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OSTEOSYNTHESIS WITH THE HOOK-PIN IN SLIPPED CAPITAL FEMORAL EPIPHYSIS

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Osteosynthetic materials, such as metallic nails, screws, pins, and bone pegs, used in the surgical treatment of slipped capital femoral epiphysis, have caused peroperative problems because of increased displacement of the femoral head and postoperative problems because of bone resorption and growth of the femoral neck, resulting in loosening of the osteosynthetic material and reslipping of the femoral head. Premature closure of the growth plate and shortening of the femoral neck have also been registered.

In order to avoid these problems, a hook-pin was developed. This device has now been in use for a period of 6 years and has been applied in 38 cases, the pin being placed in a drilled channel with the hook in the femoral head. The operation has been performed on the slipped side with or without reduction of displacement and on the asymptomatic side. Seventy-five hips have been operated on.

The advantages of the hook-pin and of the operative technique are presented.

No avascular necrosis has been noted in 74 hips pinned *in situ* or after closed reduction. Avascular necrosis occurred in one hip after femoral neck osteotomy.

All 28 asymptomatic hips and 27 out of 37 hips with slipped epiphyses showed no tendency toward premature closure during a postoperative observation period of 1–6 years. The growth in length of the femoral neck was found to be up to 15 mm, almost the same on the slipped side as on the asymptomatic side.

Only one of the 75 hips required reoperation because of resorption around the hook-pin.

After the end of the growth period the hook-pin was extracted in 19 hips without problems.

Key words: femur; growth; hip; osteosynthesis; physis; slipped epiphysis

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In the surgical treatment of slipped capital femoral epiphysis, different types of metallic nails, screws, pins, and bone pegs have been used (Wiberg 1959, 1966, Bianco 1966, Howorth 1966, Tachdjian 1972, Cameron et al. 1978). The purpose of the osteosynthesis, according to the literature, is to prevent further slipping of the epiphysis and also to provide early fusion of the growth plate of the femoral neck (Bianco 1966, Howorth 1966).

Different problems arise in using osteosynthetic materials:

1. peroperatively, further displacement of the epiphysis;
2. postoperatively, loosening of the osteosynthetic material because of bone resorption;
3. postoperatively, loosening of the fixation of the femoral head owing to the growth in length of the femoral neck.

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Table 1. Number of cases with slipped capital femoral epiphysis operatively treated using the hook-pin 1975–1980

	Total	Male	Female
1975	6	2	4
1976	7	4	3
1977	7	6	1
1978	6	4	2
1979	7	7	0
1980	5	2	3
Total	38	25	13

These problems in some cases cause increased deformity and avascular necrosis of the femoral head. The risk of displacement on the slipped side and on the asymptomatic side is not eliminated until the growth plate of the femoral neck has fused (Jerre 1950).

In order to eliminate the above-mentioned risks of per- and postoperative complications and to permit growth in length of the femoral neck, a pin with a hook was developed (Hansson 1975) using the hook of the spring-loaded nail (Rydell 1964). Seventy-five hips in 38 patients treated with this device since 1975 are reported here.

PATIENTS

Thirty-eight cases (Table 1) with unilateral (33) or bilateral (5) slipped capital femoral epiphysis were operatively treated bilaterally using the hook-pin, except in one case with an adequate Nyström nail on the asymptomatic side from a previous operation.

The material at operation consisted of 13 girls aged 10–14 years and 25 boys aged 7–15 years.

METHOD

Most cases were treated preoperatively for a few days in bed with pin traction according to Casey et al. (1972) to prevent further slipping and to reduce the displacement in unstable hips.

Pinning *in situ* was performed in hips with minor displacement, in hips with moderate and major displacement with signs of corresponding periosteal bone formation and also in the asymptomatic hips. Gentle closed reduction and pinning was performed in hips with moderate and major displacement without signs of corresponding periosteal bone formation, whereas femoral neck osteotomy, as an exception, was performed in a hip with major displacement and signs of remodelling.

Table 2 lists the treatment, relating it to the degree of displacement and the signs of remodelling.

Operative technique

The patient is placed supine under general anaesthesia on a fracture table, with the possibility of using biplane fluoroscopy and radiography. A lateral approach to the trochanteric region is made through a 2–4 cm long skin incision. One or two Kirschner wires are placed peripherally in the femoral neck and head to avoid slipping and rotation of the epiphysis during the

Table 2. Number of hips in cases with slipped capital femoral epiphysis operatively treated using the hook-pin

Degree of displacement	Total	Male	Female	Pinning *in situ*	Closed reduction and pinning	Femoral neck osteotomy and pinning
No displacement (asymptomatic side)	32	19	13	32		
Minor displacement (<1/3 of femoral neck)	20	18	2	20		
Moderate displacement (1/3–1/2 of femoral neck)	11	7	4	10	1	
Major displacement (>1/2 of femoral neck)	12	5	7	5	6	1
Total	75	49	26	67	7	1

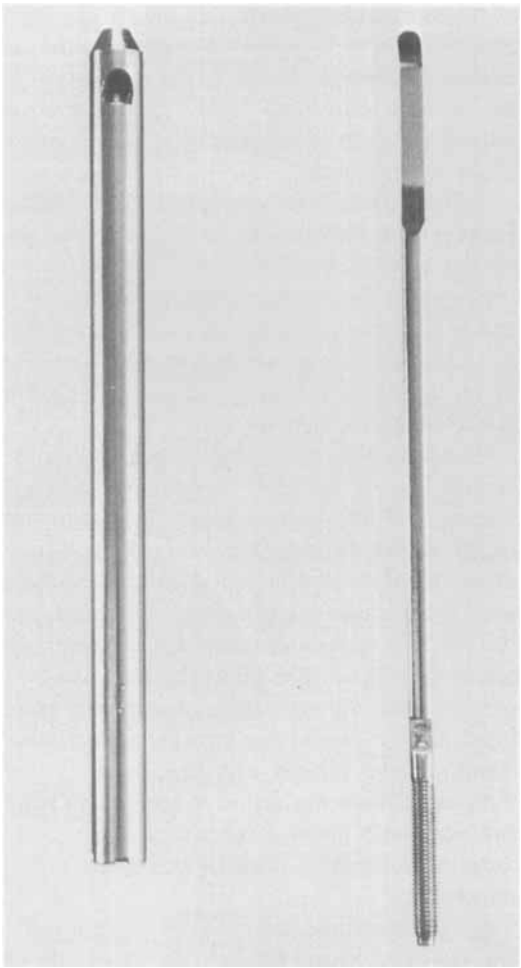


Figure 1. The pin and hook.

operation. A channel, diameter 6.7 mm, is drilled through the femoral neck, the physis, and the epiphysis up to the subchondral bone of the epiphysis. A Hall® air drill is used. A cylindrical pin (Figure 1), diameter 6.5 mm and between 91 and 126 mm long, is chosen. Depending on the calculated residual growth of the femoral neck, the pin is chosen so that it is 5–15 mm longer than the channel. The pin is gently pushed into the channel and locked with the hook in the epiphysis. Finally, the peripheral wires are extracted.

As the risk of slipping in the asymptomatic hip has been estimated to be about 40 per cent (Jerre 1950, Stulberg et al. 1975), the asymptomatic side was routinely operated on. Both hips were operated on in most cases on the same occasion, starting on the side with the slipped epiphysis.

Where there was pinning *in situ*, weight-bearing was allowed immediately. Where there was closed reduction and pinning, weight-bearing was allowed 4–6 weeks after operation. After femoral neck osteotomy, weight-bearing was allowed after 6 weeks in a hip spica.

Follow-up

Postoperative clinical and radiographical examinations were usually performed at 6 or 12-month intervals until the end of the growth period. After closure of the growth plates of the hip region, the hook-pin was extracted.

RESULTS

Peroperative observations

In 7 hips with moderate and major displacement of the femoral head, closed reduction was performed under general anaesthesia. In 4 of them, reduction to an acceptable position took place during muscle relaxation, and a manual closed reduction was actually performed in only 3 hips.

During the operative procedure with pinning *in situ* and after closed reduction, no signs of increased displacement of the femoral head were found. With the aid of fluoroscopy, the position of the pin and hook in the femoral neck and head was easily seen.

The hook-pin was used where there was up to 60° deformity, without problems achieving an acceptable position of the pin and the hook.

Postoperative observations

The range of movement of the hip rapidly normalized in most cases after operation in hips pinned *in situ* and after closed reduction. The patients resumed their normal activities within a few weeks after weight-bearing was allowed. However, in the case with the femoral neck osteotomy and postoperative hip spica, and later avascular necrosis, the range of hip movement and walking ability was reduced. In a patient with preoperative chondrolysis and protrusio acetabuli after unilateral slipped capital femoral epiphysis, the range of movement was as restricted as preoperatively, but the pain ceased and the walking ability increased after operation.

One patient had a superficial wound infection which healed rapidly.

Observations during follow-up

Experience with the hook-pin now covers a period of 6 years. Out of 38 cases, 18 have grown up. In 33 cases, the follow-up period is 1 to 6 years, and the other 5 have been operated on during the last 12 months and are thus excluded from the follow-up.

Clinical observations. The hip motion and the walking ability have been normal, except for the 2 cases described above. In cases pinned *in situ*, the outward rotation deformity caused by the slipping persisted.

A few patients had minor discomfort with the laterally protruding pin with crepitations between the *fascia lata* and the pin. These problems have been reduced, as the growth in length of the femoral neck has retracted the pin into the bone.

Radiographical observations. The growth in length of the femoral neck and its growth plate was evaluated in 33 cases and 65 hips observed for more than 12 months after operation. Out of these, 28 hips were in the asymptomatic group and 37 hips belonged to the slipped group.

Growth plate of the femoral neck: 28 asymptomatic hips and 27 hips with slipped epiphysis showed no tendency toward premature closure compared with other growth plates in the hip region. Out of 10 hips with slipping, premature closure was found 3–5 months after operation in 2 hips; one was the hip with preoperative chondrolysis and the other was the one with postoperative avascular necrosis after femoral neck osteotomy. The growth plate in the other 8 hips closed partially and gradually before normal closure.

Growth in length of the femoral neck: The hook-pin on the asymptomatic side was placed perpendicularly to the growth plate in the central part of the femoral neck and head in the direction of the longitudinal growth. On the slipped side, depending on the degree of displacement, the pin deviated slightly in relation to the normal axis of the femoral neck and head. There were no radiological signs of asymmetric growth in length of the femoral neck.

i) Slipped side: The longitudinal growth of the femoral neck was obvious in 25 hips as the pin moved with the femoral head in relation to the neck and to the trochanteric region (Figures 2 and 3). The protruding base of the pin was gradually retracted. This growth has been measured to be up to 15 mm during a postoperative growth period of at most 4 years.

No measurable growth has been found on the slipped side in 12 hips. In one with bilateral slipping and thin growth plates, no growth was registered but the operation was performed close to the end of the growth period. In another, there were preoperative complications associated with the slipping, such as chondrolysis and protrusio acetabuli with a thin growth plate. About 3 months after the operation, the growth plate fused and no measurable growth in length was found. In the patient with the femoral neck osteotomy, there was fusion of the growth plate and no growth about 5 months postoperatively because of avascular necrosis as a result of the osteotomy.

ii) Asymptomatic side: All 28 asymptomatic hips operated on and followed for 12 months or more showed growth in length of up to 15 mm (Figure 4).

The growth in length was in some cases slightly greater on the asymptomatic side, indicating a slight growth retardation on the slipped side. However, usually the growth was the same.

Radiolucent zone around hook-pin: The asymptomatic and the slipped side in most hips showed signs of a radiolucent zone around the pin and the hook, developing 2–6 months after operation. This radiolucent zone was demarcated

Figure 2. Left-sided slipped capital femoral epiphysis in a 13-year-old boy.
a. Preoperative radiographs. AP and lateral views.
b. Postoperative radiographs after pinning in situ. AP and lateral views.
c. 2 years after operation – fused growth plate of femoral neck, growth of femoral neck about 4 mm and retraction of hook-pin. AP and lateral views.


a


b


b


c


c

from the bone by a thin sclerotic zone. The radiolucent zone was in most cases less than 2 mm wide.

In two cases, however, the radiolucent zone on the slipped side was between 2 and 8 mm wide.

In the first case there was some temporary discomfort from the slipped hip and an elevated ESR. This resorption around the hook permitted about 3 mm of movement caudally and laterally of the hook and of the pin. However, at the same time the base of the pin was retracted several millimeters owing to the growth of the femoral neck. During the following years, the ESR and the radiography normalized. The growth plate fused and the growth in length of the femoral neck stopped about 4 years after the operation.

The other case also had some temporary discomfort and an elevated ESR. There was a resorption of up to 8 mm, invalidating the fixation of the hook in the femoral head. This resorption was found to be greater than the growth in length, so the exposed base protruded more laterally than before. Around this base, there was increased resorption instead of the usual periosteal bone formation. Because of this, reoperation was performed and the hook-pin was extracted. The base was found to be in a bursa with some fluid, but the bacteriological examination was negative. A new hook-pin was placed in the same channel, but with the hook dorsally directed. Since then, the pin has retracted with the growth of the femoral neck, but a fistula from the base of the pin developed about 4 weeks after the operation. Bacteriological examination has proved negative. The patient has also been treated with antibiotics with improvement, and there have been no clinical or radiological problems. After the end of the growth period, the hook-pin was extracted and the fistula has completely healed.

Extraction of the hook-pin. So far, 18 cases have reached the end of the growth period and have closed growth plates of the femoral neck. Ten of them (19 hips) have had the hook-pins extracted without problems.

DISCUSSION

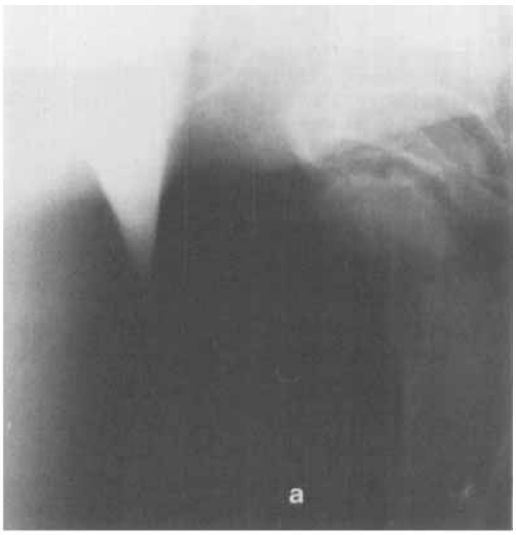
With slipped capital femoral epiphysis, a considerable risk of avascular necrosis exists because of the vascular anatomy (Jerre 1950, Trueta 1957, Hulth 1958, Wiberg 1966). It is important to avoid complications which may result in avascular necrosis of the femoral head leading to chronic disability and osteoarthrosis. Moreover, it is important for the longitudinal growth of the femoral neck to proceed at the normal rate and in the normal direction during the rest of the growth period; a growth arrest of the femoral neck could result in reduced abduction because of continued growth of the greater trochanter (Howorth 1966).

Judging from the literature, there is a considerable risk of peroperative displacement of the femoral head when using nails and screws (Jerre 1950, Wiberg 1959, 1966, Tachdjian 1972). The hook-pin and the operative technique used in the 38 cases presented offer a favourable alternative to the osteosynthetic methods used previously. The risk of further peroperative displacement of the femoral head is eliminated by drilling a channel for the pin with the femoral head fixed with Kirschner wires. The pin and the hook are gently pushed through the channel, avoiding the risk of diastasis between the femoral neck and head.

The hook prevents loosening of the fixation to the femoral head, as the longitudinal growth of the femoral neck retracts the pin in the channel thereby stabilizing the femoral head. Thus, there is no risk of loosening of the osteosynthetic material because of resorption and growth of the femoral neck under normal conditions. This loosening of fixation of the femoral head is not an

Figure 3. Right-sided slipped capital femoral epiphysis in an 11-year-old girl.
a. Preoperative radiographs. AP and lateral views.
b. Postoperative radiographs after closed reduction and pinning. AP and lateral views.
c. 4 years after operation – fused growth plate of femoral neck, growth of femoral neck about 5 mm and retraction of hook-pin. AP and lateral views.


a


a


b


b


c


c

Figure 4. Asymptomatic right side in left-sided slipped femoral epiphysis in a 12-year-old boy.
a. Preoperative radiographs. AP and lateral views.
b. Postoperative radiograph after pinning in situ. AP view.
c. 3 years after operation – fused growth plate of femoral neck, growth of femoral neck about 13 mm and retraction of hook-pin. AP view.

unusual complication when using conventional nails, screws, and pins (Wiberg 1959, 1966, Tachdjian 1972, Cameron et al. 1978), and involves the risk of the femoral head slipping.

The purpose of many types of osteosynthesis has been to provide an early fusion of the epiphysis to the femoral neck through compression or destruction of the growth plate (Bianco 1966, Howorth 1966, Cameron et al. 1978). Bone pegs have been used and long periods of no weight-bearing. Fusion of the growth plate is said to be established in 3–6 months after using bone pegs and in 9–12 months after using nails, screws, and pins (Bianco 1966, Howorth 1966). These

methods may result in unequal bone length and reduced range of movement and function of the hip joint as the growth of the greater trochanter continues (Howorth 1966). In the presented series, continued growth both on the slipped and on the asymptomatic side has been registered in most cases 2–4 years after operation with the hook-pin, depending on the skeletal maturity at the time of the operation. In 25 out of 37 slipped hips and in all 28 asymptomatic hips, followed for 12 months or more, considerable growth in length of the femoral neck has been registered amounting to at most 15 mm (Figures 2–4). In two slipped hips in the same case, operation was performed close to the end of the growth period, and no growth was registered. Only in two hips has a premature closure of the growth plate been found and this was a result of preoperative chondrolysis and avascular necrosis after femoral neck osteotomy. In 8 hips, the growth plates closed partially, no significant growth being found, probably due to local damage to the growth plate and not to avascular necrosis. This damage is probably the result of the slipping and/or the operative trauma.

The growth of the femoral neck in cases with slipped capital femoral epiphysis is an indication of a lack of per- and postoperative vascular disturbance, as the nutrition for the proliferating cells of the growth plate is provided by the epiphysial vessels. This fact strongly supports the use of the hook-pin.

The growth of the femoral neck is the reason for having the pin protruding laterally to the femoral cortex. Calculations showed that an initial protrusion of 5–15 mm, depending on skeletal maturity, is sufficient to allow the base to be outside or level with the lateral cortex at the end of the growth period. Moreover, there is no risk of the pin being trapped in the bone, as the pin surface is smooth. The patients in this series have had few problems with the protruding base of the nail. A few have had minor discomfort from crepitations between the fascia lata and the base.

The results show no avascular necrosis in the hips pinned *in situ,* indicating no vascular injury during the operation. This is also the case where acute slipping was treated by gentle closed reduction. Concerning the latter, it is interesting that in 4 cases there was a spontaneous reduction during muscle relaxation under general anaesthesia.

It is notable that these cases were placed on the fracture table in the position recommended by Casey et al. (1972). It is most probable that this method of spontaneous reduction is gentler than manual reduction and therefore does not harm the epiphysial vessels.

Concerning avascular necrosis after femoral neck osteotomy, the frequency of avascular necrosis after this operation is high, according to the literature (Bianco 1966, Wiberg 1966, Dunn 1975, Southwick 1975). In our case, the growth plate fused 3 months after operation, indicating vascular disturbance.

In the present series, three hips with complications, probably due to infection, were registered. There was no problem with the superficial wound infection. The two cases with elevated ESR, resorption and development of a wide radiolucent zone around the pin and hook were controlled by antibiotics and also in one case by reoperation. The cause is probably infection, even if bacteriological evidence is lacking. However, the growth of the femoral neck proceeded normally in both cases.

The radiological finding of a thin radiolucent zone and a surrounding thin sclerotic zone in uncomplicated hips is interesting. Probably it reflects the movements of the hook-pin in relation to the bone and movements between the femoral head and neck. This might result in periods of instability between the femoral head and neck, resulting in temporary discomfort as registered in a few cases on the slipped and on the asymptomatic side. In these cases the pin probably prevented slipping. Similar radiolucent and sclerotic zones are found after hip arthroplasty with a corresponding width in uncomplicated and in infected cases (Bergström et al. 1974).

The asymptomatic side is pinned at the same time as the slipped side because of the high frequency of bilateral slipping (Jerre 1950, Stulberg et al. 1975). Moreover, it is easier to treat the asymptomatic side at an early stage than to operate after slipping has occurred. This postulation is strongly supported by the absence of per-

and postoperative problems from the asymptomatic side in this series.

Cameron et al. (1978) found that most types of osteosynthetic materials used in the surgical treatment of slipped capital femoral epiphysis are difficult to extract and often fracture during extraction. In the present series none of the hook-pins fractured; after the end of the growth period, the hook-pins were easily extracted, thus satisfying the requirements for osteosynthetic materials.

The hook-pin was intended for cases with slipped capital femoral epiphysis; it has also been found suitable for use in children and adults with fracture of the femoral neck. It is also important in these cases to use a method that does not disturb the circulation of the femoral head.

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