails (Manninger et al, 1960).

This surgery was always considered a major intervention. Only the most experienced surgeons with two assistants were allowed to execute this procedure. The first assistant stood beside the surgeon; the second assistant stood opposite on a stool and bent over the Sajgo traction table and over the patient while holding the retractors. At least three radiographic examinations were done in two planes with two sphere-shaped mobile units (for the control of reduction, for the position of the guide wire and of the nail). Taking the radiographs including the development of the films (three pairs of pictures) took half an hour in spite of the fact that the dark room was beside the operating room. Not infrequently the films had to be repeated once or twice during a given phase. This led to an average of four to five pairs of films bringing the operating time to 1 1/2 to 2 hours.

Younger colleagues were only allowed after two years of assistance to nail a fracture. Meticulous reduction on the traction table preceded the suturing of a Jeschke wire mesh to the skin. If the radiographs in two planes revealed a correct reduction, the center of the femoral head was determined with the help of the mesh and the entry point of the nail into the lateral cortex determined as well. With two percutaneous needles the entry point and the center of the head were marked (Fig. 110). Under local anesthesia a transmuscular approach was done. At the lateral cortex, at the site of the needle, a small hole was chiseled. With a telescopic drill bit according to Kirschner a guide wire was driven in the direction determined by the two needles. Very often this maneuver had to be repeated until the guide wire was properly positioned in both planes.

The hole in the lateral cortex was enlarged with a chisel to accommodate the three-flanged nail. This nail was then driven over the guide wire (Fig. 111). Starting in 1949 we placed the nail steeper as recommended by Dániel (see Fig. 110). If the nail position was correct, the fracture was impacted with a special impactor before wound closure.

After a period of studies at the hospital of Lorenz Böhler in Vienna in 1957 we changed to the Böhler nail with broader flanges ensuring a greater stability. We used this nail for a long time and could observe a decrease in the incidence of loss of reduction (Fig. 112). At the same time we introduced a modified retromuscular approach as performed by Jörg Böhler, which diminished the blood loss.

With the event of the rapid x-ray developer the operating time decreased. We also experienced a shortage of films (shortly after 1956); they were replaced by photographic paper for economic reasons. This entailed a higher exposure to radiation and poorer picture quality. Films were only available for the final documentation.

Besides the experiences gained with Lorenz and Jörg Böhler (Vienna and Linz) the introduction of the **Müller image intensifier** and of the **Maquet operating table** in 1958 and 1959 (Szabó et al, 1964) constituted a real step forward. Initially these devices met considerable opposition as they did not posses a monitor and only occasionally could the images be seen when looking into the beam thanks to the prismatic objective (fluoroscopy). However, the marked decrease in operating time was convincing. With the introduction of the C-arm and a digital memory, image intensification was universally accepted.

Since the sixties anesthesia also has made a remarkable progress; most patients are now operated under a general or epidural anesthesia.

A three-month-use of crutches was obligatory, a requirement that caused great difficulties for elderly patients. After three months radiographs were taken and depending on the outcome a gradual weight bearing was permitted. To prevent backing out of the nail, often followed by loss of reduction, a Sherman screw was placed beneath the nail head. A backing out of the nail not infrequently caused a bending of the implant or the nail slid beside the screw (Fig. 113, see also Fig. 30b) (Manninger et al, 1961).

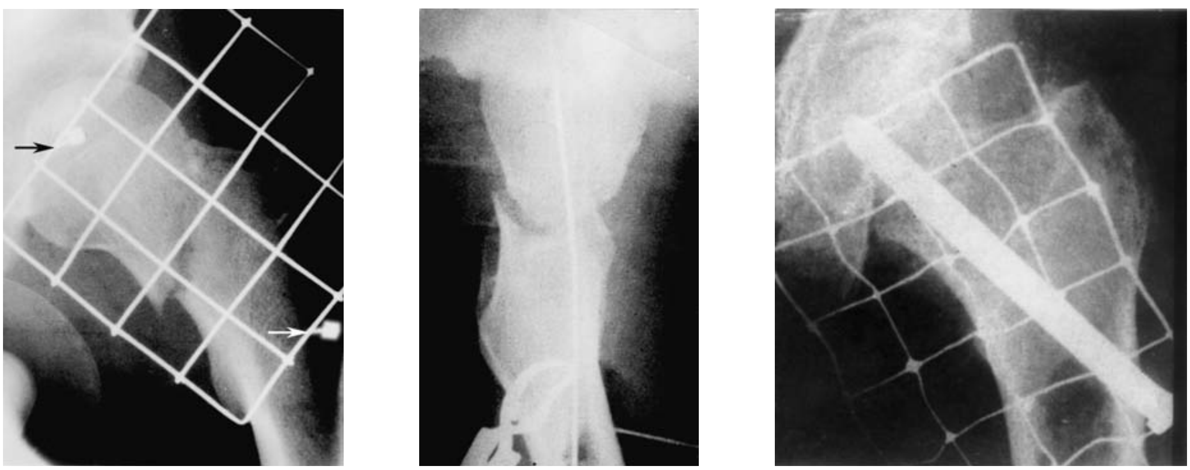

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Fig. 110. Radiographs of a femoral neck nailing taken from our archive.
a, b. After reduction the entry point of the nail is marked with the help of a Jeschke mesh and two needles (arrows); **c.** Steep angled nailing according to Dániel

Fig. 111. Consolidated fracture after Smith-Petersen nailing.
16 years postoperatively a normal femoral head contour is seen

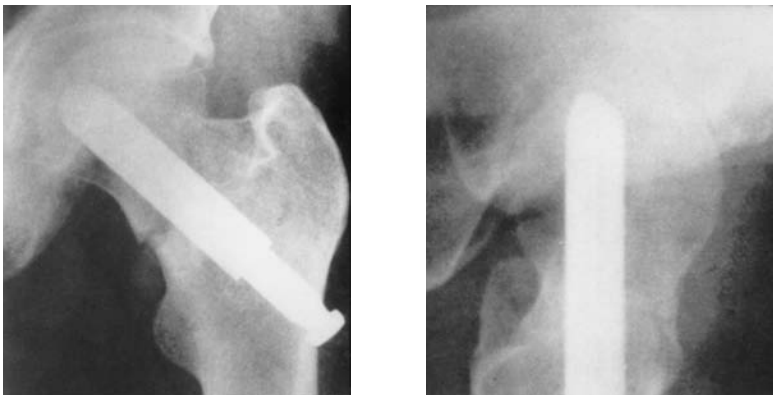

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Fig. 112. Nailing of a displaced neck fracture according to Böhler.
a. A.-p. film showing the correct position of a Böhler flanged nail placed close to the Adam's arch; **b.** lateral radiograph showing a central position of the implant

Fig. 113. Buttressing of a Smith-Petersen nail with a Sherman screw.
During backing out of the nail the screw did bent

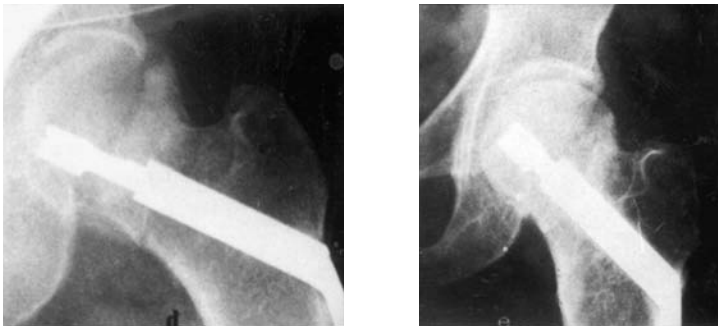

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Fig. 114. Treatment of a neck fracture with a Pugh telescoping nail.
a. A.-p. film after internal fixation, normal neck length. The fracture line is still visible caudally;
b. A.-p. film one year postoperatively, the fracture has healed with shortening of the neck by 1 cm due to settling of the fracture

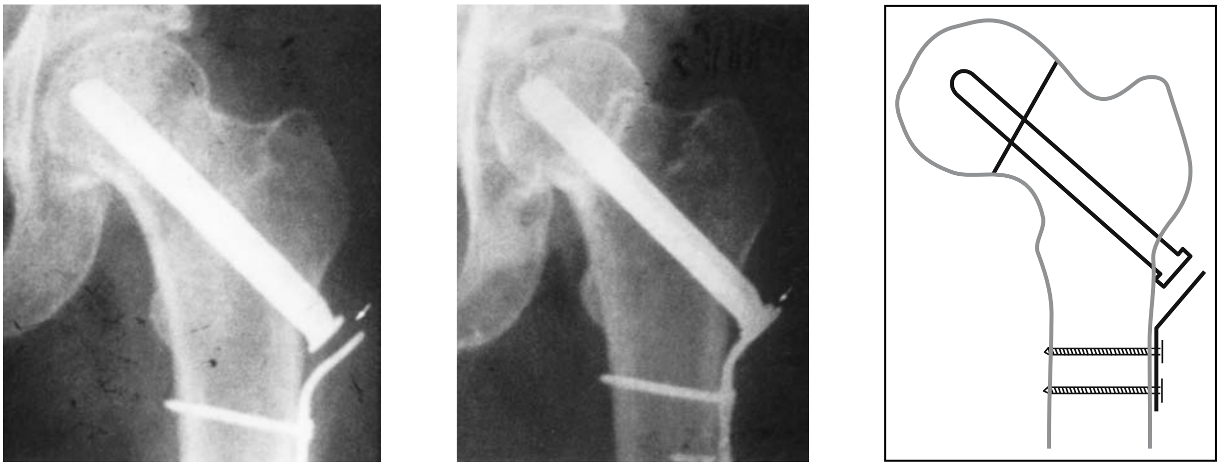

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Fig. 115. "Distant" buttressing plate.
a. Early postoperative a.-p. film showing a correct position of the implant; (the arrow points to the gap between end of nail and plate);
b. A.-p. after fracture healing. The neck has shortened at the fracture site by 5 mm, the position of the nail in the femoral head remained unchanged (the arrow points to a contact between the nail end and the plate); **c.** This schematic drawing was taken from a publication of our technique in a German monograph (Nigst, 1964) with the caption "Manninger's method to allow a limited backing out of the nail"

To solve the problem of backing out dynamic nails and screws were introduced. These implants were not freely available to us on account of their high costs (Fig. 114).

In 1959, we replaced the Sherman screw by a small buttressing plate ("distant" buttressing side plate, according to Manninger) at a slight distance from the nail head (Manninger et al, 1961). The principle of this method was the result of our experiences and observations made during the follow-up study of 1057 patients operated between 1940 and 1955. We discovered that the majority of fractures treated by only one Smith-Petersen nail had consolidated after a backing out of the nail by 3 to 8 mm without any positional change of the implant in the femoral head.

We concluded that for an uneventful consolidation of a neck fracture the buttressing of the nail must be done in a way that preserved the stability in spite of the impaction/resorption (settling) of the fragments by 3 to 8 mm (Fig. 115). According to our experiences settling occurred already during the first postoperative days. If the nail is attached directly to the buttressing side plate, a diastasis of

Fig. 116. Buttressing side plates.
Right: the former buttressing plate (Aesculap®). Left: the plate later designed by us giving a better protection **against** backing out thanks to its socket

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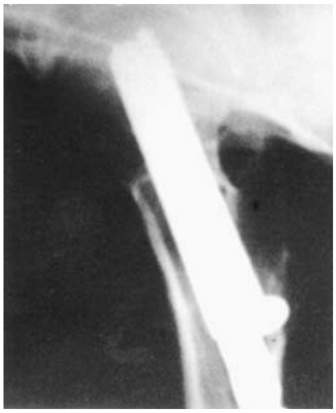

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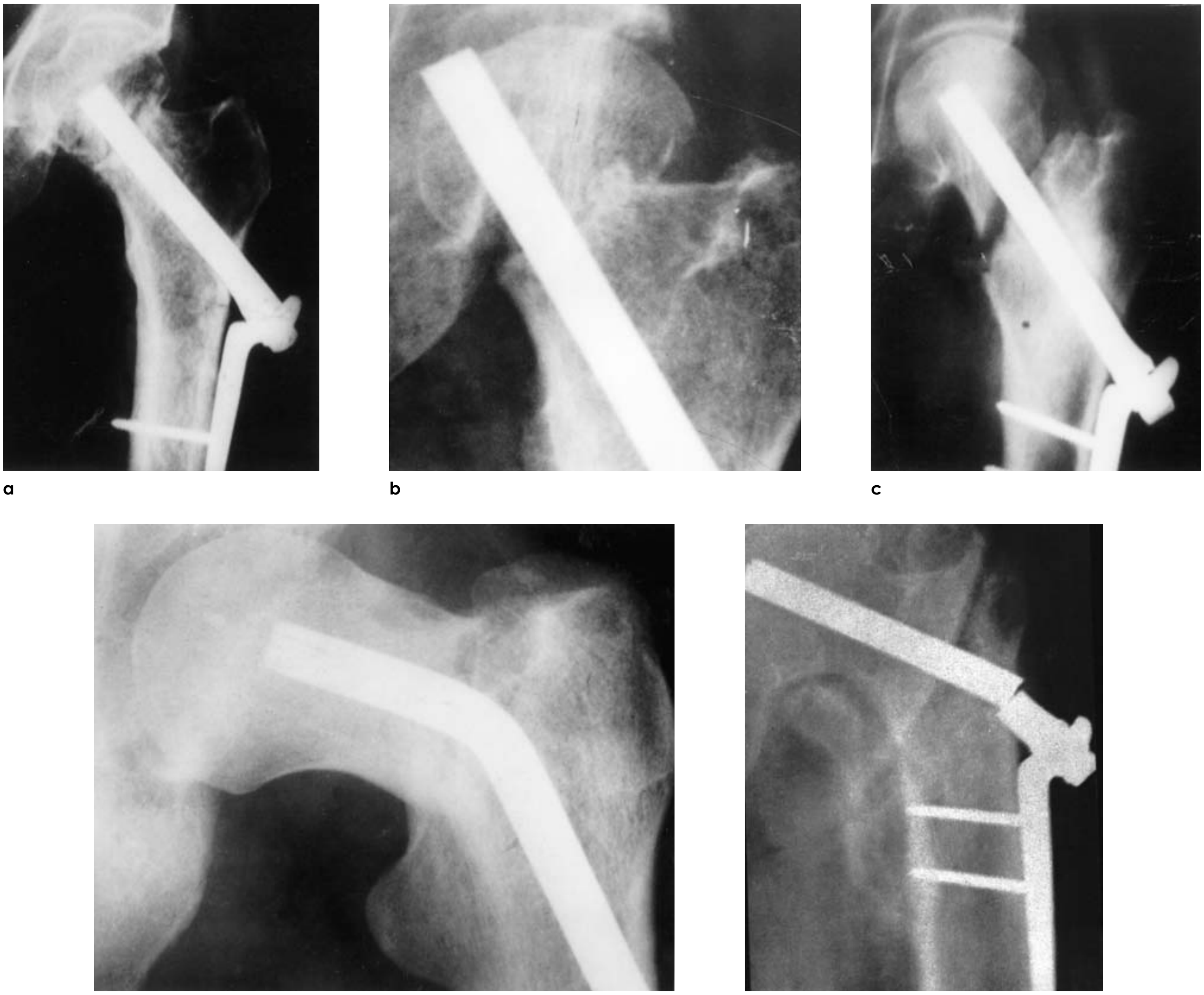
Fig. 117. Böhler flanged nail in combination with a cranially inserted cancellous bone screw.
a. A.-p. film; **b.** Lateral film

the fracture may occur in younger patients causing a delayed or non-union. In older patients one has to expect **a perforation of the femoral head** (Fig. 118b).

The incidence of backing out of a single Smith-Petersen nail was approximately 20% in patients treated between 1940 and 1955. The use of the "distant" buttressing side plate reduced this incidence by half. Although this had been a major improvement, incidences were observed where the nail backed out above or beside the buttressing side plate. To prevent this complication we designed a small buttressing side plate with a socket at the proximal screw hole. This led in the 1960s to a further reduction in the incidence of complications (Fig. 116).

To increase the stability (particularly rotational stability) **two implants** of various designs were introduced. At the end of the sixties we frequently placed a cancellous bone screw cranial to the Böhler nail (Fig. 117).

Another possibility to increase stability was the nail-plate (see Fig. 107, 6. Jewett nail). This implant proved its value only in the stabilization of



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d e

Fig. 118. Complications after internal fixation with a plate-nail for femoral neck fractures.
a. Delayed healing. Five months postoperatively the fracture gap is clearly discernable; **b.** The nail perforates the femoral head; **c.** Gap between the fragments, diastasis of the fracture; **d.** Bending of a nail of poor quality; **e.** Fatigue fracture of an implant

trochanteric fractures as the rigid buttressing prevented a backing out of the nail. When used for femoral neck fractures this implant caused complications (Szabó et al, 1961) (Fig. 118).

It happened rarely that a **diaphyseal fracture** developed at the insertion site of the flanged nail. In these instances the use of the buttressing side plate was advantageous (Fig. 119).

The additional application of **homologous bone grafts** inserted parallel to the screw led to a better consolidation when used for revisions after loss of reduction, delayed union or even nonunion (Manninger, 1959) (Fig. 120).

To further reduce the incidence of loss of reduction we employed occasionally in the sixties and regularly in the seventies an **internal fixation**

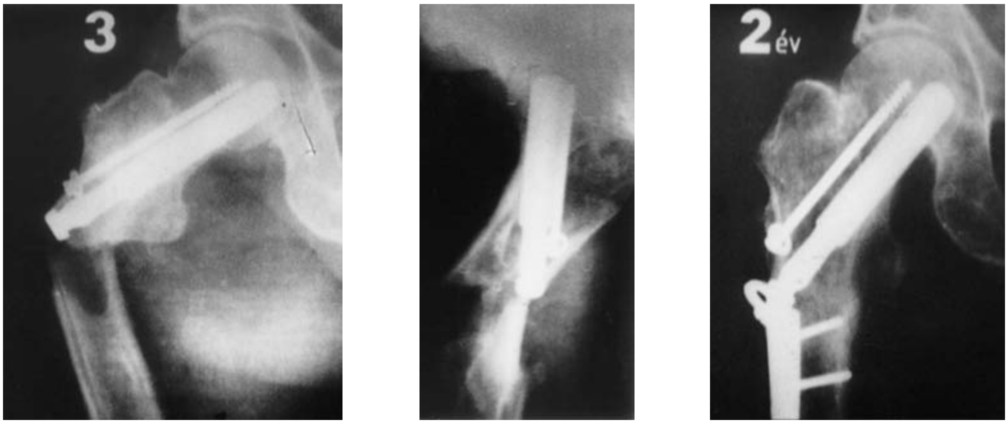

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Fig. 119. Complications after internal fixation of femoral neck fractures. Shaft fracture at the level of the insertion of the nail.
a, b. Three months after internal fixation with a Böhler flanged nail and screw. The patient suffered a fracture during a fall just distal to the lesser trochanter; **c.** Two years after reinforcement of the nail with a buttressing side plate, the fracture consolidated

with two Smith-Petersen nails. This increased considerably the rotational stability without preventing the problem of backing out of the nails (Fig. 121).

Even the use of the buttressing plate with a socket did not prevent a backing out of the nail. Therefore, we **connected the nail to the plate with a sliding screw**. This sliding screw was inserted through the hole in the plate into the inner threads of the nail end. Before surgery the threads of the sliding screw close to the screw head had been removed so that the screw would not get stuck in the plate. This solution had two advantages: the nail slid in the direction of the plate and the application of the tension band principle prevented a varus tilting of nail and femoral head and thus no loss of reduction could occur. For the same reason it was important to buttress the nail against Adam's arch. In this way we transformed the one-arm lever into a two-arm lever leading to a more reliable stability. From 1983 on we combined the Böhler nailing with a sliding screw buttressing (Fig. 122).

The second important factor, beside the supplementation with a "distant" buttressing plate, was the reinforcement of the lateral fixation: the **meticulous preparation of the entry point of the nail in the lateral cortex**. During the sixties we first drilled a hole and then prepared the channels for the three flanges with a chisel (in the shape of a "Mercedes Star"). This laborious and time consuming procedure was later facilitated by the use of a three flanged stepped chisel. In spite of the use of this instrument fissures occurred or great fragments broke out during hammering of the nail into the cortex. This decreased the lateral purchase of the nail end. Even fractures of the femur occurred. A further disadvantage was the prominence of the buttressing plate, a design necessary to accommodate the backing-out of the nail. Particularly in slender patients this prominence caused serious complaints and sores. Therefore the plate had often to be removed later.

An ensuing modification eliminated this disadvantage. The new Smith-Petersen nails made by Aesculap® having a cylindrical end rendered unnecessary any chiseling. A 13 mm hole was drilled without causing any fissures. This allowed to countersink the nail end and therefore the corresponding buttressing side plate **was less prominent**. In addition, the even surface at the lateral cortex improved the bony buttressing of the nail end.

The preparation of the lateral entry point thus became easier, faster and better; fissures or fractures occurred rarely. At the same time the stability of internal fixation was increased by the lateral but-

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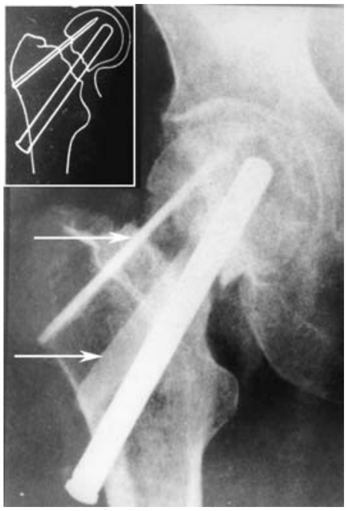

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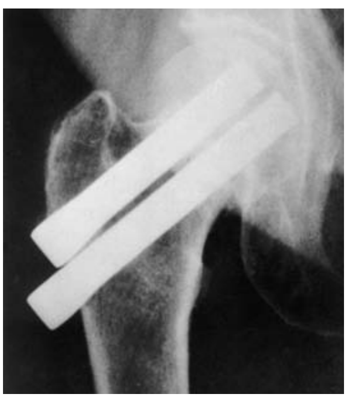
Fig. 120. Implantation of a homologous bone graft during revision surgery.
a. 6 months after the femoral neck fracture a diagnosis of a defect pseudarthrosis accompanied by a cortication of the fracture surfaces was made; **b.** Treatment with a nail and two cortical strut grafts, one cranial and one anterior (arrows); **c, d.** Two years later the pseudarthrosis has consolidated and remodeled



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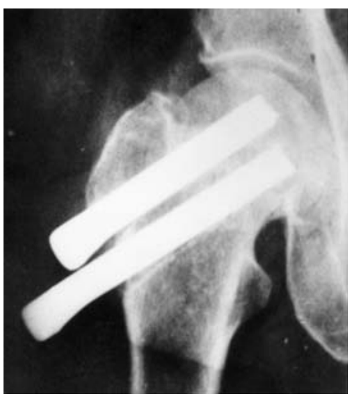

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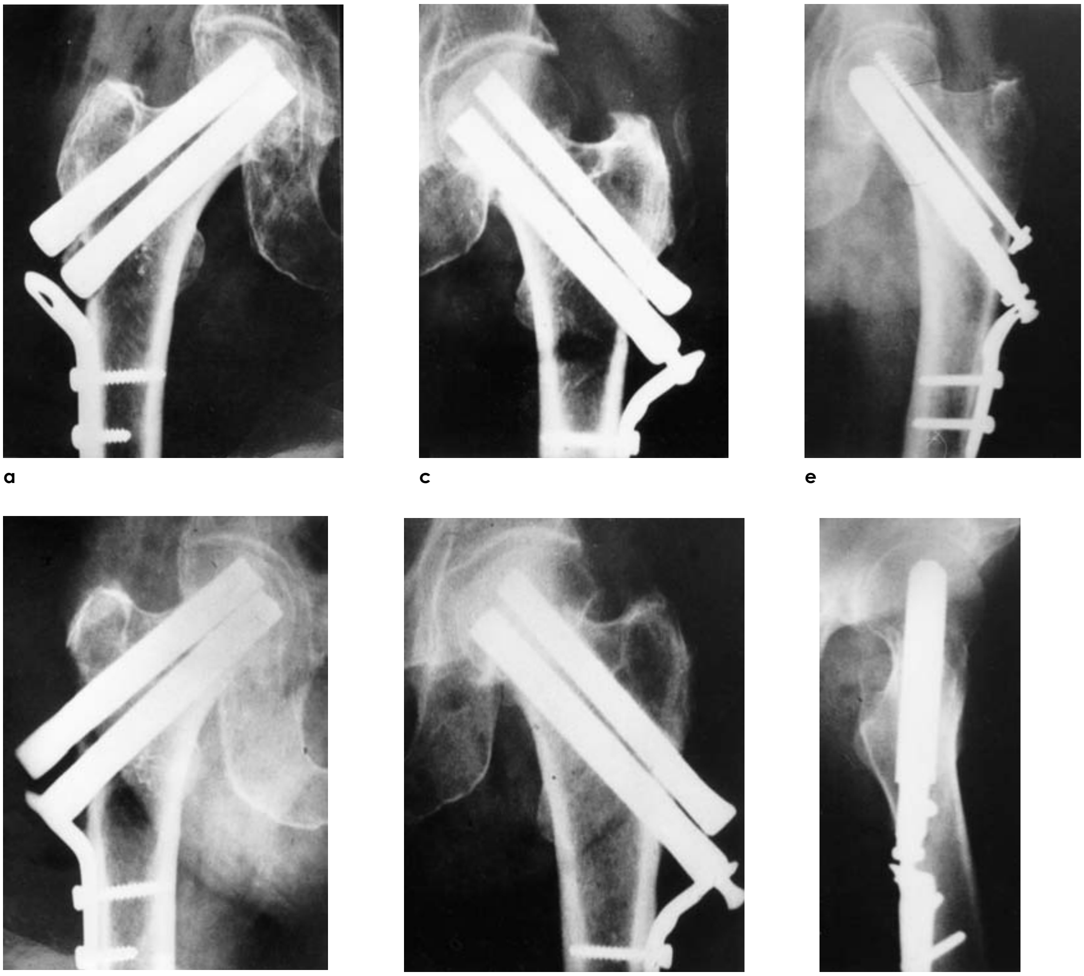
Fig. 121. Internal fixation with two Smith-Petersen nails.
a. Immediate postoperative a.-p. radiograph; **b.** Film taken after two weeks. Due to a shortening of the femoral neck and the nails' displacement in the femoral head the nails backed out. The loss of reduction was caused by the backing out of the nails from the femoral head and not due to settling



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b d f

Fig. 122. "Distant" buttressing of the implant.
a, b. The caudal Smith-Petersen nail backed out and is in contact with the plate; **c, d.** The same buttressing supplemented with a sliding screw; **e, f.** Addition of a sliding screw and plate to a Böhler nail

tressing. Nevertheless, the 13 mm hole weakened the strength of the involved bony segment leading occasionally to secondary (usually subtrochanteric) fractures.

For this reason the sliding screw was connected to a **stronger plate** that was fixed to the femur with two screws. The proximal screw was bicortical and the distal screw found purchase only in the lateral cortex (Fig. 123).

With this modification we obtained such a stable internal fixation that starting in the eighties we could **omit the use of crutches and allowed the patients weight bearing with a walker**. As soon as the patient could leave the bed and the wound pain had subsided, weight bearing was allowed. In light of the fact that elderly patients could rarely use crutches and often put weight on the operated limb against our advice, this was a tremendous advantage.

The early mobilization made possible by the internal fixation and the weight bearing had a beneficial effect on the patients' physical and mental conditions. The danger of complications due to prolonged confinement to bed (pneumonia, thromboem-

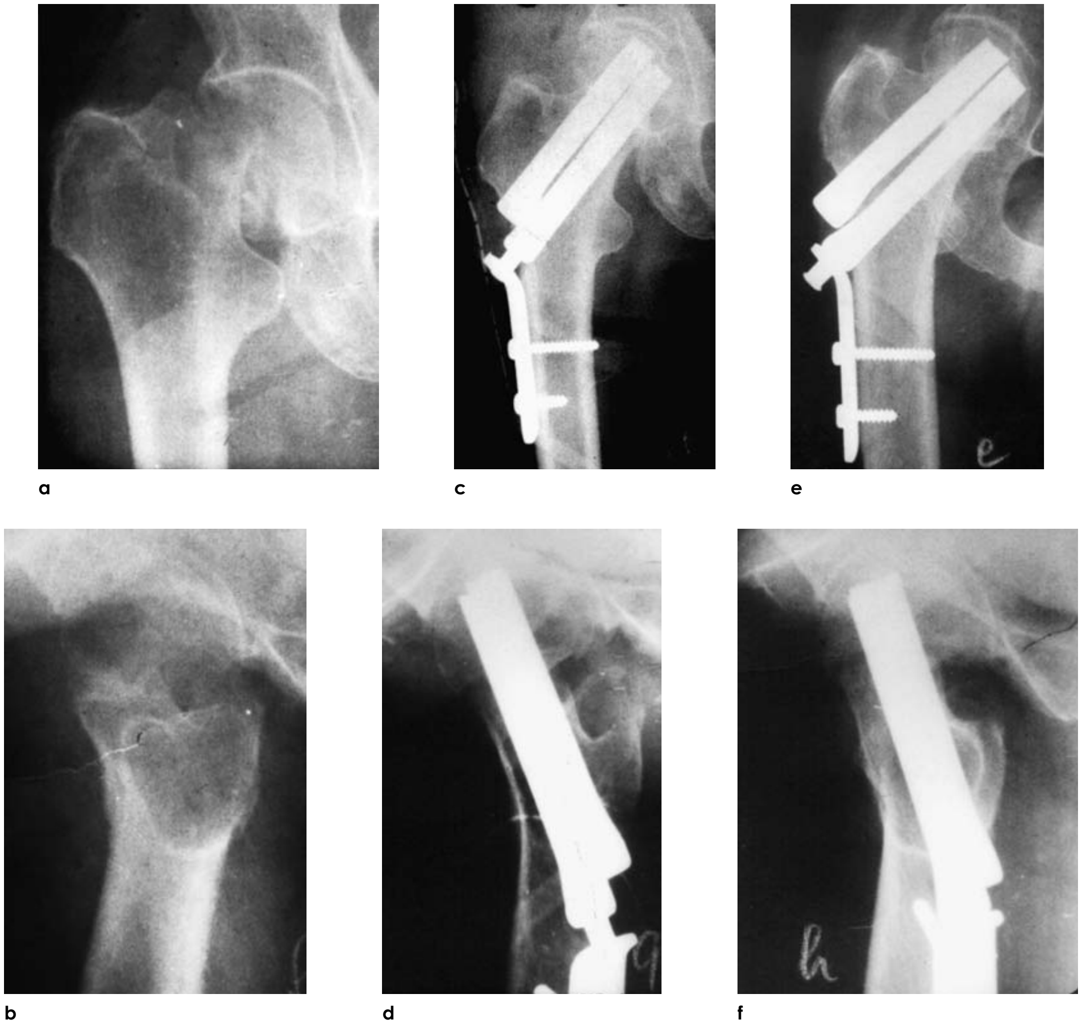

Fig. 123. Results of improved internal fixation after a lengthy process of development: internal fixation with two Smith-Petersen nails, distal sliding screw and buttressing side plate.
a, b. Garden-IV neck fracture; **c, d.** Postoperative radiographs. Good demonstration of the countersunk cylindrical nail end and the buttressing side plate fixed to the cortex with two screws and only slightly separated from the femoral cortex; **e, f.** One year later the fracture has consolidated after settling of the fracture

bolism, decubitus, urinary infections) decreased and the incidence of mortality secondary to these complications also diminished. People using crutches are often regarded to be invalids, whereas elderly patients circulating with a walker feel less being an invalid because they can weight bear and walk safely.

4.2.2 Summary of the basic principles gained during 40 years of experience

(1) The femoral head has to be fixed with **two (or three) nails or screws**, mainly to increase the rotational stability.
(2) The internal fixation must be done in such a way that an **impaction/resorption (settling) of 3 to 8 mm should be** possible, otherwise a diastasis at the fracture site or perforation of the head will occur.

Table 1. Incidence of loss of reduction as seen in our analyses during different time periods (Manninger et al, 1960; Manninger et al, 1985; Manninger et al, 1989)

Year	Number of patients	Number of loss of reduction	% of loss of reduction	Internal fixation	Mobilization
1940–55	300	60	20	One Smith-Petersen nail	3 month with crutches
1962	50	5	10	One Smith-Petersen nail + "distant" plate	3 month with crutches
1981–83	70	2	2.9	Two Smith-Petersen nails + "distant" plate	Walker after a few days
1985–87	127	4	3.1	Two Smith-Petersen nails + "distant" plate + sliding screw	Immediate weight bearing with walker

(3) **The caudal implant must rest on Adam's arch.** Only in this way can the implant prevent a loss of reduction in varus because of the implant's two-arm lever effect.

(4) **It is important to properly drill the hole in the lateral cortex and to use a buttressing side plate.**

(5) The dimension of the applied metal implant should be kept at an optimal minimum necessary for a reliable internal fixation. The distance between plate and buttress (Adam's arch), that is the lever arm to which the force is applied, is considerably greater than the distance between the center of the head and Adam's arch that is the load arm. For this reason, a **small buttressing side plate** is sufficient for **an adequate tension band effect** in the majority of neck fractures and it is therefore not necessary to use a massive plate as in instances of trochanteric fractures, where the plate compensates foremost for the broken Adam's arch.

(6) The goal is to obtain a stability that allows the elderly patient **an early postoperative mobilization with weight bearing**. Consequently, the barely enforceable use of crutches can be omitted. In this way the internal fixation shares all the advantages of a joint replacement, but with a considerably lesser surgical trauma.

Internal fixation with two Smith-Petersen nails combined with a "distant" sliding screw side plate meets all these requirements. This combination was the result of the above described development and was used for one decade as a standard intervention. **A marked decrease in the incidence of loss of reduction** resulted from this modification (Table 1).

4.2.3 Internal fixation with screws

Already in the sixties the treatment of neck fractures in 50 to 60 year-old patients and also in adolescents and children was done by screw fixation. Driving nails into the compact bone is difficult and is accompanied by a very extensive damage to the bone. On the other hand, screws can be introduced with less damage thanks to predrilling and tapping. The screws are sufficiently stabilized in the relatively solid bone. The introduction of cancellous bone screws further increased the stability (Manninger et al, 1970; Manninger et al, 1985).

The rule also applies here that a single implant does not protect sufficiently against loss of reduction in rotation. However, the insertion of several screws has its own problem in that it is difficult to place the screws in a parallel fashion in the narrow neck using a free-hand technique. Any divergence or convergence of screw placement precludes impaction/resorption (settling) and thus leads to a delayed or nonunion.

In the eighties we introduced in our institute a **parallel guide for parallel placement of three screws** to counteract this problem. This guide is fixed to the lateral cortex with a guide wire placed in the center of the neck. Holes in the guide ensure a parallel drilling, tapping and later insertion of the screws after removal of the guide. To reinforce the lateral buttressing of the screw head we designed **a plate with "reversed keyholes"** that was inserted from cranial over the screw heads and pulled down before tightening the screws. This plate was attached to the femur with one cortical screw. Thanks to the caudal cancellous screw lying in contact with Adam's arch a tension band effect was obtained and protected against loss of reduction in varus. The three screws together with the plate protected against a loss of reduction in rotation (Fig. 124).

We used this technique foremost for the treat-

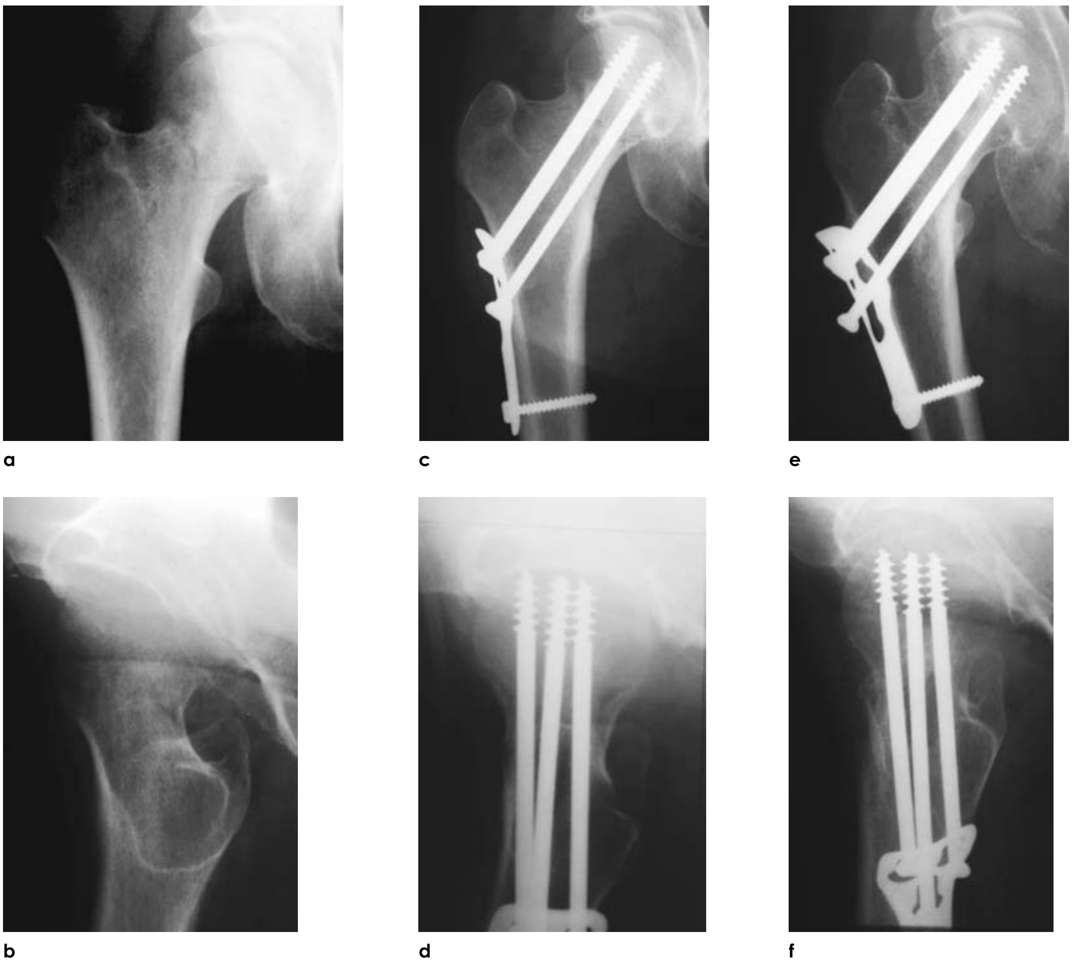

Fig. 124. Internal fixation with three cancellous bone screws and plate with reversed keyholes.
50-year-old patient who suffered one year previously a left hemiparesis secondary to occlusion of the internal carotid artery. She fell on the day of admission and hit her right hip; **a, b.** Films in both planes show a Garden-I fracture with slight valgus position and anteversion. A small bony fragment is also seen at the posterior aspect of the neck. Since the right hip was exposed to greater weight bearing due to her stroke, we decided in favor of surgery; **c, d.** The fracture was stabilized with three cancellous bone screws and a keyhole plate. The patient was mobilized after a few days; **e, f.** 5 years later the fracture healed with a shortening of the neck, the function was good

ment of displaced fractures in younger persons or for the stabilization of Garden-I and -II fractures. In several studies we could prove that well placed screws produce a reliable stability; no loss of reduction was observed (Manninger et al, 1990; Cserháti et al, 1996).

The greatest advantage of this technique in instances of undisplaced fractures in the elderly was the elimination of the aggravating **three-week confinement to bed and the three-month use of crutches, both being part of the conservative treatment**. Similar to the patients treated for displaced fractures with the Smith-Petersen nailing, these patients can weight bear with cane or walker a few days after surgery without running the risk of loss of reduction.

From the static standpoint our methods, double nailing or fixation with three screws, has also responded to the requirements of internal fixation. Chiseling, insertion of the nail by hammering, application of the parallel guide and insertion of the plate with key holes were time consuming and could only be executed by a precise retromuscular approach. This led to a lengthening of the operating time and an increased stress for the older patient. Consequently, a longer preoperative preparation became necessary (availability of blood transfusions) and forced us frequently to exceed the 6-hour limit before surgery.

A percutaneous insertion of screws could constitute the method that would also be advantageous for the patient from **the biologic aspect**. However, the screws available up to this moment did not seem to guarantee the necessary parallel insertion. Besides, the stability obtained, particularly in rotation, could not match that of two Smith-Petersen nails that allowed also a reliable fixation of displaced fractures. This situation changed dramatically with the introduction of **cannulated cancellous bone screws**. Their parallel insertion was guaranteed by using guide wires.

4.2.4 Percutaneous insertion of two screws

In 1987, Professor C. Olerud presented the use of two percutaneously inserted cannulated screws at our institute. Screws and instruments were designed by his group (Rehnberg and Olerud, 1989; Olerud and Rehnberg, 1991; Olerud and Rehnberg, 1993; Olerud et al, 1995). This so-called Uppsala technique, known to us from the thesis of **Rehnberg** (1988) resembled in some aspects the techniques developed by us: the nailing with two Smith-Petersen nails and the fixation with three cancellous bone screws combined with the keyhole plate. Also in these techniques the strictly parallel insertion of screws and the importance of compensation for resorption had been emphasized. The new method was a step in the right direction for two reasons: a less invasive approach and a more stable internal fixation. On one hand, parallel guide and guide wires allowed a reliable **parallel insertion of the cannulated screws through a smaller incision**. On the other hand, advancing the screws into the **subchondral bone** of the femoral head led to a better purchase also in the hope of a better hold in severely osteoporotic bone.

In November 1990, we performed the first two insertions of the original Swedish implants. In the following year we added another ten implantations. In our opinion the subchondral stability of the screws and the shorter operating time are two outstanding advantages. We attempted from the beginning to use our past experience in the development and clinical use of earlier methods to incorporate them into the new technique.

The **lateral buttressing** was not part of the original Swedish method. In the first two cases we attached the lateral screw ends to a modified one third tubular plate. As its placement met technical difficulties, we constructed a small side plate exerting a tension band effect, mostly to prevent a tilting in varus (see Fig. 241a). Rectangular holes contributed to a certain rotational stability. During the development of the plate we perfected the **percutaneous insertion** and the relevant **instruments**. Up to the moment of the introduction of this plate we performed the internal fixation only with two screws. During that time we observed on radiographs in a considerable number of these patients a slight displacement in varus and rotation after mobilization of the patient (Fekete et al, 1992).

The necessity arose to adapt the screw shank to the rectangular holes of the small plate and to flatten its end over a longer distance to preserve the stability without interfering with the sliding. To compensate for this flattening we increased the shank diameter to 7 mm. This stronger shank also allowed to insert larger compression screws. At the same time this prevented a migration of the cannulated screw in a superomedial direction (see Fig. 192d). We also **deepened the threads** and removed the spikes at the tip of the cancellous bone screw to increase the subchondral purchase. In addition, we designed **holes** between the threads and two **longitudinal grooves** at the surface of these screws to improve the drainage of the congested blood in the femoral head (see Fig. 57).

We also modified considerably the surgical technique. During the earlier performed open reductions we observed that the tip of the guide wire slipped off the bone and displaced the femoral head, particularly in younger patients. For this reason we perform now a **predrilling** with a 3.2 mm spiral drill bit.

For a more stable fixation of porotic, certain subcapital or vertical fractures (Pauwels-III) as well as for basal neck fractures we use screws with **a greater thread diameter** (9.5 mm) and **thread lengths of 18, 34, and 44 mm** (standard length 24 mm) (Fekete et al, 2000b; Fekete et al, 2000c). For the internal fixation of neck fractures in younger patients where MRI and CT follow-up examinations are necessary, we also use titanium implants (Melly et al, 1999) (see Fig. 189).

We discussed repeatedly certain modifications with representatives of the manufacturer. We wanted to make sure that our wishes based on experience are respected permitting us the introduction of cannulated screws. As our efforts were not successful we approached the Hungarian company Sanatmetal. Over many years this company had manufactured for us numerous implants of reliable quality with the result that our cannulated femoral neck screws are made in Hungary from imported cannulated steel rods (Sandvik®).

We tested the majority of developed implants before their clinical use in **cadaver specimens at the Department of Material Science and Mechanics at the Budapest University of Technology and Economics (BUTE)** (see chap. 5) and patented them (Patent number 85256, valid to 2007).

The collaboration of medical doctors and engineers at the National Institute of Traumatology (Budapest), the members of the BUTE and the development engineers of the manufacturer led to numerous new and considerably modified implants and instruments. Our research and development was also supported by grants from the Hungarian Ministry of Health (ETT) and the Hungarian Academy of Science (OTKA) (Project Nr. ETT 140/1993, 103/1996, 426/2000, 254/2003, 344/2003, OTKA 970/1991, F6193/1992, T016341/1995, T024006/1997, T034680/2000).

The following short summary lists the most important new models and modifications for the internal fixation with standard screws:

(1) Screws:

- The shank of the neck screw was increased to 7 mm to ensure that the flattening of the shank's end would not weaken the implant. This, in turn, allows a dynamic auto-compression secondary to impaction/resorption (settling) as well as fixation ensuring rotational stability thanks to a small straight side plate having a tension band effect.
- The tip of the screw is blunt; the threads reach the tip and are self-cutting.
- The other end of the cannulated screw has a bore (∅ 5 mm) with threads in the metric system. Another long screw is inserted into the T-handle and screwed into the cannulated screw. This allows a secure hold of the T-handle. The 5 mm bore can also be used for a stronger compression screw.
- The accumulated intraosseous blood can drain through four holes made between the threads and two longitudinal grooves in the shank. This is the principle of the "draining screw".
- The length of threads is available in four lengths: 18 mm, 24 mm (standard length), 34 mm and 44 mm.
- Thread diameters of 8 mm and 9.5 mm are available.
- The slotted screws can be introduced exacter, faster and simpler through the 10/8 mm sleeve.

(2) Instruments:

- To ensure a parallel insertion of the guide wires two 300 mm long spiral drill bits have been included in the set (∅ 3.2 mm).

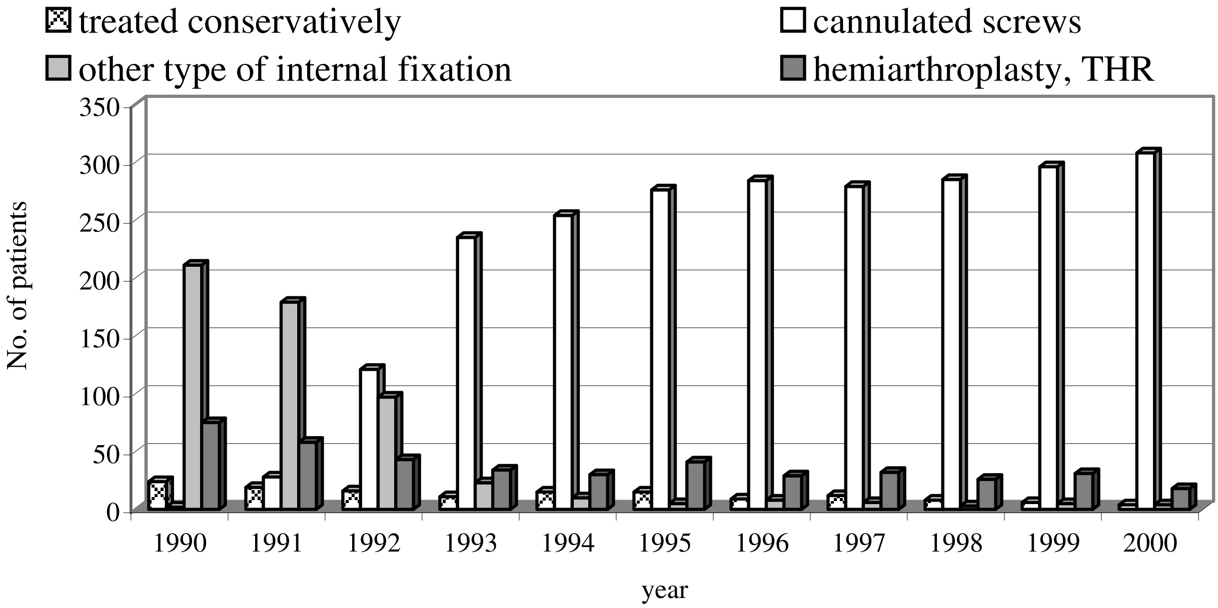

Fig. 125. The treatment of femoral neck fractures at the National Institute of Traumatology (Budapest) between January 1, 1990 and December 31, 2000.

- Instead of the reamer a stepped drill bit of two lengths (250 and 300 mm) has been manufactured.
- The T-handle can be attached to either of the two 300 mm long taps (∅ 8 mm and 9.5 mm).
- The new parallel guide and the new 10/7 and 10/8 mm drill sleeves render screw insertion more precise.
- For precise insertion of the third screw an additional device can be attached to either the left or right side of the parallel drill guide.
- The sleeve of the soft tissue protector with handle (∅ 10 mm) has a beveled end that fits the femur's surface and two little spikes for better hold on the bone. This allows a precise drilling and insertion of guide wires while at the same time protecting the soft tissues.
- At the end of surgery a new instrument for proper seating of the side plate permits a fast percutaneous insertion of the straight side plate.

Thanks to these additions and while respecting the requirement for emergency intervention, it was possible since 1993 to treat the majority of patients with fresh neck fractures with two cannulated screws (Fig. 125) (Cserháti et al, 1999).