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From the Orthopaedic Department of Karolinska Institutet, Stockholm.
Chief: Professor Sten Friberg

THE SHELF OPERATION

AN EVALUATION OF RESULTS IN CONGENITAL DYSPLASIA, SUBLUXATION AND DISLOCATION OF THE HIP JOINT

By Åke Jakobsson

EJNAR MUNKSGAARD
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Translated from the Swedish
By Catherine Djurklou

ESSELTE AKTIEBOLAG
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"When workmen strive to do better than well,
They do confound their skill in covetousness"

WILLIAM SHAKESPEAR:
King John Act IV: 2

Preface

My chief, Professor *Sten Friberg,* gave me the task of analyzing the material of shelf operations performed at the Clinic.

Norms for evaluating the shelf operation were difficult to establish. Various attempts to solve the problem by means of arthography, loading of the hip joint under anesthesia, and studies of the femoral epiphysis in relation to displacement were fruitless. It is thanks to Professor *Friberg's* help and encouragement that I was finally able to complete the investigation.

Professor *Folke Knutsson,* former chief of the roentgen department of the Clinic, gave me much valuable advice concerning the roentgenographic examinations.

Docent *Carl Hirsch,* assistant professor at the Orthopedic Clinic, facilitated my task both with sound advice and practical assistance.

Docent *Rudolf Hiltscher,* chief of the Photoelastic Laboratory at the Royal Institute of Technology, Stockholm, helped me to make the model experiments according to the photoelastic method.

Dr. *Arne Sollberger* allowed me access to his investigations on the anatomy of the abductors of the hip joint.

Mrs *Margareta Fromell* and Miss *Greta de Verdier* devoted much time and energy to the roentgenographic examinations, while Miss *Karin Lundin* assisted me with the printing of the roentgenograms and with the preparation of diagrams.

The Gustaf V Institute for Scientific Research provided me with working quarters for a long period of time.

The costs of the investigation were defrayed in part by funds from the Orthopedic Clinic and from the Gustaf V Eightieth Anniversary Foundation. I was also the recipient of a research grant from Karolinska Institutet.

I welcome this opportunity to express my profound gratitude to the individuals and institutions whose generous help and support enabled me to complete my task.

Stockholm, January 1954.

Åke Jakobsson

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Introduction

The shelf operation in congenital dislocation of the hip was first described by *König* in 1891. His purpose was to find a substitute for the surgical method of constructing a new acetabulum in the ilium, which was in general use at that time. Later, *Lorenz'* method of closed reduction (1895) was generally accepted as the standard form of therapy. The results were nevertheless not always satisfactory. The shelf operation was then revived as supplementary treatment of residual conditions following closed reduction. Later it was also adopted for the treatment of cases of pain and of osteoarthritis in the hip joint, in which the cause was believed to be dysplasia or congenital subluxation. Meantime the results of the shelf operation have not always been good, and the value of the method has even been questioned in the literature. At the suggestion of my chief, Professor Sten Friberg, I have therefore made a follow-up study of our cases.

The purpose of the study is to determine whether the shelf operation is effective and if so in which cases.

In this connection, problems related to surgical indications and technic are also discussed.

Finally, I shall describe attempts to illustrate experimentally the stress and weight-bearing in the hip joint under different conditions.

Survey of the Literature

I. Historical Review

The shelf operation was described for the first time by *König* (1891). Closed reduction was unknown in those days. *Pravaz'* method of prolonged extension and repeated reduction maneuvers (1838) had been forgotten. The surgical approach was now applied to the problem of the treatment of congenital dislocation of the hip. König pointed out that the method of excavating a new acetabulum out of the ilium was not always practicable owing to the thinness of the bone. To prevent upward displacement of the head, he envisaged a barrier of bone above the head. This barrier was constructed simply by turning down a flap of bone from the ilium over the head of the femur without opening the joint capsule. The head was drawn down as far as possible by prolonged extension before the operation. König first operated on two children, but both died three weeks and four months after the operation, respectively, the first one of scarlatina and the second of diphtheria. At a congress in 1891, König demonstrated with specimens that a strong barrier of bone could be constructed by his method. Despite his initial failures, König tried his operation in three or four more cases. At a surgical congress in 1893, he reported that he considered the method of no value, partly because the head of the femur remained in the same position as before and partly because of the difficulty or even impossibility of preparing a satisfactory flap of bone. He therefore expressed his preference for Hoffa's operation with open reduction in a newly constructed or deepened acetabulum. *Gussenbauer* (1893), at the same congress, stated that he had performed König's operation on both hips in one case and achieved relatively good results.

From the moment the closed reduction treatment was introduced, the shelf operation disappeared from the literature for many years to come. *Ridlon,* it is true, wrote in a discussion on the subject (1924) that *Ferguson* (1904) had operated on a child of two and a half years according to a method similar to König's, but in this case also the operation was done in place of reduction.

Eventually the problem arose of what to do with recurrences following closed reduction. *Jackson Clarke* (1909) described a new surgical method for relapsed cases. The description of the operation is unclear, but it apparently consisted of a kind of reefing of the capsule.

Lexer (1914) tried König's method on older children, but since he had only one success and several failures with redislocation and rigidity, he changed over to arthroplasty. *Delagenière* (1916) cured one case of habitual dislocation of the hip by implanting a graft from the tibia in the articular margin.

Albee (1917) proposed a method of retention of the femoral head in dislocation of the hip where the acetabulum is shallow and the superior rim insufficient to retain the femoral head. The bone above the capsule attachment to the acetabular rim is incised with a thin osteotome in a semicircular line. This bone segment is pried outward and downward to deepen the acetabulum sufficiently to offer an obstruction to displacement of the femoral head. The prying downward leaves the capsule somewhat lax, and the slack is taken up by reefing this portion of the capsule. A segment of bone from the crest of the tibia is removed, in order to fill up the bone gap and to secure the permanent fixation of the new rim. Albee stated that the method was used successfully in a number of instances. The operation was performed by Albee and Ellis-Jones in two cases of paralytic dislocation of the hip.

Ellis-Jones (1920) published four cases of paralytic dislocation of the hip in which this operation was used. The description of the operation is the same as Albee's ("a four-inch curved lip was turned down and outward approximately one inch above and behind the acetabulum"). Meantime, a diagram revealed that in reality the whole roof had been broken down, a procedure that was entirely new at the time.

As far as can be judged from the literature, Ellis-Jones never performed the operation in cases of congenital dislocation of the hip.

A number of important works were published in the nineteen-twenties. *Fairbank* (1922) was, as far as I know, the first to use the shelf operation in the reduction treatment of dislocation. In cases with insecure retention, he made an upper lip by drawing down a flap of bone from the ilium, which, in his pre-war operations, he fixed into position by sutures to the capsule. He later modified the operation by securing the flap with a wedge of bone pressed into the angle above. Fairbank confined his indications to recurrences in patients under seven years of age. *Spitzy* (1923) performed his first "*Künst-*

liche Pfannendachbildung" in a nine-year-old boy with a dislocation that had recurred following reduction one year previously. This was an entirely new type of operation. A wide, strong graft from the tibia was driven into the pelvis immediately above the acetabular margin, the purpose being to provide a barrier against dislocation immediately after the operation. In the first two cases he also secured reduction by transarticular fixation, but thereafter he found that the tibial graft sufficed to prevent dislocation. This method later became very popular in Germany and Austria.

During the twenties, the most important contribution to the development of the operation came from France. In order to combat pain in chronic dislocation of the hip, *Mauclaire* (1922) constructed a buttress with "*greffons ostéopériostiques*". *Dujarier* (1923) followed König's method, while *Hallopeau* (1923) employed an old animal bone as graft. Although these were only single cases, they signified new indications for surgery. *Lance* (1925) was the first to present a detailed method and to broaden the indications to include dislocation in older children and adults. In the first version, he stressed that, irrespective of the patient's age, reduction should be done in Lorenz' first position, which could only be achieved by rupturing the adductors. In this position the head does not press upward against the roof. Chisels were then introduced into the acetabular roof at the capsular insertion after which their shafts were forced down. The margin below the chisels was at the same time pressed outward and the roof was pressed downward. The resultant bone pocket was then filled with three thin bone grafts from the tibia, one of them being allowed to protrude laterally. In irreducible cases, a bone buttress was constructed above the head after the latter had been drawn downward, and if necessary the insertion of the abductors in the femur was also moved downward. In 1927 the method was modified to suit the individual cases. In subluxation cases in which the head was well inside an acetabulum with excessive sloping of the roof, the margin of the acetabulum was pried down and held in its new position with thick bone grafts. In subluxation cases in which at least half of the head was outside the joint and the roof "*très éculé*", a bone flap was pried down and thin bone grafts were packed above it. In cases that could not be reduced, a bone buttress was built out above the head, either with a bone flap or a pile of grafts, which was placed against the roughened bone. In all the cases the head was lowered by forced abduction.

Lance (1937) published still another modification of the operation after it had been in use for several years. In cases of subluxation with

marked antetorsion, in which the head points forward, the usual bone flap was chiseled out above the head, and a number of soft curved bone grafts were packed above the flap, but were allowed to protrude forward under the tendon of the femoral rectus muscle, thus providing anterior support. It would appear that he did not break down the articular margin in these cases.

Nové-Josserand and *Pouzet* (1933) published an interesting method for six to ten-year-olds. They only pried down the cartilage roof and fixed it in its new position with bone grafts. Apparently this method was not used thereafter. Some of the cases described by *Trillat* (1937) were operated on according to Nové-Josserand, but the method was not discussed. Furthermore, Lance rejected the method in 1937.

Dickson (1924) published a report on surgical treatment of old congenital dislocation of the hip. The technic was the same as König's, but the capsule was excised and the flap fixed in place by a wedge of bone taken from the crest of the ilium. It was the first time the term shelf was used.

Gill (1928 and 1935) outlined a plan for the operative treatment of different types of case, as follows:

Type I: The acetabulum is too shallow to hold the head securely. Dislocation recurs in children, and in adults the hip is subluxated and is unstable and painful. Operation: A bone shelf is turned down above the head. The entire roof of the acetabulum is reflected downward by driving an osteotome deeply into the ilium just above the roof and prying the roof down, bone wedges from the crest of the ilium are driven deeply into this open space to maintain the roof and the bone shelf securely in position.

Type II: The head cannot be replaced in the acetabulum. Open reduction is done and fibrous tissue and occasionally a little of the cartilage is removed. The bone shelf is formed and the roof is reflected down.

Type III: The dislocated head lies higher and cannot be brought all the way down. The socket must be enlarged upward until the head slips in, after which the shelf operation is done as prescribed.

Type IV: The head lies very high. A new acetabulum is formed.

Type V: Absent or short neck of the femur with the capsule attached around the very edge of the cartilage of the head. The capsule must be detached from the head, after which the latter will enter firmly into the socket; the trochanter should be transposed downward on the shaft.

Type VI: Congenital dislocation complicated by infantile paralysis: Arthrodesis is the operation of choice.

We are only concerned here with Type I, not with the more extensive operations used in Types II to VI. For Type I *Gill* suggested a form of shelf operation which, by breaking down the entire roof, aims at

complete anatomic reconstruction of the joint. No age limits for this operation were stated.

Bade (1930) suggested pelvic osteotomy (*"Pfannensprengung"*) that would tip the acetabulum laterally. *Bisgard* (1932) described a method whereby the articular margin was broken off and displaced to the side, the defect being filled with wedges from the iliac crest. *Delitala* (1950) mentioned that he was trying a metallic roof.

The various surgical methods can be classified in two fundamentally different groups:

A. The objective is to enlarge the upper articular margin. The technic varies but the anatomic end-result is the same.
   1. *König's* method of prying down a bone flap above the head.
   2. *Lance's* method in which the bone flap is widened anteriorly with a graft.
   3. *Spitzy's* method of driving a bone graft in the acetabular margin above the head.

B. The objective is to bring the sloping roof into the horizontal plane by prying down either the whole roof or only the margin.
   1. *Albee's* method of prying down the margin.
   2. *Jones'* method of prying down the roof.
   3. *Gill's* method of prying down a bone flap combined with downward reflection of the roof.

It is important to distinguish between these two groups. The Swedish term *panntaksplastik,* the German *Pfannendachplastik,* the French *refection ostéoplastique du plafond du cotyle* and *butée ostéoplastique,* and the Italian *riconstruzione del tetto cotiloideo* all refer to these two methods. *Gill* (1936) preferred to call the operation "plastic construction of an acetabulum", as the formation of a shelf is but a part of the operation. He considered that his combined method was the only effective one. Other orthopedic surgeons were content with one or other of the two methods.

In surveying the literature, one sometimes is conscious of ambiguity due to the terminology. I therefore consider that it would be helpful if each method were given a separate name. The English word shelf and the French butée are descriptive terms for the method based on enlargement of the articular margin. The method aimed at breaking down the roof can suitably be known as *lowering of the acetabular roof,* or the French *abaissement du toit.*

II. Variations in Surgical Technic

1. Incision

The *Smith-Petersen* incision appears to be the one most generally used (*Gill, Lance, Mathieu, Schede, Bergman, Compere, Dickson, Epstein, Frejka, Howorth, Nissen-Lie, Therkelsen, Hackenbroch*). This incision provides good access to the upper acetabular rim and permits relatively thorough supervision of the course of the operation.

The risks associated with the incision are paid surprisingly little attention in the literature.

Therkelsen (1938) remarked that "in virtually all the cases the after-examination showed a more or less marked reduction of strength in this muscle (Gluteus medius)", but he did not go into any further detail.

Lorenz (1951) considered that Spitzy's operation is more satisfactory because the incision is smaller. The Smith-Petersen incision is followed by a long period of gluteal insufficiency with limping and positive Trendelenburg test.

Bergman (1948) was of the opinion that the muscular damage was minimal. He had found no signs of insufficiency, which he attributed to the use of plaster fixation after the operation.

Hackenbroch (1950) had no experience of muscular damage in connection with the Smith-Petersen incision. He discarded the longitudinal incision above the trochanter, since he believed it injured the gluteal muscles.

Spitzy was an early spokesman for a moderate incision, and from 1932 onward he practically always worked subcutaneously with *Nowotny's* special chisel. *Bergman* (1950) further developed this method in adults, in whom the bone is too hard for a chisel. He advocated a special set of instruments for the subcutaneos drilling in the articular margin for the insertion of bone grafts.

Roeren (1930) and *Kochs* (1934) used a straight incision above the trochanter. *Seiler* (1940) operated in the abdominal position and ran his incision along the fibers in the gluteal muscles. Later he changed over to a longitudinal incision at the anterior border of the Gluteus medius. *Riedel* (1930) also operated in the abdominal position. *König* and later *Juwara* (1932) used Ollier's incision.

2. Palliative Operation in Unreduced Cases

In his first report, *Lance* (1925) stressed the new element in his method: reduction by abduction following rupture of the adductors and the operation performed in Lorenz's position.

Schede (1933) used mechanical reduction of the head over the upper articular margin in patients over seven years of age. *Compere* and *Phemister* (1935) reduced older cases by means of prolonged preoperative traction, which was continued after the operation to divert the pressure on the head.

Meiss (1939) was of the opinion that reduction is a prerequisite for the shelf operation.

Gill (1936) used open reduction in the older patients, but only if reduction was easily achieved.

There is a very great danger of injury to the head in reduction in older patients, as has often been mentioned. *Kochs* (1932), for example, avoided this procedure because of the risk of stiffness. *Wiberg* (1944) stressed the risk of coxa plana.

Many workers have tried to confine the intervention to lowering the head of the femur. They have used traction both before the operation and in the postoperative treatment (*Andersson* and *Bickel* [1951], *Ober* [1935], *Dickson* [1924], *Kochs* [1934], *Wiemers* [1934]). Meantime, the great majority of them seem to consider that the risk of damage to the joint is too great. *Howorth* (1935) pointed out that it is not advisable to leave the femoral head under pressure, since this often leads to partial absorption and unevenness of the joint head. *Trillat* (1937) was of the opinion that the construction of a shelf without drawing down the head usually gives better results than the best results when the head is drawn down—all that remains is the shortening. *Lubinus* (1938) always avoided drawing down the head because of danger of osteoarthritis and ankylosis.

3. Determination of the Site of the Shelf

The literature reveals that the bone flap has sometimes been placed too high.

Massart (1946) pointed out that the joint capsule may be as much as two centimeters in thickness. This explains the fact that in some cases a satisfactorily placed shelf cannot be verified by later X-ray examination. Roentgen control is the basis of Spitzy's method. This has usually been considered unnecessary in the methods using the flap technic or downward reflection of the roof. *Hackenbroch* (1950) dissected the capsular insertion in order to be able to put the bone graft in the right place. *Waldenström* (1932) performed his first operations under X-ray supervision. He took an X-ray on the operating table when the graft was placed in position over the acetabulum. If it lay too high, he continued the chiseling to some millimeters over the acetabulum.

4. Grafts

Mathieu (1930) only turned down a bone flap and fixed it in position by applying bone chips.

Putti (1929) described a technic according to which he turned down a bone flap, above which he cut down further bone flaps in the form of shingles.

Lowman (1931) used the following technic for operations on inveterate cases of dislocation of the hip. The head was pulled down and a new socket cut in the bone. Then two flaps of cortex were pried down over the femoral head. Bone chips were then fitted above the flap.

Dickson (1924) removed the joint capsule in inveterate cases of dislocation of the hip and turned down a flap of bone over the femoral head. The flap was then fixed in position with a wedge of bone from the iliac crest.

Roberts (1944) pried down a flap of bone directly over the femoral head and brought the capsule up over the flap (cf. Gill, 1928, and Massart, 1947).

With regard to Spitzy's technic, *Roeren* (1930) inserted two bone grafts so as to achieve an angular roof. *Compere* and *Phemister* (1935) used three bone grafts, as did *Lubinus* (1938) also. *Juwara* (1932) used a very wide tibial graft corresponding to the entire anterior surface of the tibia.

Lexer (1914) and *Wiemers* (1934) used a piece of the trochanter as a roof, and *Lubinus* (1938) fastened a graft of the iliac crest with a nail in some of his cases.

Waldenström experimented with several variations of Lance's technic (published by Wiberg in 1944). In some cases he used Orell's os novum instead of a tibia graft above the bone flap. In others he used cancellous os purum only. In still another group of cases he used a large piece of the iliac crest, which he attached with two os purum nails inserted into the ala ilii.

5. Lowering of the Acetabular Roof

Dickson (1934) wrote "that the problem presented by a deficient acetabulum is a comparatively simple one" and that it can be satisfactorily remedied by a type of shelf operation described by Albee and Jones.

Gill was also in unqualified favor of downward reflection of the roof of the socket, but considered that this operation should always be supplemented by enlargement of the articular margin. Other sur-

geons have used Albee's operation only (*Lecocq* 1932, *Smith* 1937, *Crego* and *Schwartzman* 1948). *Howorth* (1947) stated that the shelf operation by itself usually proved most satisfactory compared with downward reflection of the roof or Spitzy's method. *Meiss* (1939) changed from Spitzy's method to the Lance-Albee method, since he considered that it gave a better guarantee against redislocation and that it restored the ability to bear weight relatively quickly.

Wiberg pointed out (1953) that the "chiseling medially should run relatively near and parallel with the roof, so that the part which has to be turned down is not too thick, as this may make it both difficult and dangerous".

6. Postoperative Fixation

Fixation in plaster is recommended by practically all surgeons, with the exception of Dickson and Mathieu, who prescribed extension only. The period of fixation varies from one to four months. Gill, for example, recommended plaster fixation for one month followed by extension in reconstruction cases.

III. Bases for Judging Roentgenograms

1. Classification of Cases

The roentgen-anatomic examination permits a certain classification of material. As a rule remarkably little attention is paid to this point in the literature. The only differentiation is usually between dislocations and subluxations, although a few writers have proposed a more detailed classification.

Trillat (1937) differentiated between anterior supported dislocations *(luxations antérieures appuyées)*, high posterior dislocation, bilateral cases and the other cases.

Wiberg (1944), the first to adopt a more detailed system, divided the cases into dysplasia, subluxation, and dislocation. He pointed out that the subluxation group would be relatively large, but that it was difficult further to break down this category.

Andersson and *Bickel* (1951) classified their material according to the CE-angle.

Normal hips: a) normal, b) uncertain: CE-angle to 25 degrees. Dysplasia with deformity: a) mild CE-angle, 20 to 25 degrees, b) moderate, CE-angle under 20 degrees.

Subluxation: a) moderate CE-angle, slightly positive or equal to zero; b) CE-angle negative.

Dislocation: a) secondary acetabulum, b) no acetabulum.

2. Shelf

Howorth (1935) wrote: "A shelf which laterally extends at least to the highest points of the head and is separated by no more than the thickness of cartilage and the capsule and which presents no atrophic or osteophytic changes of consequence is classified as a good result. A shelf too high or too narrow is listed as poor. Shelves between these two classes are grouped fair."

Massie and *Howorth* (1950) declared that "a shelf cannot be considered adequate unless it forms a continuation of acetabular articular surface. A projection some millimeters above the edge of the superior rim cannot effectively support the femoral head unless the head is subluxated."

Trillat (1937) considered that a satisfactory shelf does not cross the contour of the head in the X-ray, has a volume large enough to resist pressure and is placed at a minimal distance from the head.

Andersson and *Bickel* (1951) classified a shelf too high or too small as unimproved.

Most authors do not classify results according to the position of the shelf, but a case in which the shelf has been absorbed is often reported as a poor result.

3. Axial Projection

Howorth (1935) used "oblique" roentgenograms in his after-examination (a case with too narrow shelf is listed as a poor result).

Charry (1948) stressed that the "profile" projection allows inspection of the position of the shelf.

IV. Standards for Judging Results

If the operation has been performed because of a tendency to recurrent dislocation in connection with the primary treatment, like the cases described by *Fairbank* (1922) and *Nissen-Lie* (1951), the results are judged from the roentgenologic point of view. Many authors report their results in the form of a general appraisal from good to poor (*Lance, Gill, Pasquali, Schede, Dickson, Platou, Spitzy,* etc.). *Lecocq* (1932) based his judgement on stability, degree of limp and of shortening, *Schede* (1933) on range of motion, *Kochs* (1934) on roentgen results plus clinical status, *Wiemers* (1934) on clinical status and roentgen finding, *Steindler, Kulowski,* and *Freund* (1935) on clinical status and subjective reports of endurance. *Howorth* (1935), like *Smith* (1937) reported on the roentgen and symptomatic results

separately, while *Trillat* (1937) based his opinion on the degree of limp in cases operated on for preventive purposes and on subjective reports in cases operated on for pain. *Lubinus* (1938) also included in good result a good shelf, no pain, and negative Trendelenburg test. *Therkelsen* (1938) listed his results as good, improved, and unchanged; among those labelled improved, he included those in which the bone graft was not satisfactory (too high or too small). *Barcat* (1938) grouped his cases merely according to clinical status and symptoms, making no mention of roentgen findings. *Meiss* (1939) insisted on good or satisfactory support and for a good result adequate range of motion, and no symptoms. *Seiler* (1940) also insisted on clinical and roentgen evidence of success before he would call a result good. *Wiberg* (1944) graded results according to subjective reports. *Gila* (1950) reported the number of good functional results, as well as the proportion that showed satisfactory roof. Similarly *Ravaglia* (1950) reported on painless and poor cases in relation to good and poor roofs. *Lorentz* (1951) judged his cases according to function. *Andersson* and *Bickel* (1951) labelled too high or too small shelves as unimproved and judged all other cases according to function. *Massie* and *Howorth* (1951) reported the results of shelf operation in open reduction according to the roentgen result.

V. Results of the Shelf Operation

A. Classified Material

1. *Unstable Retention*

Fairbank (1922) published the results of his "upper lip" operation for recurrence of reduced dislocation in nine patients under seven years of age. The results were satisfactory in four cases. Fairbank considered these results encouraging. He did not, however, discuss the question whether the good results were due to the operation or only to the renewed reduction treatment. Nor did he define the term "satisfactory results".

Lance (1927) reported that reliable retention was achieved in five children with recurrent luxation. In 1942 he gave an account of 20 cases with no acetabular roof, in which the stability was poor after reduction: the results were satisfactory in 80 per cent. Here, too, various data are lacking, including information as to whether the patients were given after-examination.

Gill (1943) stated that the results were poor in only four of 42 operations on Group I cases (the head can be reduced but the aceta-

bulum is too shallow for firm retention of the head) with an observation period of 3 to 20 years. He did not mention the total number of cases operated on or the age at the time of operation. It would appear that no patients operated on before the age of five years were included. He mentioned that he had a few failures in children under five years. He therefore postponed operation until the patients were five, keeping the extremity abducted in plaster or a brace in the meantime.

With regard to the indication unstable retention, *Nissen-Lie* (1951) published the largest series, consisting of 57 patients and 60 operations. He concluded that if reduction is not successful, a shelf will not prevent a poor result, and if reduction is good a shelf is seldom necessary.

Crego and *Schwartzman* (1948), in a follow-up study of reduced dislocations, also reported on the results of acetabular reconstruction. The indication for operation was unstable retention following reduction. Results: normal in nine operations, almost normal in seven, satisfactory (acetabulum deficient) in 16, and failures in eight. There was no discussion of the way in which the operation affected the results.

Kochs (1934) published a follow-up study on 33 cases operated on according to Spitzy. Most of the patients were operated on between the ages of five and seven years after several attempts at bloodless reduction had failed. The results were good in 48.6 per cent. However, since the material also included both poliomyelitis and coxitis cases as well as older patients, it is difficult to form an opinion of the results in the dislocation cases. In 1950 *Kochs* published a second follow-up on 27 of 70 cases operated on. This study showed good clinical and roentgen results in 55 per cent, poor in 22 per cent, and clinical improvement in 78 per cent.

2. *Pain*

Tillier (1927) reported on five secondary cases from Nové-Josserand's clinic (11 to 12-year-olds), in which freedom from pain was achieved despite the fact that the shelf was too high. However, the period of observation (six months to one year) is not long enough to permit of any conclusions.

Trillat (1937) published 27 operations, in 19 of which the pain was relieved, although the shelf had been absorbed in some of them. In conclusion it was stated that the clinical results in subluxation often corresponded with the anatomic. The pain, however, disappeared

regardless of the mechanical qualities of the shelf. Meantime, some of the cases had been after-examined by correspondence, and it is impossible to deduce how the cases were evaluated, how many of them were X-rayed and the length of the observation period.

Lance (1942) reported satisfactory results in 87.5 per cent of 89 operations, combined with osteotomy in nine. Follow-up was done in 27 cases with an observation period of 3 to 13 years, revealing satisfactory results in 70.4 per cent. However, not all these cases were secondary subluxations.

Therkelsen (1938) published the results of the Lance-Mathieu operation in subluxation (primary and secondary). The results were good in 55 per cent, improved in 23.3 per cent, and unimproved in 21.7 per cent. Since the improved cases included those with poor shelf, the 55 per cent represents the genuinely good results. The period of observation was one to nine years, with an average of 3.25 years. This investigation is well documented. With regard to pain, 45 per cent of the results were good and 42.4 per cent improved.

Barcat (1938) published a follow-up study of cases treated by Mathieu and Lance. Primary subluxations were free from pain in 64 per cent (good results in 77.3 per cent) and secondary subluxations in 70 per cent (good results in 88.2 per cent). The period of observation varied between 18 months and 13 years. No mention is made of whether after-examination had been done nor of the number of cases X-rayed. Barcat considered that the operation is indicated in painful subluxation. Concomitant osteoarthritis or considerable epiphyseal deformity constitutes a relative indication, in his opinion, while the operation is counter-indicated in severe osteoarthritis, osteoarthritis plus major deformities of the head and in patients over 45 years.

Loubat and *Pouyanne* (1947) made a study of ten operations in cases of painful subluxations. The period of observation was 14 months to 16 years. Seventy per cent were free from pain. No mention is made of the anatomic results.

Wiberg has already (1944) made a follow-up study of part of our material. 72.3 per cent of the dysplasia, subluxation, and dislocation cases were free from pain. Pain was suffered by 33 patients before the operation, while 13 had pain after the operation, three of them for the first time. Wiberg used the subjective symptoms as standards of evaluation.

Putti (1929) considered that the results in subluxation are good between the ages of 12 and 15 years. After the age of 20 years, he believed that the operation does no good in reduced joints.

Pasquali (1939) advised against the intervention in old inveterate cases and confined the operation to 15 to 20-year-olds. He considered that the reconstruction may provide an obstacle to displacement of the head of the femur, but that one cannot expect the new roof to relieve symptoms that have resulted from previous treatment.

Salaroli and *Cozzolino* (1950) made a follow-up study of 50 cases of subluxation of a series of 101 cases operated on. The period of observation was under one year to five years. These authors concluded that the best results are achieved in the second decade of life, in view of the fact that they found the same results in the age groups 10 to 14 and 15 to 20 years. The flap technic and a method resembling Spitzy's gave the same results.

Ravaglia (1950) published 30 cases. Indications: pain and displacement. He considered that the shelf operation lessens the risk of osteoarthritis. He was of the opinion that the operation gave good results in the cases of primary subluxation, but that the indications are more difficult to determine in the secondary cases because the anatomic conditions are less good and are sometimes complicated by severe osteoarthritis. He considered that the type of method was of no importance.

Gila (1950) operated on primary and secondary subluxations both with pain and with osteoarthritis. He considered that the best age for the operation is 13 to 19 years.

Bocchi and *Massera* (1951) had 11 successful cases and 6 poor ones. The age of the patients ranged from 4 to 19 years. Their best results were in untreated patients of 9 to 12 years. The period of observation was 7 to 16 years. They considered that the operation gives good results, improves function, relieves pain and prevents arthritis deformans.

In summarizing some of the best documented investigations, we find relatively good results in primary subluxation, as follows: *Therkelsen,* 44.4 per cent good; *Pasquali,* 57.1 per cent good; *Ravaglia,* 64.3 per cent good (excluding those with poor shelf). In the secondary cases the results varied widely: *Therkelsen,* 58.8 per cent good; *Pasquali,* 19 per cent good; *Ravaglia,* 40 per cent good (excluding those with poor shelf).

Therkelsen considered that age has no importance. *Pasquali* confined the operation to the age group 15 to 20 years. Without referring to any specific series, *Putti* stated that 12 to 15 years is the best age, and *Scaglietti* (1950) was against operation after the age of 18 years.

Casuccio (1950), on the other hand, stated that the operation is unreliable, since the results cannot be foreseen and the late results

may be poor even if the immediate postoperative picture is successful. He also wrote that one may achieve good antomic results with poor functional and vice versa. Unknown factors are at play, in his opinion, and the symptoms are periodical.

3. *Osteoarthritis*

It has long been recognized that osteoarthritis may develop on the basis of a subluxation. *Wiberg* (1939) published a series in which previous X-ray examination had revealed dysplasia or subluxation without signs of osteoarthritis. He, however, found roentgen signs of osteoarthritis in every case in the series. Wiberg noted that the symptoms of osteoarthritis appear earlier in women (mean age 36.6 years) than in men (mean age 54 years). In women, however, there was a predominance of subluxation cases as compared with dysplasia only in men. From this he intimated that osteoarthritis develops earlier in subluxation than in dysplasia.

Why a dysplastic hip joint becomes osteoarthritic we do not know. *Preiser* (1907) assumed that the explanation is poor adaption between the articular surfaces. *Schede* (1933) suggested that it is not only the incongruity of the articular surfaces but primarily the displacement of the head of the femur that gives rise to osteoarthritis. *Wiberg* (1944) assumed that the decreased supporting surface is the cause of erosion of the cartilage.

It has been assumed that the development of osteoarthritis could be prevented with the help of the shelf operation, but this point has received little attention in the literature. *Schede* (1933) and *Bergman* (1948) were of the opinion that the shelf removed the chief cause of osteoarthritis by preventing displacement. *Ravaglia's* (1950) operative aims were to treat pain and slipping and in that way reduce the risk of osteoarthritis.

So far it has not been possible to present evidence of the value of the shelf operation in preventing osteoarthritis, since the periods of observation are too short.

Only a few papers have been published concerning the shelf operation in cases in which osteoarthritis has already made its appearance. *Ravaglia* (1950) stated that the results are poorer in advanced osteoarthritis. *Filippi* (1950) was of the opinion that osteoarthritis can neither be improved nor checked, and *Delitala* (1950) advised against operating on deformed cases. *Hackenbroch* (1950) considered it pointless and even harmful to perform the shelf operation if even the beginnings of osteoarthritis are discernible.

4. *Palliation in Dislocation*

As long ago as 1893, *König* advised against the shelf operation in dislocated hips. Likewise, *Lexer* (1914) reported, on the basis of eight years of experience, that his results had been poor—redislocation and rigidity—and that he had changed over to arthroplasty.

Dickson (1924) published five cases, in which he drew down the femoral head and excised the capsule. One year after operation he found three of his cases to be successful, one case of osteoarthritis and one of rigidity. In 1935 he had better results with a series of 28 cases: satisfactory results, 82.2 per cent; improved 7.7 per cent; failures, 10.1 per cent. However, he did not mention the length of observation, nor did he define the results.

Lance (1942) published a study on the results of the shelf as a palliative measure in 32 non-reduced cases, in 11 of which the operation was combined with osteotomy. His results were satisfactory in 78 per cent. Only a few of the cases were followed-up.

Steindler, Kulowski, and *Freund* (1935) used the operation as a palliative measure in 21 cases, with good subjective and functional results in 10 and fair results in 6 cases. The shelf was absent in 5 cases, not checked in 4 and present in 11 cases. The distribution of these cases between good and bad results is not revealed. The average observation time was 2.18 years.

Smith (1937) did shelving as a palliative operation in 25 patients with an observation time of one to nine years. Twenty of his cases were X-rayed one year or more after the operation. He had good results in 14 and fair results in 4 cases. In 15 of them the anatomic and functional results were in conformity. In 3 cases the functional results were poor despite the good anatomic results. All the patients with good functional and anatomic results were over ten years of age.

Andersson and *Bickel* (1951) published the results of 76 cases with 86 operations. The observation time for 70 cases was from 13 months to 13 years, or an average of 56 months. After-examination was done in 43 cases. Of 80 hips examined, 40 were in good condition. These patients underwent heavy traction for several days.

McCarrol (1948) described the treatment of anterior congenital dislocation with anterior massive shelf in 12 cases with the following results: good, 1; fair, 5; poor, 6.

Compere (1939) concluded that shelving of unreduced hips gives such slight improvement (freedom of pain in 20 per cent) that the operation is not justified. *Wiberg* (1944) reported good results in 8, improved in 4, and poor results in 6 cases.

It should be noted that the majority of workers aim at achieving greater stability of the hip joint and, therefore, perform the operation under more or less pronounced downward traction of the head. This is a procedure that will easily damage the head, and one might, therefore, expect less satisfactory results with this method than if the shelf were constructed above the head without downward traction. However, opinions vary widely on this point. It has obviously been very difficult to provide after-examinations for the entire series presented by the various authors, and it is therefore impossible to form any clear opinion of the results. Finally, observation periods of one year would appear to be inadequate.

B. Unclassified Material

Table I.

Authors	No. of cases	No. of follow-ups	Results			Length of observation
			Good	Improved	Poor	
Lecocq 1932	23	—	19	2	2	< 1 yr—4 yrs
Nové-Josserand and Pouzet 1933	12	—	5	4	3	20 mos—4 yrs
Schede 1933	20	—	10	8	5(?)	—
Wiemers 1934	44	—	22	11	4	1—8 yrs
Howorth 1935	18	—	anat. 78 % symp. 78 %	anat. 11 % symp. 22 %	anat. 11 % symp. 0 %	1—9 yrs
Ooms 1935	16	13	10	—	3	3—21 yrs
Lubinus 1938	46	38	31	4	2	—
Meiss 1939	57 19	44	66.5 % 52.6 %	22.8 % 36.8 %	10.4 % 10.6 %	> 2 yrs < 2 yrs
Seiler 1940	39	20	36.8 %	36.8 %	26.4 %	—
Platou 1950	12	—	5	—	7	—

VI. Views on Indications

Wiemers (1934) found the operation unsuitable in high dislocation, in patients over ten or eleven years, and in cases in which the acetabulum is too small and irregular in shape.

Kochs (1934) considered that the operation is indicated if reduction is possible but retention impossible because of an inadequate acetabular margin.

Meiss (1939) listed the indications as follows: all reduced dislocations, which show insufficient development of the acetabulum four years after reduction; all reducible luxations in patients over six years; all late exacerbations from puberty to the fourth decade, as soon as the femoral head is found to become displaced on weight-bearing.

Seiler (1940) was of the opinion that the operation should be performed on children in whom the acetabular roof does not grow, in all cases of recurrent dislocation or subluxation and in all older patients with coxa valga luxans who complain of pain and who still exhibit no osteoarthritis.

Gill (1943) wrote that "dysplasia of the acetabular roof does not demand operation unless it is accompanied by persistent or increasing subluxation".

Bergman (1948) stated that the shelf operation according to Spitzy cannot be expected to do more than prevent displacement and will not have any effect on the Trendelenburg symptom. Correction of the incongruity of the joint and increase of the weight-bearing surface will, in his opinion, prevent the development of osteoarthritis.

Howorth (1935) expressed the view that the "shelf operation is rarely necessary for patients under the age of five years and is usually inadvisable before that age because of the difficulty of getting the shelf low enough, due to the large amount of cartilage in the acetabular roof".

Wiberg (1944) considered that cases with negative CE-angle after reduction should be submitted to operation, but that operation can be postponed if the CE-angle is between 0 and 15 degrees at the age of four years. He later stated (1953) that the shelf operation is indicated when reduction is attempted as late as the sixth or seventh year, when redislocation occurs, and in cases under seven years with a tendency to subluxation.

VII. Function of the Shelf from the Roentgen Aspect

1. Transformation of the Shelf

Spitzy (1932) pointed out that there is moderate thickening of the bone graft in all cases, since only the free end projecting beyond the head is absorbed. He did not elaborate on this point.

Therkelsen (1938) noted that the shelf increased in size in 25 cases, grew smaller in 8, and was sclerosed corresponding to the conditions of pressure in 4.

2. Absorption of the Shelf

Gill (1943) considered that the failure of the operation under five years of age may be due to the fact that the acetabular roof is largely cartilaginous and the operative procedure damages its blood supply and prevents its conversion into bone. He had not observed this absorption of the shelf or buttress in patients over five years of age.

Colonna (1951) had the experience in the younger age groups of having the shelves undergo absorption.

Ober (1935) wrote: "In one half of the 26 cases the shelf partially or wholly disappeared leaving the head in its original position. The reason was not clear. There were only treated cases of persistent dislocation".

Lance (1942) considered that absorption of the shelf does not occur if the technic of reflecting down a bone flap is followed. He mentioned 33 operations in patients from two to six years of age with no absorption. He did not state the observation periods.

Crego and *Schwartzman* (1948), who practised downward reflection of the roof, reported that "the results before five years are good".

Massie and *Howorth* (1951) wrote: "It is technically difficult to produce an adequate shelf in a patient younger than five years of age, but when properly constructed the shelf remains adequate and materially improves the prognosis." Their results were as follows: 3 to 6 years: adequate in 2, poor in 5 cases; late operation: adequate in 4 and poor in 3 cases (observation: 15 to 18 years).

Bergman (1948) considered, on the basis of case reports, that absorption occurs if the graft is placed too high or covers the head so inadequately that displacement cannot be prevented. He agreed with Roux that mechanical factors are primarily responsible for the fate of the graft. The alternation between pressure and removal of pressure stimulates the formation and growth of bone. The bone graft is absorbed if the pressure of weight-bearing is removed, and always is absorbed if the graft is placed too high (after only 1.5 years).

VIII. Complications

Table II.

Authors	Infections Late sequelae	Damage to femoral head with osteoarthritis	Deaths
Scholder 1930		1	
Froelich 1930			1
Spitzy 1932		1 (ankylosis)	
Trillat 1937	1 (ankylosis)		
Therkelsen 1938	2 (one ankylosis)	2	
Barcat 1938	2 (one ankylosis)		
Meiss 1939	3 (poor results)		
Loubat and Pouyanne 1946	1 (ankylosis)		
Andersson and Bickel 1951	1		

IX. Shelf Operation in Sweden

Hybbinette (1929) published four cases of dislocation operated on successfully.

Waldenström appears to be the first in Sweden to have used the method consistently. In 1932 he published his first two cases of primary subluxation operated on according to Lance. He had them under observation for 18 months, and, since the results were good, he considered he was justified in continuing to use the operation.

Wiberg (1939) reported the results of Waldenström's first 28 cases, two years being the shortest observation time, as follows: good 17.9 per cent, considerably improved 57.1 per cent, slightly improved 21.4 per cent, and unimproved 3.6 per cent.

Wiberg (1944) published a follow-up study on 90 cases with an observation time of one to seven years. The results were excellent in 16.7 per cent, good in 55.6 per cent, improved in 14.4 per cent, unimproved in 12.2 per cent, and worse in 1.1 per cent.

In two subsequent papers (1951 and 1953), *Wiberg* discussed both operative technic and indications.

To illustrate the position of the operation in orthopedics, I shall quote the views of two authorities in the field:

H. Platt (1943): "The shelf operation, attractive in theory but difficult in execution, has been practised far too indiscriminately. Many shelf operations are in my judgement of pictorial value only—merely anatomical exercises in one plane. This is true of some of my earlier operations. I am not convinced that a shelf which merely prolongs a sloping roof over an eccentrically placed head contributes materially to the stability or function of the hip. The same criticism is applicable to the construction of a shelf over an unreduced dislocation, which a number of eminent authorities continue to regard as a sound procedure. The essential basis of the shelf operation is that the socket roof should be lowered over a concentrically replaced head. This is a formidable undertaking in the young child, and there is the risk of interference with future acetabular growth."

A. Bruce Gill (1949) commented on a paper concerning the shelf operation as follows: "I have repeatedly emphasized the importance of correcting the obliquity of acetabular roof and of constructing the shelf as an integral part of this reflected roof so that the roof with its added extension covers snugly and accurately the entire upper portion of the head of the femur. If this operation is performed properly, the head of the femur can never thereafter travel upward and outward. This demonstrates not the futility of the shelf operation *per se* but rather the poor results of inadequate surgical treatment. When the head of the femur does not lie in the primary acetabulum or cannot be placed within by gentle manipulation, the shelf operation should be considered as a palliative procedure which cannot be expected to produce a perfect hip, but which will relieve or abolish some of the symptoms, particularly pain and disability, if the operation is properly done. This paper on the end-results of the shelf operation, like similar previous papers, serves chiefly to demonstrate the poor results that may by obtained by doing a good operation badly."

Present Investigations

I. Material

The material upon which the present investigation is based comprises the cases submitted to operation at the Orthopedic Clinic of Karolinska Institutet, Stockholm, from 1935 through December 1946.

Altogether 173 patients were operated on, representing 213 operations.

Six cases (7 operations) were discarded because of the lack of adequate after-examination. The records in these cases indicate that one of the patients was free from symptoms for seven years, after which pain set in; one was improved two years after the operation but had not returned to work; one showed no improvement; one was worse with continued dislocation. The results were not known in the two remaining cases.

Another five cases were eliminated, in which acetabular reconstruction was supplemented by stabilizing operations:

Four cases of subtrochanteric cuneiform osteotomy (Nos. 1903/36, 3022/36, 2580/36, 2770/36);

One case of downward displacement of the trochanter (No. 1616/44).

Three patients who had been followed up and who represented five operations (Nos. 3475/39, 3867/39, 3969/44) were eliminated because of uncertain diagnosis. These cases will be discussed later.

After-examination was conducted in 167 cases, or 96.3 per cent of the patients operated on. Excluding the discards, there remain 159 patients, or 91.3 per cent of the total operated on. Follow-up examinations were conducted by the writer in 163 cases and by other orthopedic surgeons in four cases. Sixteen of the patients were men, 143 were women. The operation was bilateral in 35 patients.

Altogether 196 operations were evaluated; two of them were repeats (Nos. 31034, 1871/36). The results of each operation will be discussed separately. *Bilateral interventions are therefore recorded as two separate cases.*

Two years was the minimum period of observation. Within this period the shelf should be incorporated and the muscles should be

rehabilitated. The observation time was less than two years in two cases, in one of them because it was already evident that the result was poor and in the other because observation for 23 months was considered to be relatively satisfactory. In the youngest patients the age at after-examination is more important than the length of the observation period, because the anatomic results in some cases cannot be evaluated before the patients have reached the age of nine or ten years. Higher ages at after-examination are obviously preferable if one is interested in evaluating the operation as a preventative of osteoarthritis.

The age distribution of the material at the time of the operation and the observation times are shown in Diagrams 1 and 2.

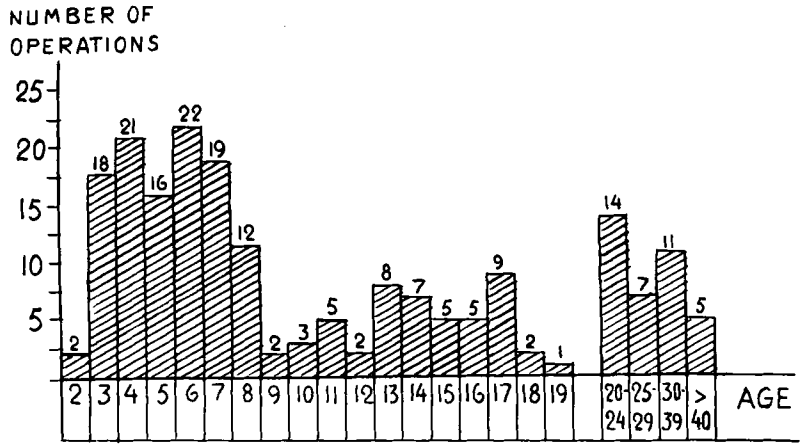


Diagram 1. Distribution of the material in different age groups at the time of operation (196 operations).

The earliest operations were performed according to Lance; a bone flap was reflected downward and the upward sloping articular margin was pried down. The bone flap was fixed in place by tibial grafts which protruded anteriorly. It does not appear from the case records whether the pronounced reduction-abduction position was applied, as prescribed by Lance. The limb was fixed in plaster after the operation. The operation was later modified in various ways. Os novum was used instead of tibial grafts in occasional cases, while wedges from the iliac crest, attached with os purum nails, were employed in others. The tibial grafts were replaced by cancellous os purum in a few cases. Meantime, from 1938 onward the bone flap was fixed with wedges from the iliac crest in all the cases. In some of the cases the articular margin was also reflected down, while part of the roof could

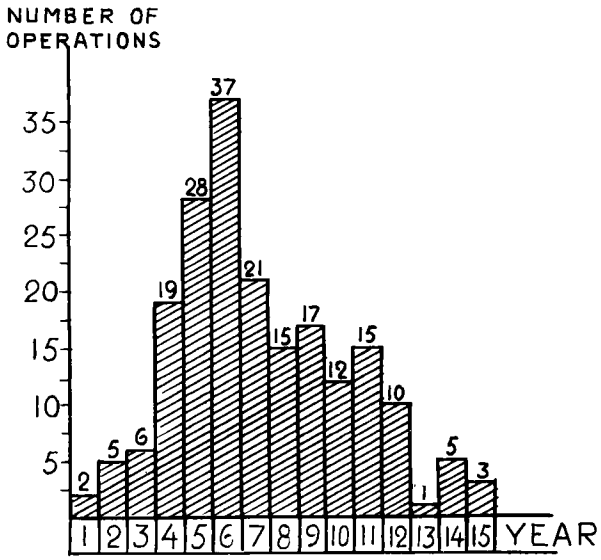


Diagram 2. Distribution of the material with regard to the observation time.

be pried down in rare cases. Only in the latter group may it be claimed that Gill's principles were applied. In the others, in which the margin was reflected down, the operation rather represented Albee's method combined with a shelf. Most of the cases had only a bone flap reflected down over the femoral head, according to König, and held in position with wedges of the iliac crest. The Smith-Petersen incision was used in all the cases. This, of course, represents complete detachment of the origin of the tensor fasciae latae and partial detachment of the gluteus medius and minimus from the ilium. In some of the cases the oblique tendon of the femoral rectus was resected. The acetabular margin was located with the help of X-rays in a few cases, although this was generally done by palpation. A bone flap, large enough to fit the antero-posterior extent of the joint, was then reflected down over the femoral head. The chisel was inserted about three centimeters above the femoral head, just behind the corticalis. As the capsule was approached the chisel was directed medially, i.e. held in a more horizontal position, parallel with the roof. The shaft was pressed downward, whereupon the bone flap settled over the femoral head, and in some cases an attempt was made to break the roof down. The bone flap was fixed into position with three or four bone wedges from the iliac crest. The muscles were then sutured back into place with silk or catgut.

The first four cases (method: bone flap plus iliac crest wedges) were put into plaster fixation, as in earlier operative procedures.

Thereafter, traction with a weight of three or four kilograms and the leg in mild abduction was used in all cases with the exception of four unstable ones. In the majority of cases, traction was maintained for six weeks in children and eight weeks in adults. After a further four weeks in bed, with physiotherapy (recently shortened to two weeks), the patients walked with crutches for two months before full weight-bearing was permitted. The period of fixation was longer in the earliest cases.

II. After-examination

A. Bases for Judging the Anamnesis and Clinical Findings

The after-examination was in general conducted as a clinical examination, with recording of the case history, checking of the physical condition, and a roentgen examination. The patient described his condition with regard to fatigue and endurance, pain and limp, and possible stiffness. He was then queried as to the improvement or exacerbation of his symptoms since the operation, only definite answers being recorded. In addition, the patient was questioned regarding possible periods of exacerbation during the observation time. The patient's habits with particular reference to physical exertion were carefully analyzed. A patient who avoids all physical exertion after the operation and even changes from manual labor to sedentary work may have improved considerably as the result of his change of occupation. This type of case must be excluded from the material if it is hoped to determine the direct effect of the operation. In the case of children, the patient's statements regarding freedom from symptoms are not always truthful, because the child does not want to risk further hospitalization. It is therefore important that the mother be present at the examination. The examiner noted the degree of limp, range of movement with the hip in extension, circumference of the thigh, and length of the leg.

The *Trendelenburg* test was graded as follows:

1) the half of the pelvis not bearing weight could be elevated;
2) the half of the pelvis not bearing weight could be elevated only to the mid-position, i.e. to the level of the contra-lateral gluteal fold;
3) the half of the pelvis not bearing weight dropped down.

In addition, note was made of active and passive abduction motion in the lateral position. At the same time, the strength was tested by resistance movements in abduction, extension and flexion. Furthermore, the tensor fasciae latae and the gluteus medius were palpated

in connection with the *Trendelenburg* test. Absence of the normal bulge on muscular contraction or the existence of a muscular defect in the form of a depression were noted.

B. Bases for Judging the Results of the Roentgen Examination

Two pictures were taken at each examination before and after the operation: one frontal exposure with the roentgen tube at a distance of 80 to 100 cm with the central ray immediately above the symphysis and the legs parallel with the patellae facing upward; one exposure with the *Lauenstein* projection. The same principles were followed in the after-examination, except that an axial exposure of the joint was also made. The purpose of this was to form an opinion of the

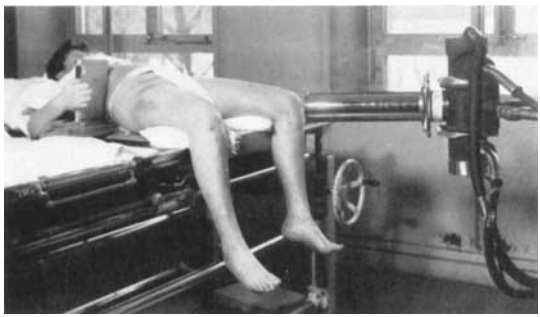


Fig. 1. Position of the patient for axial exposure.

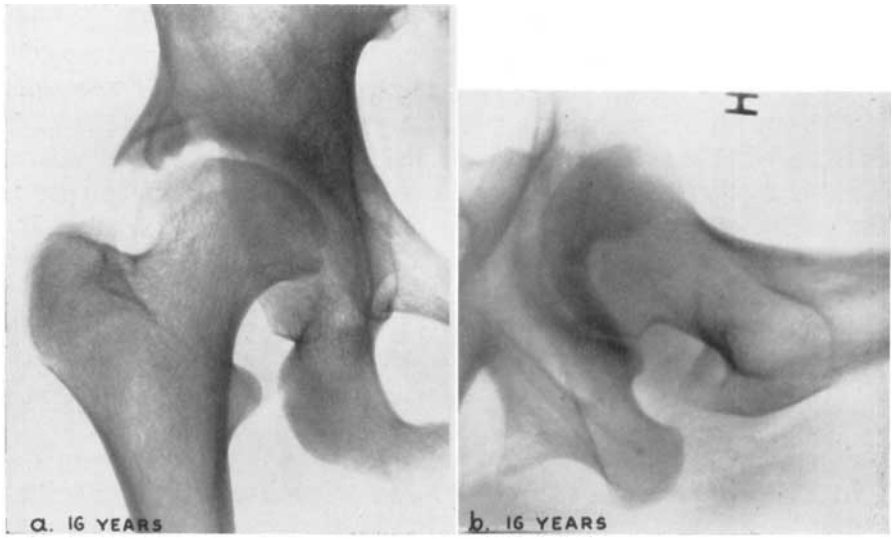


Fig. 2. Case No. 3924/42. Type: secondary moderate subluxation. a. Shelf: good. — b. Axial projection: The shelf covers the anterior half of the femoral head.

extent of the shelf in the sagittal plane, i.e. the proportion of the head covered by the shelf. Obviously the frontal picture only would not suffice to show the appearance of the shelf.

The profile exposure was taken with the patient lying on a table with the backs of the knees on the edge of the table, the lower legs hanging straight down in 90 degrees flexion, and the hips in 15 to 20 degrees abduction (Fig. 1). Small cushions were placed under the knees to prevent extension in the hips. The roentgen tube was centered on a point behind the antero-superior iliac spine corresponding to the position of the joint and at an angle with the longitudinal axis of the body of approximately 15 to 20 degrees. The film container was pressed into the patient's waist just above the iliac crest at right angles with the central ray. The shelf is much less dense than the head, and the contrast between the two was, therefore, not clear, though it was adequate in most cases to permit determination of the extent of the shelf in the sagittal direction (Fig. 2).

1. *Measurement*

Evaluation of the X-rays proved to be very complicated. The material was so varied that practically every case was unique. In many cases the picture changed considerably during growth. Naturally the Y-cartilage as a fixed point was helpful, but after ossification it was hard to define the changes that occurred. Wiberg's CE-angle is exceedingly helpful, but it is restricted to dysplasia. In cases of subluxation, which are combined with deformed femoral head, it is difficult to determine the center of the head. Even more important, it is impossible in cases that have been operated on to use the CE-angle to ascertain whether displacement has occurred, or rather to estimate the extent of displacement visible to the eye.

In the hope of establishing a more objective and recordable norm for measuring displacement in the hip joint, I went through the roentgenograms in 40 cases in the series and measured them by different methods.

First I experimented with a center line for the pelvis; such a line will be relatively uncertain, since it must be drawn through rather large surfaces like the spinous processes of the sacrum and the symphysis. However, since these bearings are on different planes, even a slight lateral tilt of the pelvis results in an appreciable change in the central line. A horizontal line drawn as a tangent to the two tear figures' lower convexity is more stable in relation to the head of the femur. If two vertical lines, one through each tear figure, are drawn from these two tangential points, one can state the position of

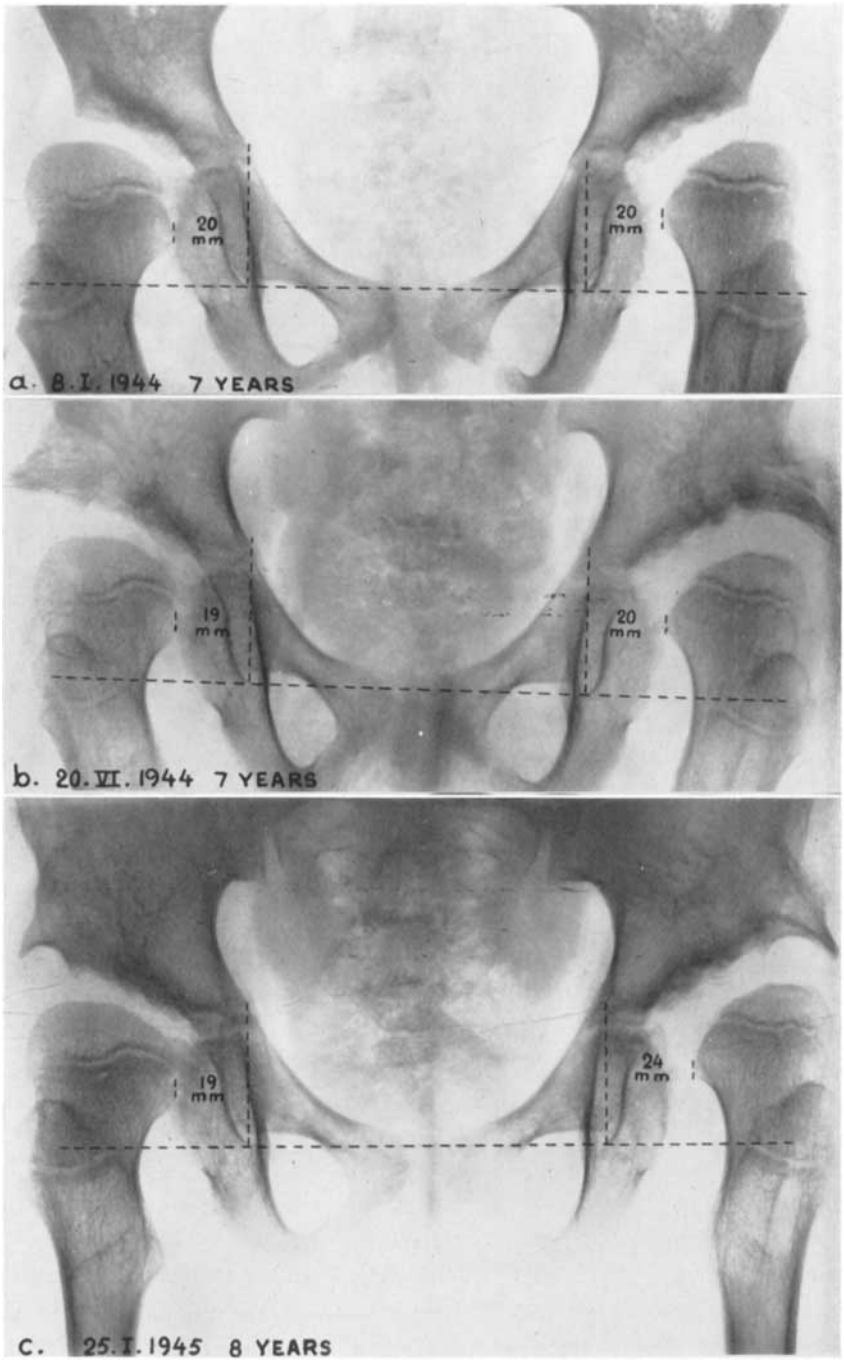

20 mm
20 mm
a. 8.I.1944 7 YEARS
19 mm
20 mm
b. 20.VI.1944 7 YEARS
19 mm
24 mm
c. 25.I.1945 8 YEARS
R
L

Fig. 3.

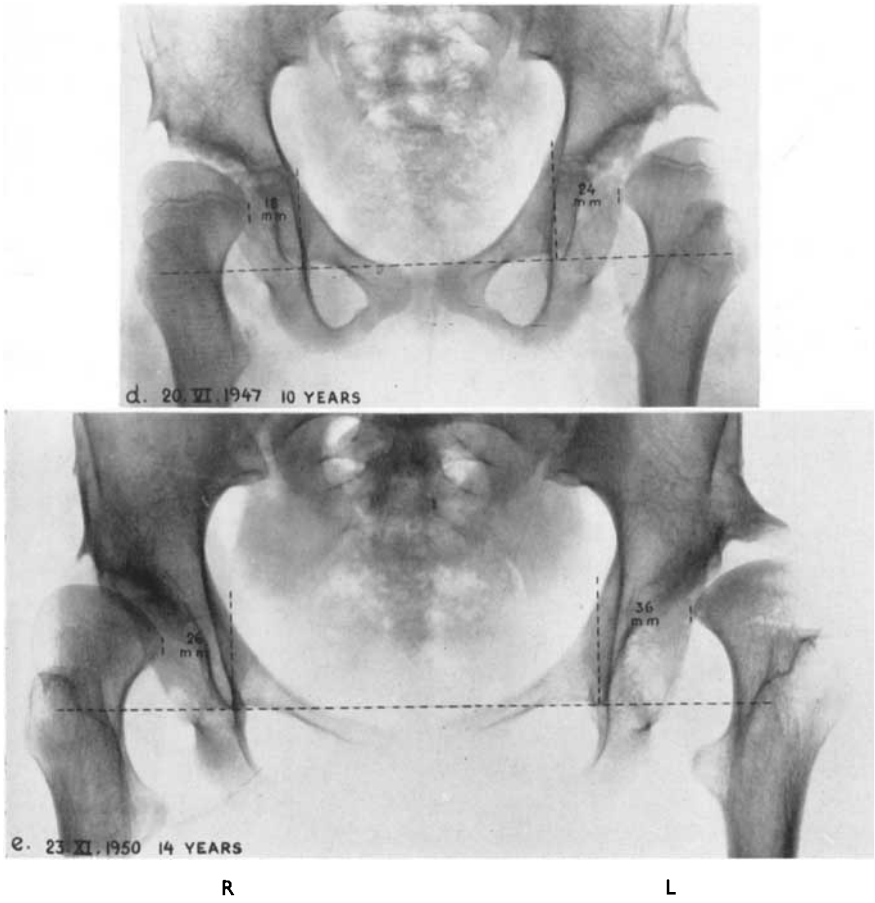


Fig. 3. Case No. 3246/38. The horizontal line of the pelvis is seen as a tangent to the inferior convexity of the tear figures. A vertical to the horizontal line is drawn through the tangential point of each tear figure. The distance between the most medial point of the femoral head and the vertical is called CT. The figures show how CT increases at the same time as the femoral head subluxates.

the femoral head in relation to these lines (Figure 3). As measuring points on the femoral head, I tried to use its highest point, its center and its most medial point. By measuring the entire series of roentgenograms in each case from the time of reduction through the period of growth until the after-examination, I endeavoured to determine how the measurements corresponded with the ocular inspection. I found that of these three points on the femoral head, the shortest distance from the vertical line to the medial bony margin of the head gave the most dependable figure, i.e. the figure that remained most

constant during the years of growth both in normal and pathologic joints. This dimension I called the CT-distance. The variations in the CT-distance in normal cases and pathologic cases are shown below.

a. Normal cases: 220 normal hips in children between 2 and 15 years.

Age	Number	Variation
2	(18 hips)	0.9—1.3 cm
3	(16 ")	0.8—1.3 "
4	(22 ")	0.6—1.2 "
5	(20 ")	0.6—1.2 "
6	(10 ")	0.9—1.3 "
7	(20 ")	0.6—1.2 "
8	(16 ")	0.6—1 "
9	(12 ")	0.5—1.2 "
10	(12 ")	0.2—1.1 "
11	(22 ")	0.6—1 "
12	(10 ")	0.6—1 "
13	(18 ")	0.5—1.1 "
14	(12 ")	0.6—1.2 "
15	(8 ")	0.6—1.1 "

No changes of interest occur after growth has been completed, although there may be a slight decrease in the distance. The longest distance in this series of normal hips was 1.3 cm.

b. Dislocation and Subluxation Cases: A group of 36 cases were selected at random from the operation material. Nine cases were excluded because of uncertain tear figure. The remaining 27 cases represent more than 130 roentgenograms. First I went through the X-rays and noted the cases in which the head had definitely become displaced. Thereafter measurements were made on all the roentgenograms (Table III).

Table III. CT-distance in Hips with and without Displacement.

Type	CT unchanged	CT increased				
		2 mm	3 mm	4 mm	5 mm	> 5 mm
Stable hips	19	4	6	1	1	—
Unstable hips	0	0	2	2	0	10

I did not take into consideration either changes in the appearance of the tear figure or in the position of the pelvis in hyperextension or flexion. I included dislocation cases in which the displacement was mostly upward. This cannot, of course, be determined by measuring the CT-distance. Nevertheless the variation for the stable cases was under 6 mm and for the displacement cases over 2 mm. The foregoing figures indicate that an increase of the CT-distance of at most 2 mm is of no importance. An increase of more than 5 mm reveals that displacement has occurred.

c. Sources of Error

Any change in the tear figure during the course of the years in the form of a considerable increase in breadth or of varus will cause an increase in the CT-distance without outward displacement having occurred. On the other hand a dislocation case may, as stated above, show considerable upward displacement without any change in the CT-distance.

The CT-distance may conceivably change with different positions of the hip. I investigated this point by taking roentgenograms in different positions in five cases, or ten hips. Five pictures were taken in addition to the frontal projection: inward and outward rotation, flexion and extension of the pelvis, and adduction. Two normal hips and three with insignificant subluxation varied 2 mm. Four more pronounced subluxation hips varied 3 mm and a low dislocation varied 2 mm. There were thus no major changes.

However, these investigations show the undependability of measurements of pathologic hip joints. I have, therefore, refrained from using exact measurements when judging the X-rays.

d. Obliquity of the Roof

An important factor in judging subluxation cases is the degree of obliquity of the roof of the acetabulum. Here one can use a connecting line between the tear figures as a horizontal line for the pelvis. But it is practically impossible to choose two fixed points on the roof that can be recognized on roentgenograms taken at an interval of several years.

In the pre-school child, measurement of the obliquity of the bone roof is of no interest. Arthrograms would be required to show the obliquity of the joint roof, or rather the cartilage roof, and none are available. I therefore refrained from measuring the obliquity of the roof.

e. Relation between Acetabular Roof and Femoral Head

Finally, it is important to determine how large a portion of the femoral head is covered by the acetabulum before the operation and by the acetabulum plus the shelf after the operation. The CE-angle (*Wiberg* 1939) provides an ideal solution to this problem in dysplastic joints. Strictly speaking, the method cannot be used in subluxation cases. Using the horizontal line between the tear figures, it should nevertheless be possible in many cases to obtain satisfactory approximate values. In some cases, howewer, the femoral head is so deformed or so flattened that it is difficult to find the center. I therefore found it safer, though more difficult, to convert the CE-angle to the relation between roof and head, i.e. the approximate percentage of the head that is covered by the acetabulum or by the acetabulum plus the shelf.

The amount of the head covered by the roof with different CE-angle can be computed as follows:

The radius of the head is assumed to vary between 1.5 and 2.5 cm. The thickness of the cartilage is 0.5 cm. Relation between acetabular roof and femoral head = $\frac{BC}{BB^1}$ (Fig. 4).

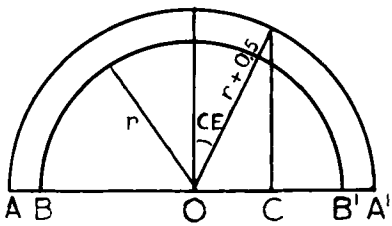


Fig. 4. AA^1 = The acetabular roof. BB^1 = The femoral head. r = Radius of the femoral head. Thickness of the cartilage = 0.5 cm. Relation between the acetabular roof and the femoral head at different CE-angles is computed from the formula:

$$\frac{BC}{BB^1} = \frac{r+(r+0.5)\sin CE}{2r}$$

The following figures for extent of coverage of the head of the femur were found in different CE-angles:

		Radius 1.5 cm	Radius 2.5 cm.
CE	30°	83 %	80 %
CE	25°	78 %	75 %
CE	20°	73 %	70 %
CE	10°	62 %	60 %

The variations that depend on the size of the head are thus of no importance. The relation between acetabular roof and femoral head will be inaccurate in the cases in which the lateral part of the head has been absorbed, but this is of no significance since the cases are recorded as poor results on the basis of the roentgen-anatomic findings.

Fig. 5. Case No. 3804. Type: Dislocation.

Because of the sources of error inherent in them, the measuring methods can only be used to facilitate evaluation. The horizontal line of the pelvis, the CT-distance and the relation between the head and the roof must serve as bearings. In suspected lateral displacement one must first make sure that the projections are in correspondence.

2. *Classification*

To facilitate evaluation of the results, I classified the cases as follows, on a roentgenographic basis:

a) Dislocation (Fig. 5).
b) Subluxation.
   a^1 Slight subluxation: Shenton's line shows a slight break (Fig. 7).
   b^1 Moderate subluxation: remaining cases with the exception of the following group (Fig. 2).
   c^1 Pronounced subluxation: the head of the femur is riding on the joint margin, often with a new acetabulum (Fig. 6, right).
c) Dysplasia: This group includes the youngest patients in which the pronounced obliquity of the bone roof constituted the operative indication (Fig. 8).

There were also transitional forms, especially between dysplasia and slight subluxation in younger cases. One of the advantages of the classification is that one can differentiate between the mild and

Fig. 6. Case No. 33650. a. Right side: Secondary pronounced subluxation. Shelf sloping upward. Left side reduced at the time of shelf operation. — b. Right side: Shelf absorbed. Left side: Shelf sclerosed.

the pronounced subluxation cases and study the results in each group separately. In that way, the question whether the operation gives poorer results in the more pronounced cases of subluxation will be answered.

3. *Evaluation of the Shelf*

The axial projections usually give a fair idea of the extent of the shelf in the antero-posterior plane in relation to the head. In many of the cases, one-third to one-half of the shelf projected in front of the head (Fig. 7 c). It appeared at first that the shelf had been situated wrongly, i.e. too far to the front. However, verification of

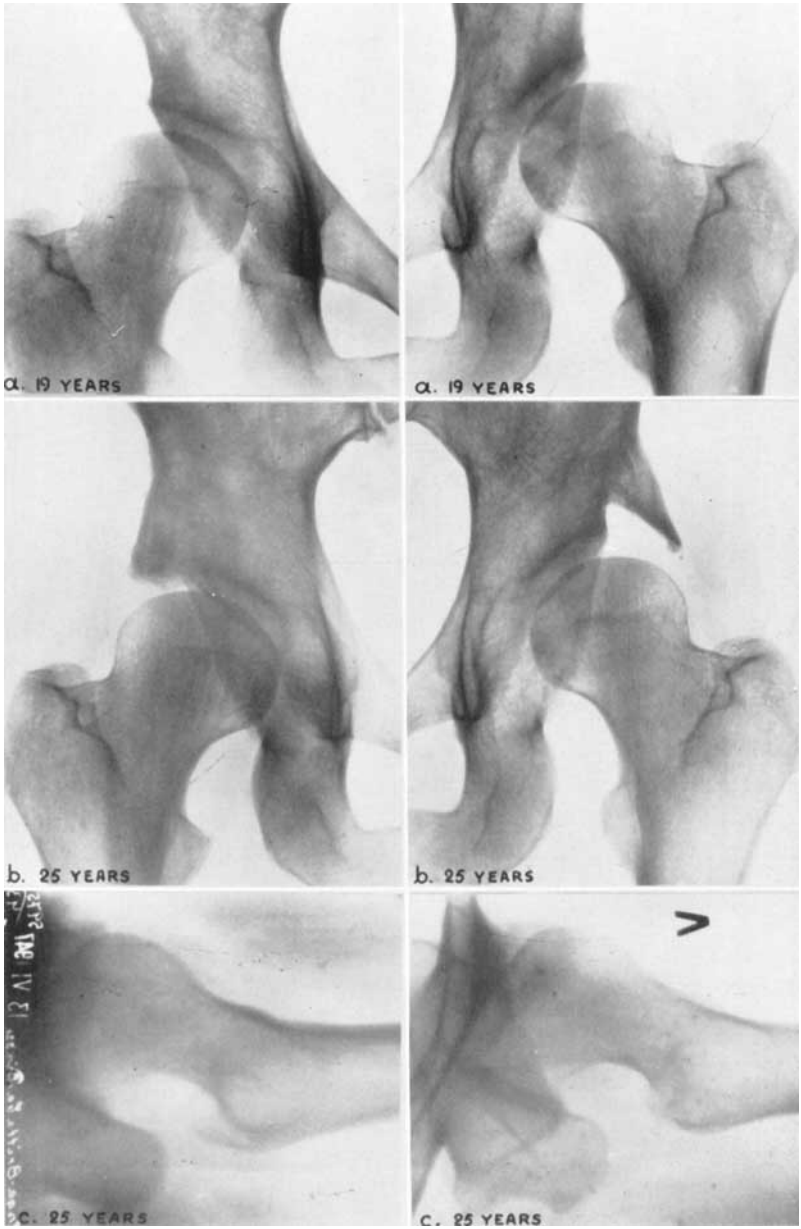


Fig. 7. Case No. 5975/53. a. Bilateral primary slight subluxation. — b. Right shelf at the level of the bone roof. Left shelf too high medially. — c. Axial projection: Right shelf covers the whole femoral head; left shelf projects anteriorly and covers about two thirds of the femoral head.

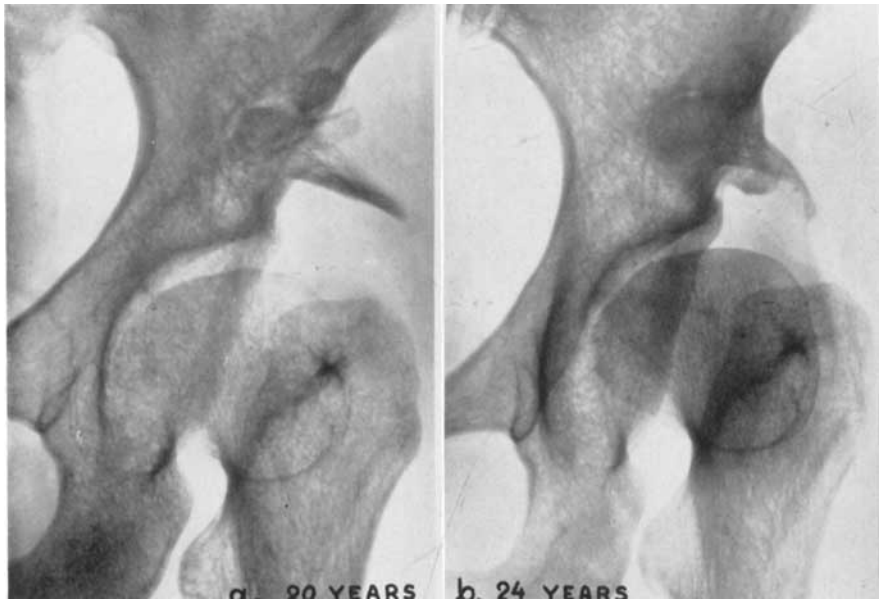


Fig. 8. Case No. 16661. Type: Secondary dysplasia. a. Shelf too high. — b. Shelf not sclerosed.

the position of the pelvis at several operations revealed that this was not the case. The position of the patient, with the legs hanging over the operating table, leads to contraction of the flexor muscles of the hip joint. The hips come into some degree of extension, although an attempt to counteract this is made by placing cushions behind the knees. The result is increased lordosis, i.e. hyperextension of the pelvis. The shelf will thus be rotated forward in relation to the head. Because of the oblique position of the shelf, it will appear shorter on the roentgenogram. Control X-rays with the pelvis in the mid-position and pronounced extension show that this shortening represents at most ten per cent of the width of the shelf, which is of no importance (Fig. 9). Of greater significance is the fact that the investigation revealed that pronounced lordosis may result in one-third to one-half of the shelf not being subjected to weight-bearing. In the cases in which the shelf only covers about two-thirds of the diameter of the head, it can be assumed that a large part of the postero-superior portion of the head is not adequately covered.

The purpose of the operation is to enlarge the articular surface. It is, therefore, appropriate to judge the result from this point of view, and the classification was therefore based on the position of the shelf in relation to the bony articular roof.

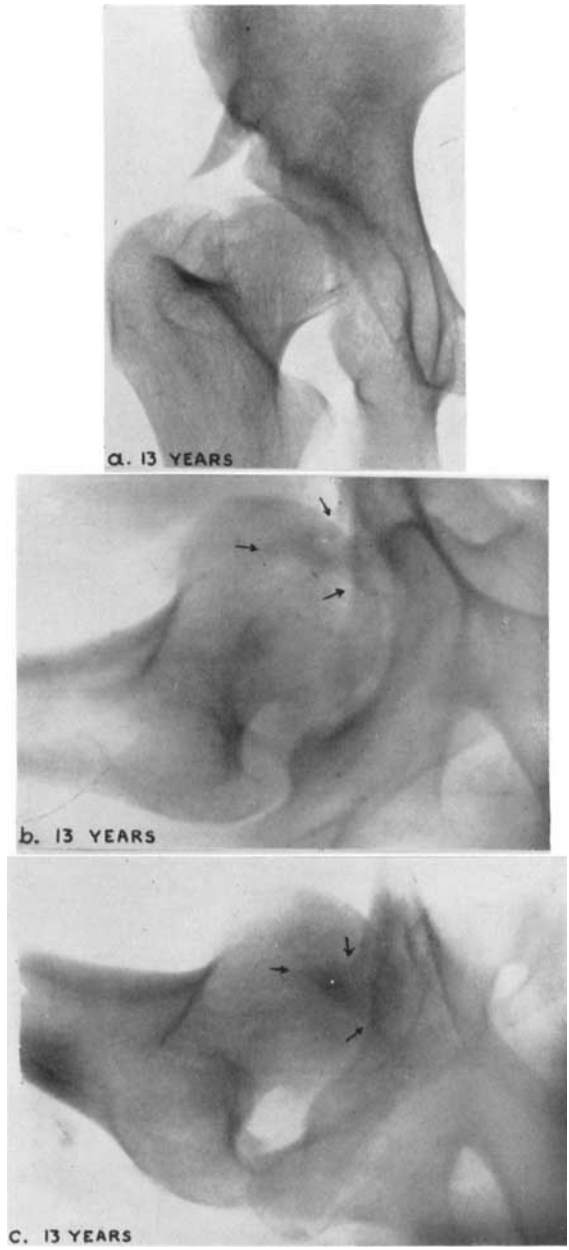


Fig. 9. Case No. 2081/38. a. Frontal projection. — b. Axial projection with the pelvis in extension (lordosis of the lumbar region): Shelf covers the anterior part of the femoral head. — c. Axial projection with the pelvis in flection (kyphosis of the lumbar region): Shelf rotates posteriorly.

The following variations are observed:

a) The shelf is at the level of the bone roof (Fig. 7 B, right).
b) The medial portion of the shelf emerges too high on the ilium while the lateral portion is at the right level (Fig. 7 B, left).
c) The entire shelf is above the margin of the joint (Fig. 8).
d) The shelf slopes upward (Fig. 6 a, right).

It was also noted if the shelf exhibited normal bone structure with a sclerosed cortex or consisted merely of a cancellous structure.

4. *The Bony Trabeculae in the Head of the Femur*

Since the trabecular structure in the femoral head might possibly be an indicator of the distribution of weight-bearing, I examined it for postoperative change. The articular margin was also studied from the same standpoint.

5. *Deformity and Osteoarthritis*

Deformity or erosion of the head following the operation was also noted.

Appreciable sclerosis, cyst-like areas of rarefaction, narrowed joint space, and osteophytes were interpreted as signs of osteoarthritis.

6. *Downward Reflection of the Roof*

The X-rays were inspected with regard to downward reflection and it was noted whether the roof or the articular margin had been reflected down. For this purpose, a general view of the pelvis is required. The control X-rays immediately after the operation were all unilateral and did not permit evaluation of the effect of the attempt at downward reflection.

III. Registration of the Material

All pertinent data referring to anamnesis, clinical status, operation and roentgen examinations were recorded on a special form for each patient.[1] A punch-card system was also set up to simplify analysis. The accuracy of the entries on the punch-card was checked once again. The material was thus evaluated in three occasions.

[1] These case reports are deposited at the Orthopedic Clinic Library.

IV. Grouping of the Material

The character of the material is exceedingly heterogeneous. The patients underwent the operation at ages ranging from 2 to 45 years. The operation was performed in different forms of acetabular dysplasia and all degrees of subluxation and dislocation. The indications were sometimes based on purely preventive grounds, particularly in the younger patients, while in other cases the objective was to check beginning subluxation. In still other cases the purpose of the operation was to relieve symptoms of insufficiency in the form of fatigue and pain by providing a better weight-bearing surface. Finally, the treatment was aimed at amelioration of osteoarthritis as one of the final stages of the joint changes. The premise in these cases was that improved stability of the joint would act as a check on the progress of osteoarthritis.

A. Etiologic Grouping

Despite great individual differences, the material can be divided in various ways into groups. First of all the grouping can be done etiologically. There are two different groups: 1) dislocation, 2) primary subluxation and acetabular dysplasia. The dislocation cases were often submitted to reduction and protracted fixation in plaster; they were by nature unstable and subject to continuous subluxation. Primary dislocation cases, on the other hand, could often be regarded as stable, and had seldom undergone previous treatment.

In the following, the cases of primary congenital dislocation and dysplasia will be known as primary cases, while the residual conditions resulting from congenital dislocation of the hip will be called secondary cases.

B. Age Grouping

In order to evaluate the results in detail, the material must be broken down into age groups, which, for practical reasons, must be as large as possible. The question is where to draw the line between the different age groups. In the literature, the five-year limit is considered to be significant, due to the fact that certain authors state that their results were less satisfactory under that age (*Gill,* 1943). Meantime, the opposite view has also been expressed (*Lance,* 1942). Obviously the limit must be set somewhere. Indications and surgical technic are different at 4 years and at 15. The difference is probably due to the fact that the roof in young children consists mainly of cartilage, which is gradually transformed into bone in subsequent

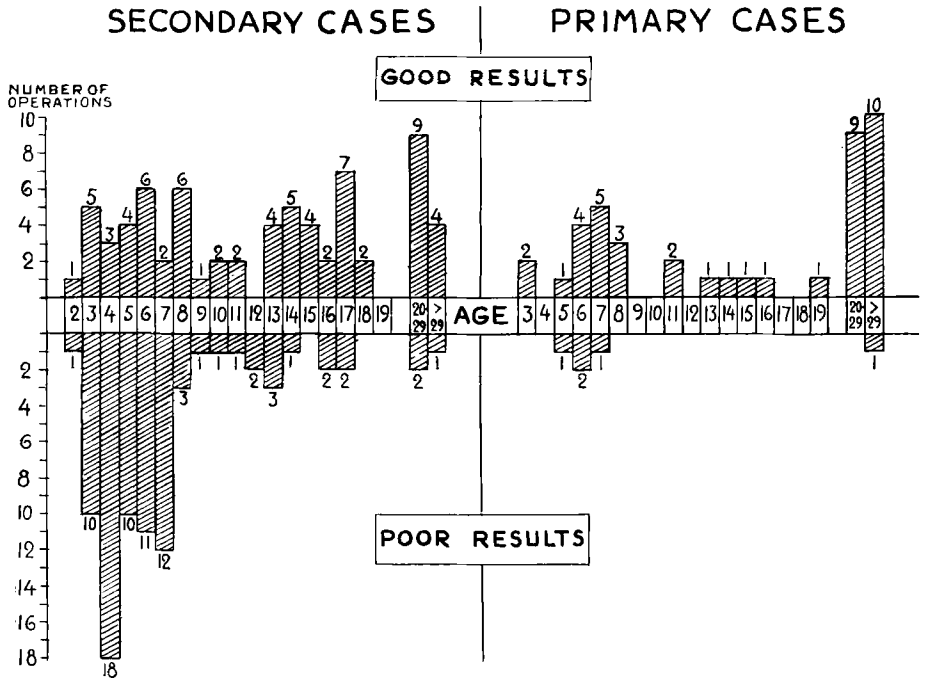


Diagram 3. Distribution of the roentgen-anatomic results with regard to the age at operation.

years. *Wiberg* (1944) discussed this problem in an investigation on the development of accessory bone nuclei, which he called dislocation nuclei, at the margin of the joint. He was of the opinion that the chief growth of the joint margin in these cases occurs before the age of four to five years.

It is undoubtedly impossible to determine a fixed developmental plan for a pathologic joint. In order to form an opinion on the ages that can be grouped together, I divided the material into age groups. Diagram 3 reveals that the roentgenographic results were not satisfactory for the first seven years. From the age of eight years, the trend was reversed, and satisfactory results began to be in the majority. I therefore divided the material into one group up to the age of eight years and another for patients over eight years. The latter group covers the ages of operation from 8 to 44 years. Those with roentgen signs of osteoarthritis were assembled in a special group. In order to evaluate the remaining cases, I broke them down into two age groups, 8 to 15 years and over 15 years. The first group thus covers those operated on during puberty, as well as most of the school children, while the age group over 15 years consists mainly of patients who had recently started to work.

C. Grouping According to Operative Indications

The case records and the roentgen examinations before the operations with reference to the operative indications gave rise to the following classifications:

1. Prevention, if there was considered to be a risk of displacement
2. Unstable retention: cases which had redislocated during reduction treatment
3. Beginning displacement
4. Symptoms
5. Osteoarthritis

V. Criteria for Evaluation of Results

How should the results be evaluated? This apparently simple question actually presents one of the most difficult problems. The shelf operation is often the last stage of a series of treatments. It is evaluated in different ways with different premises by different authors, which explains the great divergence of opinion. Those who judge the treatment of dislocation as a whole and who require a normal joint with normal function for a good result will inevitably report different results than workers who judge the direct result of the operation. Those who report the results of the operation within a limited range of indications usually have a uniform basis of evaluation.

To grade the results according to a plan that takes into consideration signs, symptoms, and anatomic facts, would give rise to too many different groups. To allow the patients' own reports to determine evaluation would lead to absurdities. For example, a patient who had no symptoms before the operation might well have remained free from symptoms without any operation. If the operation is a technical failure, but the patient remains or becomes free of symptoms, the result would be wrongly recorded as good. Preventive operations in hips which might have developed satisfactorily without operation would be recorded as good results. The objective results, which include limp, the Trendelenburg test and range of movement, are also not suited as criteria for evaluation. In most cases, the operation consists only of downward reflection of a bone flap over the head of the femur, which cannot, of course, influence the function of the abductors of the hip. Nor can one expect an improvement in the range of movement. First and foremost, the signs and symptoms are not necessarily directly due to poor joint stability but may also depend on already existing joint lesions which are not affected by the shelf operation.

In my opinion, evaluation of the shelf operation should primarily be based on the roentgen-anatomic results. If these are good, it should then be determined whether the operation has had the desired effect, i.e. whether it has prevented displacement, relieved the symptoms, etc.

The results are called good if the shelf lies at the level of the bone roof or, if the base of the shelf is situated higher up, the apex reaches the level of the articular margin. Naturally it is not impossible that higher shelves may be effective. This point will be discussed later on, in connection with the analysis of the results.

With regard to the extent of the shelf in the frontal plane, it would seem logical to use the figures for the CE-angle computed by *Wiberg* (1939) and *Severin* (1941), i.e. 25 degrees for adults down to 14 years and 20 degrees for the 4 to 13-year-old patients. Converted into proportion of the head covered by the roof, these figures are 76.4 per cent (radius of the head 2 cm) and 72.7 per cent (radius 1.5 cm).

Meantime, the CE-angle only applies to relatively normally shaped joints in which the measurements are more or less exact. In this material with deformed heads, the errors of measurement are greater, due to the difficulty of establishing the center of the head and the acetabular margin. Furthermore, it has not been proved that symptoms of insufficiency and osteoarthritis are as common in mild as in pronounced cases of dysplasia. Therefore, I consider we are justified in approving of smaller shelves. Under all circumstances, however, the vertex of the head should be situated inside the apex of the shelf. In my opinion a shelf should cover two-thirds of the head in the frontal plane and one-half in the sagittal plane. As already mentioned, one may reckon with ten per cent more than the figure measured in the sagittal plane. In this way, we eliminate only those cases that are definite failures from the anatomic point of view (Fig. 10).

Shelves that sloped upward and cases in which the shelf had been absorbed or in which joint damage followed operation were considered failures.

In some of the younger patients the acetabular margin was found to grow out under a good shelf (Fig. 11). A slow ossification of the cartilaginous roof had taken place, with a satisfactory joint as the result. Any visible remnant of the shelf in these cases was situated above the acetabular margin. *The result here was labelled uncertain,* since there was no proof that the growth of the acetabular margin was a consequence of the operation.

As far as the symptoms are concerned, it is by no means certain that good results are due to the operation. *A good result can only be*

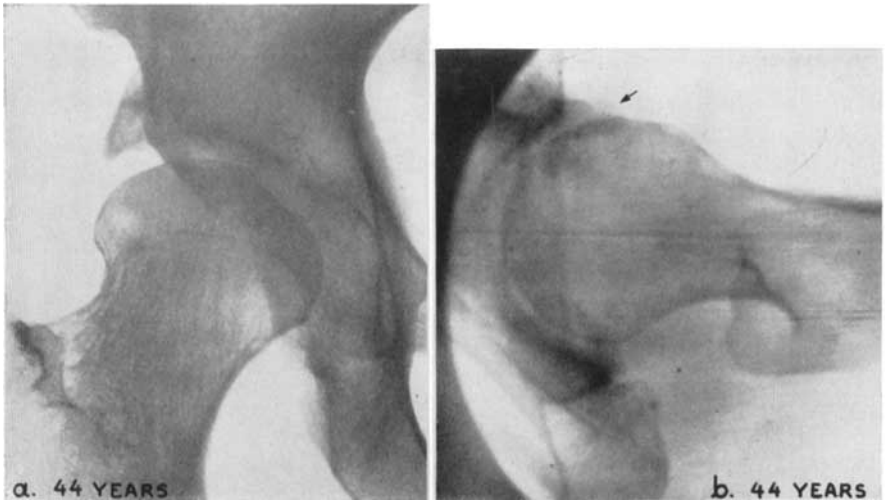


Fig. 10. Case No. 864/45. a. Frontal projection. — b. Axial projection: Shelf too small.

ascribed to the operation if the patient has not changed his way of life since the operation. Oddly enough, this is overlooked in the literature, and freedom from symptoms is usually regarded as indicative of a good result. Symptoms in the form of pain or fatigue in the hip generally come from weight-bearing. A patient with an active occupation who transfers to sedentary work after the operation may improve or become free from symptoms purely due to his change in habits. The same applies to patients who previously have been very active, played games, taken long hikes, etc., and who after the operation avoid all forms of sport and even short walks. The results in these cases are labelled uncertain in the present study.

The results are thus classified as follows:

A. *The operative indication was the prevention of displacement of the femoral head;* under this heading are grouped operation for preventive reasons or because of unstable retention and progressive displacement of the femoral head.

Good: Good anatomic result; no displacement of the femoral head.

Moderate: Good anatomic result; further displacement of the femoral head after the operation has been checked.

Uncertain: Good anatomic result, but the articular margin has grown under the shelf.

Poor: Poor anatomic result.

B. *The operative indication consisted of symptoms;* under this heading are grouped pain, fatigue and osteoarthritis.

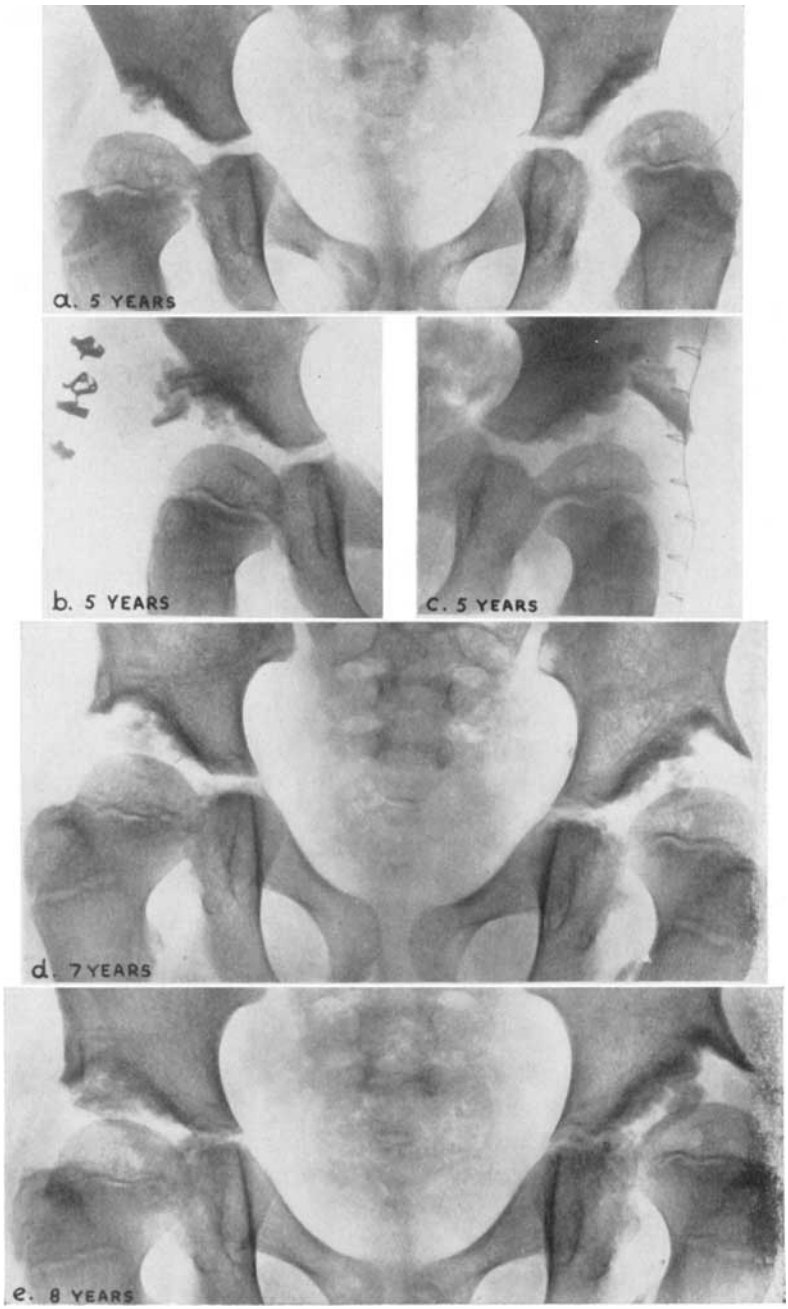


Fig. 11.

Fig. 11. Case No. 3078/11. Right side: Advancing ossification of the acetabular roof below the shelf. At ten years the shelf (arrow) is incorporated in the acetabular roof. Left side: Shelf too high medially, sclerosed.

Good: Good anatomic result; freedom from symptoms without special precautions.

Moderate: Good anatomic result; improvement without special precautions.

Uncertain: Good anatomic result; improvement or freedom from symptoms with precautions.

Poor: Poor anatomic result, or no improvement.

Analysis of Results

I. Survey of Classification and Results

For the purpose of analysis, the material was divided according to the aforementioned principles into two etiologic groups of primary and secondary cases. Each group was divided into age groups, which in turn were broken down according to operative indication.

Table IV shows the classification of the material, as well as results.

Table IV. Classifications and Results.

196 Operations

Secondary Cases

150 Operations

Primary Cases

46 Operations

Under eight years

	Prevention	Displacement	Unstable retention
Good	6	14	1
Moderate	3	5	3
Uncertain	12	4	1
Poor	11	17	6

	Prevention	Pain
Good	5	4
Moderate	0	0
Uncertain	2	0
Poor	3	1

Over eight years

	Prevention	Displacement	Pain 8—15 yrs	Pain 16—27 yrs	Fatigue 10—17 yrs	Osteoarthritis
Good	4	7	5	0	0	1
Moderate	0	0	1	4	0	0
Uncertain	0	0	2	3	1	3
Poor	2	3	7	11	4	9

	Prevention	Pain 13—39 yrs	Osteoarthritis
Good	5	2	1
Moderate	0	0	1
Uncertain	0	4	7
Poor	0	2	9

Total Results

Good	38 (25.3 %)
Moderate	16 (10.7 %)
Uncertain	26 (17.3 %)
Poor	70 (46.7 %)

Good	17 (37 %)
Moderate	1 (2.2 %)
Uncertain	13 (28.3 %)
Poor	15 (32.6 %)

II. Results of Different Surgical Methods

In a few cases the operative technic was varied with respect to the method of fixing the bone flap in position. Of particular interest is the question whether the results are influenced by these variations. The Lance method was chiefly used to prevent displacement in the age group under eight years. Patients over eight years, on the other hand, were treated with a bone flap combined with a wedge of bone from the iliac crest fixed in place with an os purum nail. These methods are, therefore, compared with corresponding cases in which bone flaps plus wedges of the iliac crest were used (Table V).

Table V. Comparison between Results with Different Operative Methods.

Under eight years.

	Bone flap + wedges of iliac crest	Lance
Good	21	4
Moderate	7	1
Uncertain	17	1
Poor	27	4

Over eight years.

	Bone flap + wedges of iliac crest	Bone flap + wedges of iliac crest attached with os purum nail
Good	7	1
Moderate	4	2
Uncertain	14	5
Poor	32	6

In principle, these variations yielded the same results with approximately the same number of poor and good results in the age group under eight years and predominantly poor results in the age group over eight years.

In three cases, cancellous os purum grafts were used instead of wedges from the iliac crest. The patients were aged four, five and six years, respectively. The indication was redislocation. The operation was a failure in all three cases, in two of which the shelf was placed too high with redislocation as the result. In the third case the shelf was partly absorbed, and all that remained were patches of calcification in the soft parts above the head. After the operation, all the cases were treated with plaster fixation for six weeks, ten weeks and four weeks, respectively. It is questionable whether these cases should be included. The cancellous os purum plates were dead matter, and there is reason to assume that they led to slower bone regeneration than live bone. The pseudoarthrosis case seems to indicate that this was the case. On the other hand, in the case in which there was upward displacement of the femoral head, a shelf strong enough to resist the pressure of the femoral head had developed. With such a small number of cases, one is not justified in assuming that os purum is unsuitable as a support for the bone flap. The cases were, therefore, not eliminated from the material in order not to embellish the results by removing two operations that were technical failures.

III. Discussion of the Results in the Different Groups

A. Under eight years

1) *Indication: Prevention (Table VI).*

Table VI.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases				Displacement after operation
Age at operation	3—6 years	5—6 years	4—7 years	3—6 years	Wrongly placed		Rightly placed		
Age at follow-up	12—14 years	12—13 years	8—14 years	8—14 years	High	Sloping	Absorbed	Small	
	Secondary Cases								
Dyspl.	2	0	8	7	5	0	2	—	0
Slight subl.	2	1	4	2	1	0	1	—	1
Moderate subl.	2	2	0	2	0	0	1	1	2
	Primary Cases								
Dyspl.	—	—	1	2	—	—	2	—	—
Slight subl.	—	—	—	—	—	—	—	—	—
Moderate subl.	4	—	1	1	—	1	—	—	1
Pronounced subl.	1	—	—	—	—	—	—	—	—
Age at operation	3—7 years	—	3—5 years	6—7 years					
Age at follow-up	9—13 years	—	9—14 years	13—14 years					

Comparison of the different degrees of dislocation reveals that in the secondary group there is an appreciable difference between the dysplasia and slight subluxation cases, on the one hand, and those with moderate subluxation, on the other hand. A good or fair result was only achieved in 5 of the 26 operations in slight cases as compared with four of six operations in the more severe cases. The same is true of the primary cases. Here there were no good or fair results in the mild cases as compared with five good results in seven operations in the more advanced subluxation cases.

The uncertain or poor results are governed by three factors:

a) *The acetabular margin grew out under the shelf* in 14 cases (Fig. 10). This can be explained either by the shelf having had a protective effect during the growth of the roof, or by the operation having stimulated the growth process, or by the operation having been unnecessary, i.e. the roof would have grown anyway. Even among the poor results, there were a few instances of the acetabular margin

growing and forming a normal or dysplastic acetabulum. The explanation here is either that the operation was unnecessary or that it stimulated the growth of the acetabulum.

This growth of the acetabulum under the shelf occurred in 13 dysplastic and slight cases and one moderate case.

At this point of the investigation, all one can say is that it is uncertain if the operation is indicated from the preventive point of view in cases of dysplasia and mild subluxation. The picture in similar cases not submitted to operation is, of course, interesting and will be discussed in another chapter.

b) The shelf had been constructed *too high* in six secondary cases. This misinterpretation of the position of the joint margin was probably due to the considerable thickness of the capsule in reduced cases.

c) A correctly situated shelf was *absorbed* in six cases.

The primary cases differ from the secondary in one respect: the shelf was constructed at the correct level in all the primary cases. This can be explained by the fact that the advanced cases were relatively more frequent in the primary group. It is probably easier to localize the acetabular margin in cases in which the head protrudes.

The age at after-examination is, of course, important in evaluating these cases. Since evaluation is based on the ability of the shelf to prevent dislocation, it is scarcely possible that a longer observation period would impoverish the results, good to uncertain. The poor results included only one patient under ten years (eight-year-old): this case was recorded as a poor result because the shelf was absorbed. Even if the age at follow-up had been higher, the result would not have changed.

Summary: In patients under eight years, the operation had a good preventive effect in moderate and severe subluxation. It is uncertain whether the operation is indicated in cases of dysplasia and slight subluxation.

The operation is technically more difficult in cases of secondary dysplasia and slight subluxation.

2. *Indication: Displacement (Table VII)*

All the cases in this group are secondary. Lateral displacement of the head was noted before the operation, indicating that there was danger that the condition would progress. The results in the different subluxation cases were relatively uniform. The results in all four dislocation cases were poor, the shelf being too narrow in one case and wrongly situated in three cases.

Table VII.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases					Displacement after operation
Age at operation	2—7 years	3—7 years	3—4 years	3—7 years	Wrongly placed		Rightly placed			
Age at follow-up	9—19 years	9—18 years	10—13 years	8—19 years	High	Sloping	Absorbed	Small	Disloc.	
	Secondary Cases									
Slight sublux. . .	3	1	1	3	—	3	—	—	—	2
Moderate sublux. . .	7	1	3	5	1	3	1	—	—	3
Pronounced sublux. . .	4	3	—	5	2	—	—	—	3	7
Disloc.	—	—	—	4	2	1	—	1	—	3

The terms "uncertain" and "poor" results were applied to cases in which:

a. The shelf was wrongly situated (12 cases). This technical failure was in most cases not due to anatomic conditions typical of the age group. On the contrary, in seven cases the shelf was not adequately reflected down and only in five was it situated too high.

b. The acetabular margin grew out under the shelf (4 cases).

c. The shelf, though correctly situated, was unable to prevent dislocation (3 cases).

Displacement after the operation occurred in altogether 15 cases, seven of which can be attributed to technical errors in the operation. The risk of displacement is greatest in the advanced subluxation cases, in which displacement occurred despite a good operative result.

On the other hand, the results were good in three cases in which the acetabular margin also was reflected down.

The age at after-examination in the groups, good and moderate results, was eight years in one case and nine years in four cases; in the group, poor results, it was eight years in one case and nine years in five cases.

A higher age at after-examination might possibly have an adverse effect on the results in the event of late absorption of the shelf. This was not, however, observed in any of the cases followed-up at a relatively advanced age, and the results would therefore not have changed by an increase in the period of observation.

Summary: The shelf operation is valuable in cases in which control examination of treated dislocation cases reveals outward displacement of the head. Here, too, it is evident that the operation is technically difficult in secondary cases. One could probably anticipate better results if the acetabular margin also were reflected down.

3. *Indication: Unstable Retention (Table VIII)*

Table VIII.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases				Displacement after operation
Age at operation	4 years	7 years	3 years	3—6 years	Wrongly placed	Rightly placed			
Age at follow-up	12 years	17—19 years	12 years	10—18 years	High	Absorbed	Small	Joint lesion	
	1	3	1	6	3	1	1	1	7

The cause of redislocation during reduction treatment is often assumed to be a poorly developed roof. However, neither in our cases nor in cases reported in the literature has it been proved that redislocation depends on a poor roof. The steeply sloping bone roof gives a misleading picture of the acetabulum. Arthrography of the hip, as developed by *Severin* (1941) and by *Leveuf* and *Bertrand* (1946) provides a more realistic picture of the cartilage roof of the joint. As long ago as 1935, *Gill* stressed the importance of removing from the acetabular floor all obstructive connective tissue. According to *Leveuf* and *Bertrand* (1946) and later *Bertrand* and *Guias* (1951), obstructive connective tissue is frequently present in congenital dislocation of the hip and is usually the cause of secondary dislocation. Consequently in their opinion the shelf operation does not constitute an appropriate treatment. *Niederecker* (1952) was of the same opinion. The appropriate form of treatment, according to these authors, is open reduction.

Severin (1950) showed that obstruction of soft tissue may disappear during treatment with fixation.

The foregoing views undoubtedly explain the fact that the shelf operation has not been performed since 1942 in cases of redislocation in our Clinic.

Up to 1942 the shelf operation was performed in eleven cases; closed reduction was done a few weeks prior to operation.

The term "poor result" was applied in three cases in which the shelf was placed too high. In the other cases, the operation was successful, although the shelf was absorbed in one case and was too small in one, while in a third severe injury to the joint was caused by downward reflection of the roof.

The shelf was situated too high in altogether six cases. Further displacement was nevertheless prevented by the shelf in three cases, while redislocation occurred in three others. Redislocation also occurred in the case with the joint injury. It was obviously very difficult to place the shelf accurately in this group also. In one case, incision

in the capsule revealed that the shelf was situated too high because of considerable thickening of the capsule. In two cases in which the shelf was too high, the joint had nevertheless been opened at the operation. Control X-rays during the operation would presumably have led to a better result. This procedure was followed in the only successful case in the group.

Summary: It appears from the foregoing that redislocation does not in itself constitute an indication for the shelf operation. First, the cause of redislocation should be determined.

This group, too, shows that surgery in the secondary cases is complicated by technical difficulties.

4. *Indication: Pain (Table IX)*

Table IX.

Results	Good	Moderate	Uncertain	Poor	Shelf in poor case
Age at operation	3—7 years	—	—	6 years	Rightly placed
Age at follow-up	9—15 years	—	—	13 years	No improvement
	Primary Cases				
Slight sublux. . .	—	—	—	1	1
Moderate sublux. . .	2	—	—	—	—
Pronounc. sublux. . .	2	—	—	—	—

Only five operations were performed in patients under eight years because of pain. All of these cases were primary subluxation. The results were good with relief from pain in four, while one was unimproved. All the operations were successful from the technical point of view. The highest age at after-examination was only 15 years. The results might have been worse with a longer period of observation.

Summary: This small group of cases supports the opinion that the operation is useful in the relief of pain in primary subluxation cases.

No technical difficulties were encountered in operating on these cases.

B. Over Eight Years

1. *Indication: Prevention (Table X)*

All the patients belonged to the age group 8 to 14 years. The results were good in four of the six secondary cases and in all the five primary cases. The poor results were due in one case to the shelf having been placed too high and in the other to a joint injury, presumably caused

Table X.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases	
Age at operation	8—14 years	—	—	8 and 12 years	Wrongly placed	Rightly placed
Age at follow-up	12—16 years	—	—	12 and 18 years	High	Joint lesion
	Secondary Cases					
Dyspl.	—	—	—	1	1	—
Slight sublux. ..	2	—	—	—	—	—
Moderate sublux. ..	2	—	—	—	—	—
Pronounc. sublux. ..	—	—	—	1	—	1
	Primary Cases					
Dyspl.	1	—	—	—	—	—
Slight sublux. ..	1	—	—	—	—	—
Moderate sublux. ..	1	—	—	—	—	—
Pronounc... sublux. ..	2	—	—	—	—	—
Age at operation	8—11 years	—	—	—		
Age at follow-up	15—24 years	—	—	—		

by the roof having been reflected down. The period of observation was only two years in one case, but the age of the patient at the after-examination was 16 years, and the roentgen findings would probably remain unchanged. No postoperative displacement was observed.

Summary: The results of the shelf operation in this group were good from the roentgen-anatomic point of view. However, the cases were very few in number.

2. *Indication: Displacement (Table XI)*

Table XI.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases		Displacement after operation
Age at operation	8—17 years	—	—	8—12 years	Wrongly placed	Rightly placed	
Age at follow-up	14—22 years	—	—	14—20 years	Sloping	Absorbed	
	Secondary Cases						
Moderate sublux. .	1	—	—	—	—	—	—
Pronounc. sublux. .	4	—	—	2	1	—	1
Disloc. . .	2	—	—	1	—	1	—

As in the age group under eight years, displacement before the operation was only seen in secondary cases. Nine cases belonged to the age group 8 to 14 years. One patient was operated on at the age of 17 years; the observation time was unsatisfactory, or only 23 months, but the good roentgen results probably did not change during the next few years. The observation period was satisfactory in the other cases, or between six and eleven years.

The results were good in seven cases. Three of the operations were recorded as unsuccessful: one technical failure, one case of absorption of the shelf, and one case of postoperative dislocation.

With the exception of the last-mentioned case of dislocation, displacement was not noted after the operation in any instance.

Summary: These results suggest that the shelf operation provided a satisfactory buttress of bone in this group also.

3. *Indication: Pain*

The results in this group are judged on the basis of the patients' own reports, in addition to the roentgen findings. A long period of observation and a relatively advanced age at after-examination are naturally important to evaluation. The material has, of course, many serious faults in this respect. It is probable, however, that the results would be found to be poorer rather than better after a longer period of observation.

a. Age group 8 to 15 years (Table XII)

Table XII.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases			Displacement after operation
Age at operation	8—14 years	13 years	14 years	9—15 years	Rightly placed			
Age at follow-up	14—25 years	19 years	18 years	11—29 years	Absorption	Joint lesion	No improvement	
	Secondary Cases							
Slight sublux. . .	—	1	—	1	—	—	1	—
Moderate . . sublux. . .	2	—	1	2	—	2	—	—
Pronounced sublux. . .	2	—	1	1	—	1	—	—
Disloc.	1	—	—	3	1	1	—	1
	Primary Case							
Pronounced sublux. . .	—	—	—	1 (13 yrs)	—	—	1 (18 yrs)	—

Fifteen secondary cases and one primary case were operated on. The primary case had undergone a preventive operation seven years previously at the age of six. The result was poor due to inadequate downward reflection of the bone flap. Because of continued displacement and of the appearance of pain, a new shelf was constructed, but to no avail. Since then arthrodesis has been performed on the hip.

Five patients were cured of their pain and one patient improved. Among the good results, the observation time was only three years in one case, but this is compensated for to some extent by the fact that the patient was 17 years of age at the time of after-examination. In another case the observation time was six years, but the patient was only 14 years old at the after-examination. Only one of the patients was over 20 years at after-examination.

In two cases the results could not be accurately appraised because the patients had changed to a sedentary way of life since the operation.

The observation time was very short in two of the cases of poor results, one year and two years, respectively. In one of them a joint lesion had developed after the operation, while in the other osteotomy was done due to residual signs and symptoms. A longer period of observation would, therefore, not have affected the results in these cases.

The poor results in this group were to a great extent due to the early onset of osteoarthritis in the secondary cases (four cases). Furthermore, the dislocation cases showed poor results, the outcome only having been favorable in one of four. When the two uncertain cases are eliminated, there remain 7 poor cases of 13.

Better results might be attained if operation were avoided in cases in which ostoearthritis usually appears soon after the operation. This form of joint lesion, which has the character of destructive arthritis, may be due to injury to the acetabular roof at operation. It may also represent early osteoarthritis in a hip that has been treated for dislocation. This point will be discussed in a later chapter.

Summary: The results of the operation were poor in this group. Better results might possibly be attained with a long period of expectant treatment in the hope of avoiding operation in potential cases of early osteoarthritis.

b. Age group over 15 years (Table XIII)

Operation was done in 18 secondary and 7 primary cases.

The secondary cases were operated on at earlier ages: 16 to 25 years (average 19.3 years) as compared with 21 to 39 years (average 29.1 years) for the primary cases. It is noteworthy that in this material

Table XIII.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases				
Age at operation	—	17—23 years	17—18 years	16—25 years	Wrongly placed		Rightly placed		
Age at follow-up	—	23—33 years	24—29 years	17—38 years	High	Sloping	Absorbed	Joint lesion	No improvement
	Secondary Cases								
Dyspl.	—	—	—	3	1	—	—	—	2
Slight sublux. ..	—	1	2	2	—	—	—	—	2
Moderate sublux. ..	—	1	1	1	1	—	—	—	—
Pronounced sublux. ..	—	1	—	2	—	—	—	1	1
Disloc.	—	1	—	3	—	1	1	1	—
	Primary Cases								
Dyspl.	—	—	1	—	—	—	—	—	—
Slight sublux. ..	2	—	—	1	—	—	—	—	1
Moderate sublux. ..	—	—	3	—	—	—	—	—	—
Age at operation	21 & 34 years	—	25—39 years	27 years					
Age at follow-up	26 & 38 years	—	27—49 years	34 years					

no primary cases of subluxation were operated on in the age group 8 to 20 years. Other authors had their best results with patients in this very group.

The observation time was only one year in one of the secondary cases. The result was recorded as poor due to a joint lesion, and probably did not change later.

Of the secondary cases, four were definitely improved with regard to pain. A further three patients were improved, but avoided strain on the joint. Nine of the eleven poor cases showed no improvement. One patient was well for four years, but then had to change to a sedentary occupation, and five years later the pain returned. The eleventh patient had no pain after the operation, but the strength of the hip was impaired to the point that the patient could not stand on the leg. In addition the shelf was oblique and the case was, therefore, recorded as poor.

The risk of joint lesion is much less in this age group. Only one of the patients showed joint lesion. This case was of special interest. The contralateral joint had undergone the same destruction in connection with a subtrochanteric osteotomy. This would indicate that the joint lesion was not directly caused by the shelf operation, but

that it arose as a result of postoperative fixation or that it would have developed even without operation.

Freedom from pain was thus not achieved in any of the secondary cases. Definite improvement was only noted in four cases, or 26.7 per cent. The uncertain cases were not taken into consideration.

The primary pain cases over 15 years showed better results. The observation time was relatively satisfactory with the exception of one of the uncertain cases, in which it was only two years.

Two cases had remained free from pain and only one showed no improvement. The uncertain cases were in the majority, representing four patients. It is noteworthy that three of these four were free from symptoms.

The operation was a technical failure in two secondary cases.

Summary: Judging by the foregoing cases, there is little hope of relieving pain in secondary cases over 15 years. In the primary cases, however, the results were so satisfactory that the operation seems to be indicated.

4. *Indication: Fatigue (Table XIV)*

Table XIV.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases		
Age at operation	—	—	10 years	10—17 years	Wrongly placed	Rightly placed	
Age at follow-up	—	—	19 years	19—22 years	High	Absorption	No improvement
Moderate sublux. .	—	—	—	1	—	—	1
Pronounc. sublux. .	—	—	—	2	1	—	1
Disloc. . .	—	—	1	1	—	1	—

Five secondary cases were operated on for symptoms of fatigue only. The age at operation was 17 years in one case, while the other patients were between 10 and 15 years.

One case was improved, but the patient avoided exerting the joint. Three cases showed no improvement. The fifth case was recorded as poor because the shelf had been placed too high up. The patient was completely free of symptoms, however, and three years after the operation she was working full-time as a maid in a restaurant, despite absorption of the shelf and moderate osteoarthritis.

Summary: The operation appears not to have any effect in cases with symptoms of fatigue only.

5. *Indication: Osteoarthritis (Table XV)*

Table XV.

Results	Good	Moderate	Uncertain	Poor	Shelf in Poor Cases				
Age at operation	31 years	—	15—23 years	13—44 years	Wrongly placed		Rightly placed		
Age at follow-up	38 years	—	26—38 years	16—50 years	High	Joint lesion	Small	Joint lesion	No improvement
	Secondary Cases								
Slight sublux. ..	—	—	—	2	1	—	—	—	1
Moderate sublux. ..	—	—	1	1	—	—	—	—	1
Pronounc. sublux. ..	1	—	2	4	—	1	—	1	2
Disloc.	—	—	—	2	—	—	—	—	2
	Primary Cases								
Dyspl.	—	—	2	—	—	—	—	—	—
Slight sublux. ..	—	—	—	3	—	—	1	—	—
Moderate sublux ..	1	—	3	1	—	—	—	—	—
Pronounced sublux. ..	—	1	2	5	—	—	—	—	8
Age at operation	23 years	44 years	15—31 years	14—42 years					
Age at follow-up	32 years	55 years	25—40 years	23—48 years					

I collected the osteoarthritic cases in a special group. According to the case records, operation was not performed in any of these cases with the aim of influencing the osteoarthritis, even though it was hoped that this would be accomplished. Most of the patients sought medical attention due to pain, and the primary indication was the relief of pain. In one case—an eight-year-old without signs or symptoms—the operation was performed as a preventive measure, and the patient, therefore, was included in the preventive group. In two patients the only signs and symptoms were fatigue and roentgenographic evidence of osteoarthritis; in one case the objective was merely to construct a better acetabulum in order to create better conditions for an arthrodesis later on. The reason the other case was operated on is not revealed.

I included as osteoarthritis even slight changes such as sclerosis of the acetabulum only or cyst-like areas of rarefaction in the acetabulum or the femoral head. *Wiberg* (1939) was of the opinion that sclerosis only is not a sign of osteoarthritis in dysplasia and subluxation but is a "physiologic condition in a defective joint of this nature".

He pointed out that "the degree of the sclerosis was in direct proportion to the degree of maldevelopment of the acetabular roof". He stated that the sclerosis often appears as early as the fifteenth year. He considered that the first sign of osteoarthritis is destruction of the cartilage, as evidenced by a decrease in the height of the joint space.

The foregoing is reasonable if osteoarthritis is considered to make its first appearance as damage to the cartilage. On the other hand, it is theoretically possible that the destruction to the cartilage is secondary to changes in the neighbouring bone. From this point of view, sclerosis or cysts may be the first signs of osteoarthritis. Since they are among the signs of osteoarthritis, it is justified to regard them as indicative of osteoarthritis even when they are not accompanied by any other signs.

Results: 18 primary cases: one free of pain; one improved; seven relatively improved, and nine failures (shelf too narrow in one case).

13 secondary cases: one free of pain; three relatively improved, and nine failures (shelf too high in two cases).

The results were poor in 50 per cent of the primary and 69.2 per cent of the secondary cases.

As in the cases with pain but without osteoarthritis, the results were better in the primary osteoarthritis cases.

The relatively improved cases were excluded in order to determine the extent to which the operation had a definitely beneficial effect. The percentages of failures were 81.8 and 90 per cent, respectively.

The primary cases were somewhat more successful, but this can be explained by the predominance of mild cases (dysplasia to moderate subluxation), or 55.6 per cent as compared with 30 per cent mild cases among the secondary cases.

In seven of the primary cases and five of the secondary, the signs of osteoarthritis remained unchanged or, in some cases, could no longer be seen. From the point of view of the patients, the results were somewhat worse in these cases. There were no definitely good or even improved cases among them, even though the osteoarthritis had not progressed.

Both sclerosis and cysts may disappear after the operation. This was true in three primary cases and one secondary case, in all of which the sclerosis was no longer present and in one of which a cyst could no longer be observed. The shelf was so narrow in one of these cases that it could not be approved. In three symptoms were unimproved and in one there was relative improvement.

Summary: The shelf operation was not effective with regard to pain in cases of dysplasia and subluxation of the hips combined with signs of osteoarthritis. It is, therefore, not indicated in these cases.

C. Cases of Dislocation

The cases of dislocation in which shelving was done are included in the foregoing groups. Meantime, it is interesting to study these cases in which it can be assumed that practically the entire burden of weight-bearing was borne by the shelf.

Altogether 18 cases of dislocation were operated on and only four of them were recorded as good results (three patients free from pain) 22.2 per cent; 14 failures—one patient free from pain—77.8 per cent. It should be added that one of the successful cases was reduced in connection with the operation. The results are not encouraging.

Investigation of Series of Hips Not Operated On

A more definite opinion of the value of the shelf operation would have to be based on a comparison with a series of similar hip joints in which no operation had been performed. I could find no such series in Sweden. The only material available consisted of the cases on the records of the Clinic that had not been operated on. I traced these cases by going through all the cases of congenital dislocation of the hip treated from 1935 through 1939. The group consisted of 46 hip joints. My point of departure was the first roentgen examination of the leg in extension after the abduction treatment. All the patients were under eight years of age. The last roentgen examination was made when the patients were from eight to fifteen years (average age: 12 years).

The cases operated on include 42 with bilateral changes in which only one joint was submitted to operation. There were 20 joints of this kind in the age group under eight years and 22 in the group over eight years.

These cases which had not been operated on do not, of course, constitute a sample comparable with the surgical cases. Due to a selective process through the years based on widely varying principles of evaluation, the surgical series came to consist of the more serious cases, while most of the control material was made up of mild cases. The results, therefore, cannot be directly compared. Nevertheless, the risk of outward displacement in the cases not operated on can be estimated. Furthermore, the cases followed-up on several occasions will yield information as to the length of the period of growth of the acetabular roof.

I. Displacement in the Cases Not Operated On

The cases are divided into two groups: cases with outward displacement and stable cases. These groups are further broken down according to degree of subluxation.

A. First Examined Under Eight Years

In the first series of patients who had undergone no operation, outward displacement of the femoral head occurred in 12 out of 46 hips.

	Distribution of displacement cases	Distribution of stable cases
Dysplasia	2	27
Slight subluxation	1	7
Moderate subluxation	9	0

Outward displacement occured in 7 out of 20 hips in the series with operation on one hip.

	Displacement cases	Stable cases
Dysplasia	2	9
Slight subluxation	4	3
Moderate subluxation	1	1

B. First Examined Over Eight Years (all cases belong to the series with one hip operated on)

	Displacement cases	Stable cases
Dysplasia	1	11
Slight subluxation	—	6
Moderate subluxation	—	2
Pronounced subluxation	—	2

The frequency of unstable hips in the first cases under eight years was as follows:

Dysplasia	4/40: 10 per cent
Slight subluxation	5/15: 33.3 per cent
Moderate subluxation	10/11: 90.1 per cent

It thus appears that there is a considerable danger of continued displacement in cases that exhibit moderate subluxation after completion of treatment.

In the group over eight years, the risk of displacement appears to be much smaller. However, this may be due to the fact that it is the unstable cases that have been submitted to operation. It is, therefore, impossible to draw any conclusions from these figures. The same objection might be raised concerning the group under eight years. However, it is not likely that the dysplasia cases would have been submitted to operation to a greater extent than the other subluxation groups.

It may also be of interest to compare the hip operated on with the one not operated on in the same patient, in whom both hips were of the same type from the outset.

Age Group Under Eight Years

Dysplasia: Good results on both sides: three cases, in all of which the shelf was absorbed.

Slight subluxation: Good result on the side operated on, displacement on the side with no operation: one case.

Moderate subluxation: Same good results on both sides: one case; the shelf had been absorbed on the side operated on.

II. Ossification of the Cartilage Roof in Cases Not Operated On

In the foregoing chapter it was pointed out that the acetabular margin grew out under the shelf in a few cases, all of them slight conditions in patients under eight years. In order to determine whether the shelf operation played any part in this growth of the acetabular margin, I made a study of the cases not operated on.

The cases should be examined about once a year to follow the development of the acetabular margin. In the present material, frequent control examinations were only made for the first few years after the treatment for dislocation. Thereafter, after-examinations were made at intervals of two or three years. The cases which were not examined during the period between the reduction treatment and the age of ten years could not be evaluated. The operation series reveals that the dislocation nuclei become consolidated between the age of eight and twelve years, and it is, therefore, desirable that the control material of cases not operated on be followed up to the same age of after-examination.

The following figures do not, of course, indicate the frequency of good end-results in the cases not operated on, but are only intended to demonstrate the possibility of a late increase in growth of the acetabular margin.

The acetabular margin became ossified in 14 cases with good end-results (Table XVI).

Thus, the acetabular margin continued to grow up to the age of eight to twelve years in 14 hips with mild conditions, or dysplasia to slight subluxation (Fig. 12). In one of these cases the ossification was completed during the period eleven to fifteen years; the exact age cannot be stated due to the lack of roentgen control examinations

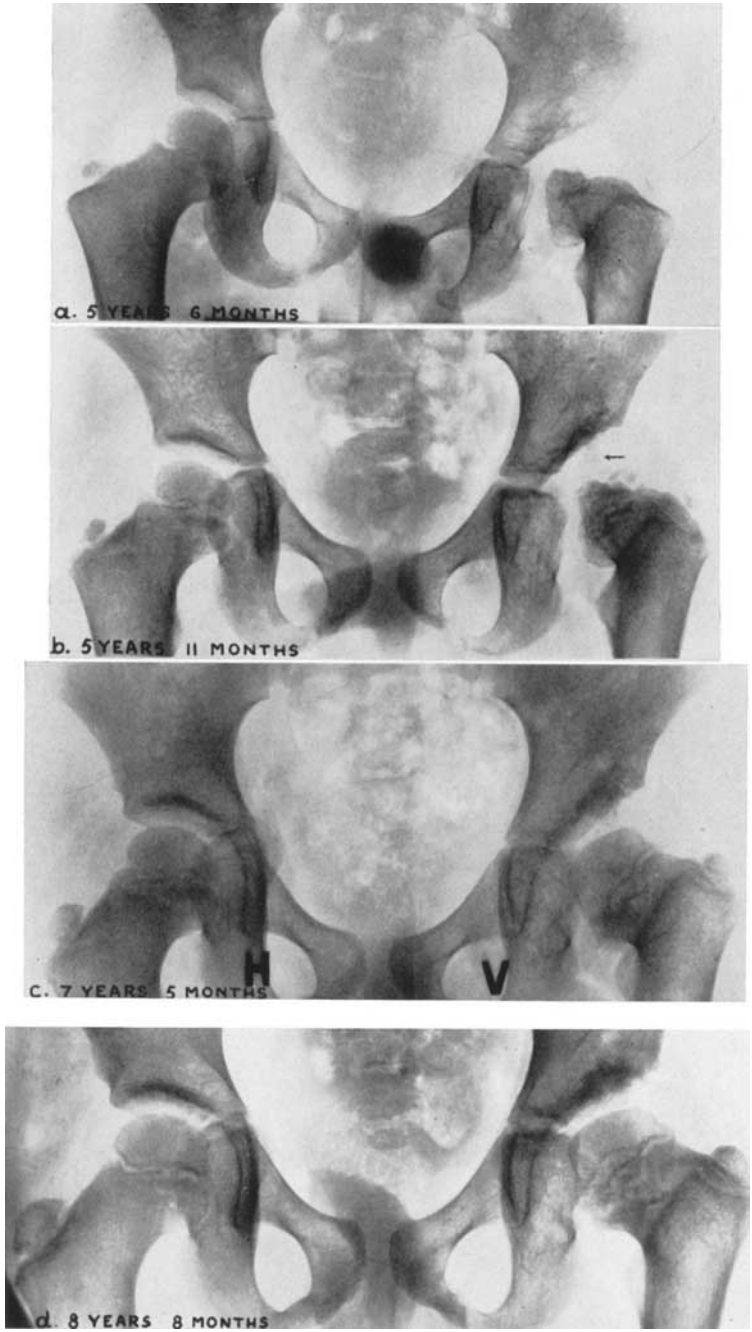

a. 5 YEARS 6 MONTHS
b. 5 YEARS 11 MONTHS
H
V
C. 7 YEARS 5 MONTHS
d. 8 YEARS 8 MONTHS
R
L

Fig. 12.

Fig. 12. Case No. 33973. Congenital dislocation of the left hip reduced at 4 years and 8 months. a. 5 years and 6 months : No ossification nuclei in the acetabular roof. — b. 5 years and 11 months: 2 small ossification nuclei appear in the acetabular roof. — c—f. Advancing ossification of the acetabular roof, not completed at 12 years.

Table XVI. Late Ossification of the Acetabular Roof.

Type after completion of treatment	Dysplasia (8 cases)								Slight subluxation (6 cases)					
Age at appearance of first nucleus ..	6 yrs	5	6	2	5	2	8	7	8	2	4	4	3	9
Age at completion of ossification of acetabular roof	9 yrs	9 not complete	12 not complete	11—15	9	8	10	9	9—11	10 not complete	10	10	9	11

during the intervening years. It should also be noted that the ossification was not completed in three cases in which the last examination took place at the ages of nine, ten, and tvelve years, respectively, although the head of the femur was well covered.

Similar ossification was observed in five other cases, but the final stage consisted of different degrees of dysplasia. A late but inadequate ossification was seen in seven cases, in which the end-result was slight subluxation in five and moderate subluxation in two cases.

The material is admittedly the result of a selection, in that the more severe cases were operated on. We find, however, that late ossification of the acetabular roof and growth of the joint margin may also occur in cases of the mildest forms of subluxation in which operation has not been performed.

Summary: The following observations are revealed by a study of a control material of cases not operated on:

1) The risk of outward displacement of the femoral head in the age group under eight years was small in cases of dysplasia (10 per cent), greater in slight subluxation (33.3 per cent) and considerable in moderate subluxation (90.1 per cent).

2) Late ossification of the acetabular roof and growth of the acetabular margin occurred even in cases of dysplasia and slight subluxation that had not been operated on.

The latter observation bears out the view expressed in the foregoing chapter that immediate operation is not indicated in cases of dysplasia or slight subluxation. These patients should be under regular observation, bearing in mind the possibility of the joints developing normally without operation.

In view of the increased risk of outward displacement in slight subluxation, patients with this condition should be examined more frequently and if necessary be submitted to operation.

Pain

The causes of pain in the region of the hip are varied and to some extent unknown. It is obviously impossible, on the basis of the present material, to reach any conclusions as to the nature of the pain. But the material does give rise to certain thoughts which may be of some interest.

I. Connection Between Pain and Changes in the Hip Joint

The frequency of pain in dysplasia-subluxation has been studied by *le Scolan* (1924) and *Nové-Josserand* (1925). Up to the age of five years they considered pain to be unusual, appearing only after exertion. In the age group 5 to 15 years and in the older age groups, on the other hand, they found pain to be a common symptom.

Lance (1941) made a study of the age at which pain made its first appearance in cases of subluxation, with the following results:

	Primary subluxation	Secondary subluxation
Before 10 years	3 per cent	3 per cent
10 to 15 years	18 "	43 "
15 to 20 "	17 "	7 "
20 to 25 "	17 "	25.5 "
25 to 30 "	3 "	20 "
30 to 40 "	34 "	3 "
40 to 50 "	7 "	
50 to 55 "	3 "	

The causes of the pain in subluxation have been attributed to stretching of the ligaments and muscles, abnormal support (*Tillier* 1927), displacement of the articular surfaces (*Lance* 1927), the poor support the femoral head receives from the acetabular roof (*Wiberg* 1939).

Massie (1951) noted that 72 per cent of hips with epiphysitis showed unsatisfactory results.

According to *Lance's* table, pain appears at a later age in primary subluxation cases than in secondary. If the subluxation position were the only cause, the pain would appear at the same age in both types. Therefore, the possibility must also be borne in mind that damage in connection with reduction—epiphysitis and joint lesions—may also give rise to pain. By the same token, the malposition of the joint in the primary subluxation cases might cause latent joint lesions which at a more advanced age might give rise to pain.

In order to determine whether there is any connection between pain, impaired movement and deformity of the femoral head, I made a study of the preventive groups under eight years. The group, "poor retention", was eliminated since it represented a special problem, consisting, as it did, of severe cases. Altogether 32 cases remained.

Free of pain:	27	hips	with	5	deficient	femoral	heads (18.4 %)
With pain:	5	"	"	4	"	"	" (80 %)
Normal movement:	26	"	"	6	"	"	" (23.1 %)
Impaired movement:	6	"	"	3	"	"	" (50 %)

The average age at operation and at after-examination in the painless cases was 5.2 years and 11.4 years, respectively and for cases with pain 5 years and 11.4 years, respectively.

The average age at operation and after-examination in cases with normal range of motion was 5.4 and 11.3 years, respectively, and for cases with impaired movement 5.2 and 12.7 years, respectively.

The cases with pain did not belong to the more severe subluxation categories, but were divided as follows: sloping acetabular roof, 3 cases; moderate subluxation, 2 cases. During the observation period, four cases produced a good acetabular roof, formed, in one of them, by the shelf. There is, therefore, no reason to blame the pain on a poor acetabular roof. It thus appears that in some cases the pain was due to a deformed joint, *i.e.* resulted from an articular lesion. The same is true of limitation of movement, which, according to the foregoing, is more common in cases with deformed joints.

In this connection, it is interesting to note that epiphysitis was present in 87 per cent of the cases of deformed femoral head (20 out of 23 hips), but in only 12.9 per cent of non-deformed or rounded heads (8 out of 62 joints). This means that epiphysitis led to deformity of the femoral head in 71.4 per cent of the cases. Since we know that epiphysitis often develops during the reduction treatment, it is clear that prevention of epiphysitis is just as important a problem as prevention of subluxation. Pain in a secondary subluxation joint might, therefore, be due to a joint lesion caused by

previous treatment. If this is true, the shelf operation would be without effect in this type of case.

II. Differential Diagnosis of Pain in the Hip Joint

Pain and fatigue in the region of the hip are not unusual symptoms. Even if roentgen reveals dysplasia of the hip joint, one cannot be certain that this is the cause. This is confirmed by the following three cases, which were eliminated from the material:

Case 1 (No. 3969/44). A 38-year-old woman, with the diagnosis, dysplasia of the hip, had for 15 years had periodical pain and stiffness in the right hip. The pain reached from the sacro-iliac region over the trochanter on the outer aspect of the thigh. She had difficulty in walking, but no limp. Roentgen showed dysplasia and a cyst in the acetabular margin. Owing to the cyst, a modified version of the Spitzy operation was done; instead of a tibial graft, wedges of the iliac crest were inserted in the acetabular margin. The shelf was placed somewhat too high. On after-examination five years later, the pains "in the hip joint" were no longer present, but the patient still complained of backache and pain in the outer aspect of the thigh. She had a slight limp and the Trendelenburg test gave a moderately positive reaction. A large indentation was palpated over the abductor muscles. Roentgen revealed a somewhat high shelf, as well as sclerosis of the acetabular roof.

Case 2 (No. 3475/39). A 37-year-old housemaid, with the diagnosis, bilateral dysplasia of the hip (borderline case), had increasing signs of insufficiency of both hip joints. She had no limp. Bilateral shelving was done. Right-sided paresis of the peroneus developed after the operation. On after-examination seven years later, the patient was found to be disabled by multiple sclerosis.

Case 3 (No. 3867/39). A 36-year-old charwoman, with the diagnosis bilateral dysplasia of the hip, had suffered from pain in the low back and in the left hip joint for three years. Roentgen showed a mild subluxation of the right hip and dysplasia with a CE-angle of 10 degrees on the left side. Bilateral shelving was done. A month or so after the operation the patient was found to have bilateral paresis of the peroneus. A neurologist was consulted. He found suspected lesions of the middle lumbar segment. Parkinson's disease was diagnosed five years after the operation, and two years thereafter the patient was totally disabled.

The *lumbago-sciatica* syndrome was undoubtedly present in the first case. We often find that involvement of a lumbar nerve root simulates disease of the hip joint. Then, if roentgen reveals a mild dysplasia, it is very easy to make a mistake in diagnosis. A careful investigation of the area involved by the pain, as well as a period of observation, usually reveals the correct diagnosis.

In the other two cases, the condition was due to chronic neurologic disease without manifest signs or symptoms. One of the patients had symptoms of insufficiency in the hip joints, and the other had symptoms of lumbago-sciatica. It is probably impossible to detect these

neurologic conditions at an early stage. Nevertheless, these two cases exemplify the risk of wrong diagnosis in adults.

III. Effect of the Shelf on Pain

A more definite opinion of the effect of the operation can be formed by comparing the subjective results in anatomically successful cases with those in cases in which the shelf is too high. The study is confined to dysplasia and subluxation cases operated on because of pain after the age of eight years. The shelf was too high in three hips. One of them was relatively improved and is not evaluated. The other two were not improved. The shelf was satisfactory in 26 hips, in which no complications occurred. Nine cases were relatively improved and are not evaluated. In six the results were good, in four there was improvement, and in seven no change. The average age at operation for cases with approved or too high shelves was 17.9 and 18.3 years, respectively, and the average age at after-examination was 23.7 and 23.1 years, respectively. The various types were evenly distributed between cases with approved and those with too high shelves.

It would thus appear that a well-situated shelf may have a favorable influence on pain.

In this connection, it is interesting to note the effect of the shelf on the acute attacks of pain. Sudden severe pain in the hip joint is often experienced by the patient as a locking or catching in the hip joint. Ache and tenderness may remain for several days. Ten of the patients operated on for pain reported similar symptoms. These attacks of pain disappeared after the operation in nine cases, eight of them with satisfactory shelves and one with a high shelf. In one case, the locking pains remained despite a good shelf. In still another, locking was first experienced after the operation; here the shelf was a failure, with partial absorption, postoperative displacement, and upward reflection of the shelf. The good results with these often intense pains constitute further evidence that the operation may influence the pains in dysplasia and subluxation.

Roentgenographic Evidence of the Function of the Shelf

We have already discussed outside influences that might affect evaluation of the results. It would, therefore, be interesting to see if roentgen discloses any joint changes that indicate weight-bearing by the shelf. In the cases in which the femoral head slips out under the shelf after operation, it is quite clear that the shelf serves as a buttress and takes over the weight-bearing function. In many cases no displacement occurred. If the operation consisted only of downward reflection of a bone flap over the joint capsule, it cannot be assumed that the shelf necessarily took over the weight-bearing function.

The following joint changes may constitute *evidence of weight-bearing* by the shelf:

1) Reconstruction of the shelf with the development of a sclerotic cortex.
2) A change in the trabecular structure of the head of the femur, which may spread out under the shelf.

Lack of weight-bearing might lead to the following:

1) Decalcification of the shelf without sclerotic cortex.
2) Absorption of the shelf.
3) No change in the trabecular structure of the head of the femur.

I. Transformation of the Shelf

Two groups of cases were selected for a comparison of the foregoing changes (Table XVII). The first group includes all the cases in which the femoral head was seen to have slipped out under the shelf (Fig. 13). The second group consists of the cases in which the shelf was too high from the outset.

In 17 secondary cases the femoral head slipped out under the shelf, and in 14 of them the graft was satisfactorily transformed with a sclerotic cortex. The cortex was absent in three cases, all of which revealed postoperative osteoarthritis. There was no absorption in these 17 cases, and the trabeculae were unchanged.

Table XVII a and b. Roentgenographic Appearance of Shelf and Bony Trabeculae of Femoral Head (a) With Weight-bearing Shelf (b) With High Shelf.

Group	a. Displacement Cases				b. High Shelf			
	Shelf			Bony trabeculae	Shelf			Bony trabeculae
	Cortex sclerosed	Cortex not sclerosed	Absorption		Cortex sclerosed	Cortex not sclerosed	Absorption	
Under eight years								
Prevention	2	0	0	unchanged	0	2	0	unchanged
Unstable retention	3	0	0	»	0	1	2 (partial)	»
Displacement..	7	1	0	»	0	0	1	»
Over eight years								
Displacement..	0	1	0	0	0	0	0	»
Prevention	0	0	0	unchanged	0	1	0	—
Pain.....	2	1	0	»	0	2	1	unchanged
Total	14	3	0		0	6	4	

In ten secondary cases the shelf was too high; in six of them the cortex was lacking (Fig. 14), and in four the shelf had been absorbed.

Displacement had occurred in two of the primary cases; in one the cortex was satisfactory and in the other the shelf had been turned upward and absorbed. In two cases the shelf was too high and the cortex was lacking. The trabeculae were unchanged in these cases.

It may be concluded from the foregoing that a transformed shelf with cortex indicates that the shelf takes part in weight-bearing. On the condition that the joint was not injured after the operation,

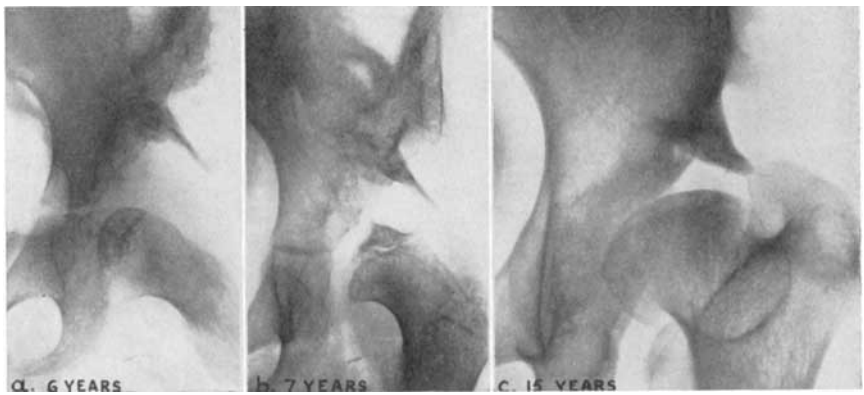


Fig. 13. Case No. 23775. a. Reduction and shelf operation at 6 years. — b. The femoral head is displaced outward under the shelf. — c. Shelf sclerosed.

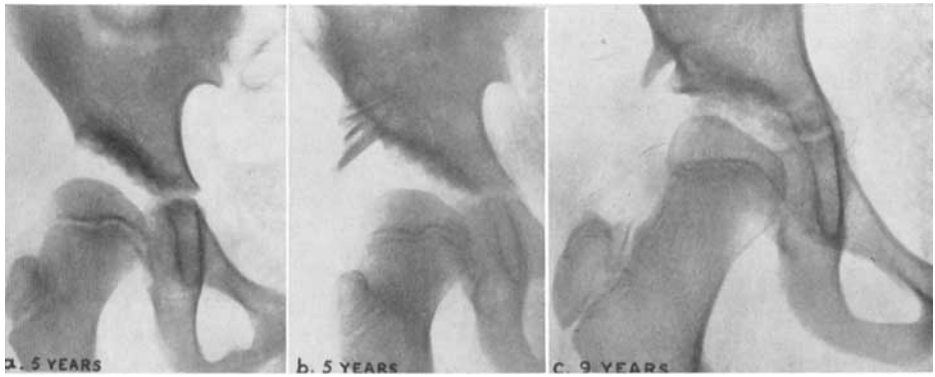


Fig. 14. Case No. 915/43. Non-weight-bearing shelf: No sclerosis.

absence of the cortex, on the other hand, indicates that the shelf does not bear weight. With the projections we used, we could not observe any change in the trabeculae even when the shelf was definitely bearing weight.

II. Absorption of the Shelf

I studied the frequency of absorption of the shelf in our material. In order to form an opinion of the importance of the position of the shelf, I divided the material into two groups, as follows (Table XVIII):

1) the shelf was too high or turned up,
2) the shelf was anatomically satisfactory.

Table XVIII. Absorption of Shelf in Relation to Positon at Operation.

	High or turned-up shelf No. of hips		Good anatomic position of shelf No. of hips	
	Absorption	No absorption	Absorption	No absorption
Under eight years	13	5	5	26
Over eight years	2	5	1	31

The cases with osteoarthritis are excluded, as are those in which displacement occurred despite a well-constructed shelf.

It will be noted that in the age group under eight years the risk of absorption was considerably greater if the shelf was poor—72.2 per cent—than if the shelf was good—16.2 per cent.

In the age group over eight years, the risk of absorption was in general much smaller: 28.6 per cent with poor shelf and 3.2 per cent with good shelf.

It appears from the foregoing that in the age group under 8 years, absorption was usually due to a poorly constructed shelf.

Summary: The frequency of a well-transformed shelf with cortex was much higher in cases in which the shelf definitely bore weight than in cases with a shelf that was too high. Good transformation, therefore, could be interpreted as a sign that the shelf was bearing weight.

Absorption in the age group under eight years appears to have been due to poor location of the shelf. The tendency to absorption was much less pronounced in the older patients.

Complications

Judging by the literature, the operation is attended by very few risks. Various mild complications without importance to recovery have presumably not been reported.

The following complications were encountered in the present material:

1) **Hematoma:** Two cases. The loss of blood would seem to be of little interest. On the other hand, hematoma may be the origin of secondary infection; in addition, a large hematoma might lead to muscular lesion if the sutures cut through the muscle.

2) **Wound Infection:** Two cases, with damage to the joint in one.

3) **Shock** was noted in three cases. In one of them shock occurred during the operation, which had to be interrupted; the result was nevertheless good.

4) **Postoperative Thrombosis** was noted in nine cases. One patient had residual symptoms, while in another the end-result was not known. All these patients were adults between the ages of 21 and 42 years. The frequency was 21.9 per cent (9/41). The risk of thrombosis, therefore, is rather great in operations on adults.

5) **Rigidity of the Knee Joint** was found in two cases. In one case it represented a troublesome complication with persistent flexion contraction. Both patients were adults who had been treated with adhesive traction.

6) **Hyperalgesia of the Thigh** was present in one case and was probably due to a suture having involved the cutaneus femoris lateralis nerve.

7) **Pneumonia** without complications was contracted in three cases.

8) **Joint Lesion.** Signs of osteoarthritis developed during the observation period in ten cases. The course was chronic and did not differ from the picture usually seen in subluxation. Cysts and sclerosis were seen in the acetabulum and the head of the femur. Thus, the condition could not as a rule be regarded as caused by the operation. In three of these cases the damage may have been due to faulty surgical technic. Two of them were subluxation patients (Nos. 146/36 and

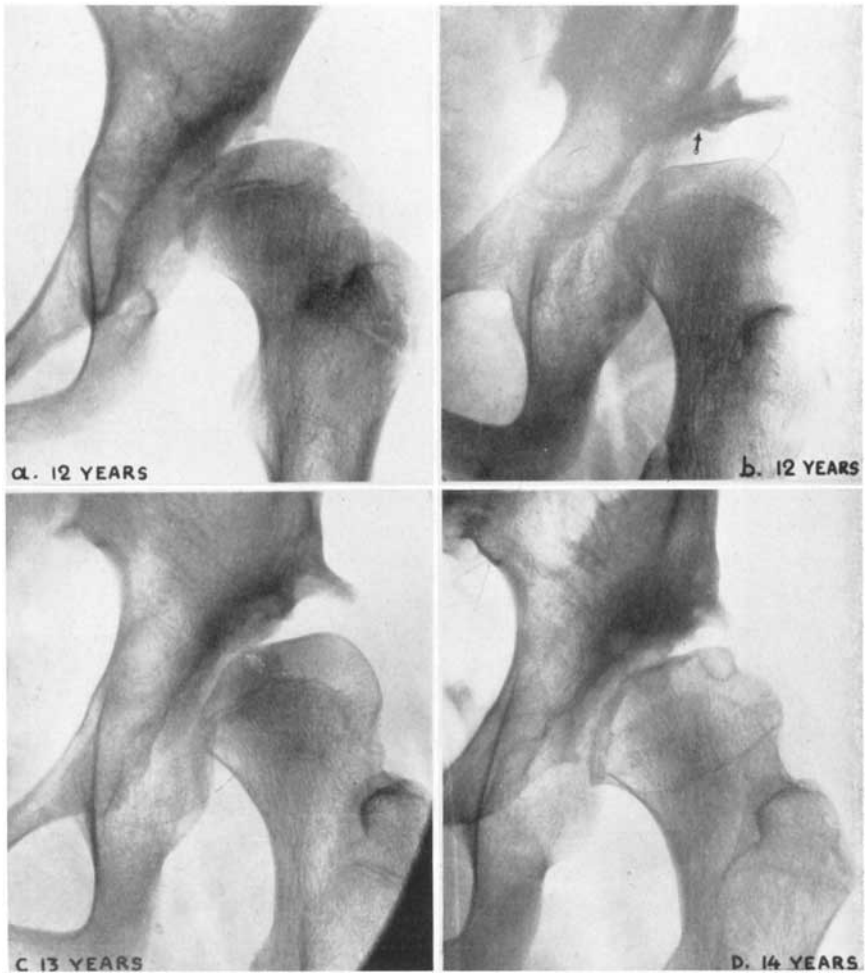


Fig. 15. Case No. 21946. a. Secondary pronounced subluxation. — b. The acetabular margin is pried down at the shelf operation. — c. Beginning absorption of the shelf. Cyst medially in the epiphysis of the femoral head. — d. Most of the shelf is absorbed. There is a lateral defect in the femoral head. Osteoarthritis has developed.

348/36), in which the femoral head was kept drawn down during the operation. In both cases the femoral head later pressed the shelf upward and became further dislocated. One of these cases was also complicated by an infection. It is probable that the femoral head had been damaged by too great pressure. In the third case (No. 21946—age at operation: 12 years), the acetabular margin was broken down. The roentgenograms gave the definite impression that the femoral head had been damaged by pressure and forced to adapt its shape to fit the new acetabulum (Fig. 15).

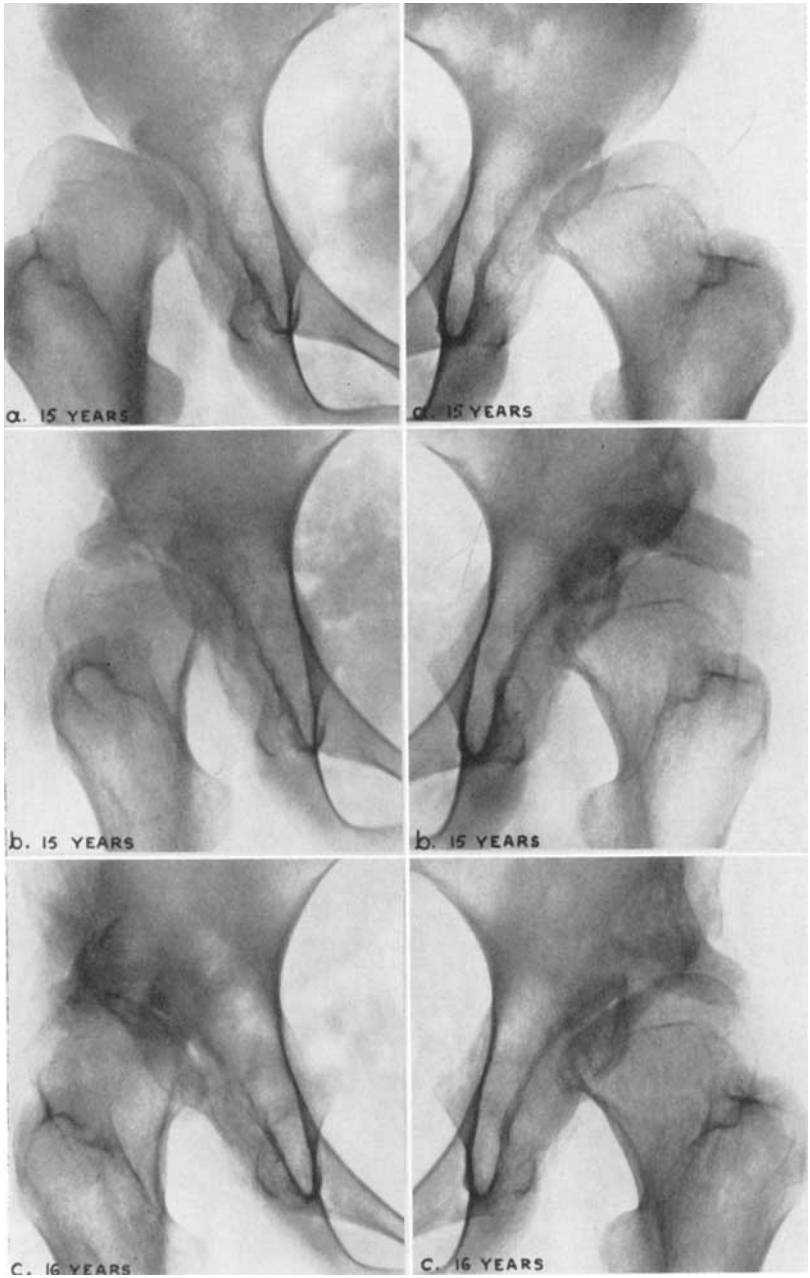


Fig. 16. Case No. 26193. a. Bilateral secondary pronounced subluxation. — b. Shelf operation without downward reflection of the acetabular margin. — c. Rapid development of osteoarthritis after the operation.

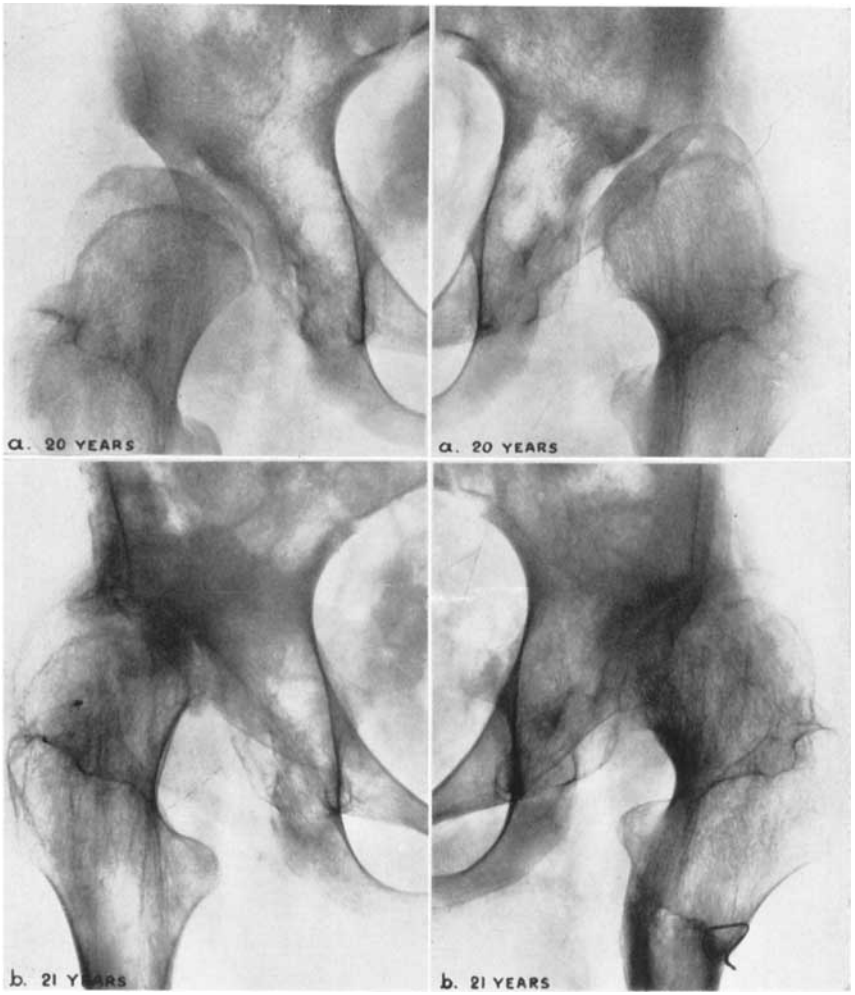


Fig. 17. Case No. 4693/44. a. Bilateral secondary pronounced subluxation. — b. Right side after shelf operation. The femoral head has subluxated and osteoarthritis has developed. — c. Left side after stabilizing osteotomy. Osteoarthritis has developed.

In the discussion of the results, we have already mentioned the risk of relatively rapid destruction of the joint after operation in secondary cases in the age group 8 to 15 years. The joint injury made itself felt already during the first year after the operation. The roentgenograms in some cases showed only erosion and decalcification, but in the majority they also revealed rapid narrowing of the joint space and diffuse contours (Fig. 16). One had the definite impression that the operation had damaged the joint. Meantime, a survey of the cases

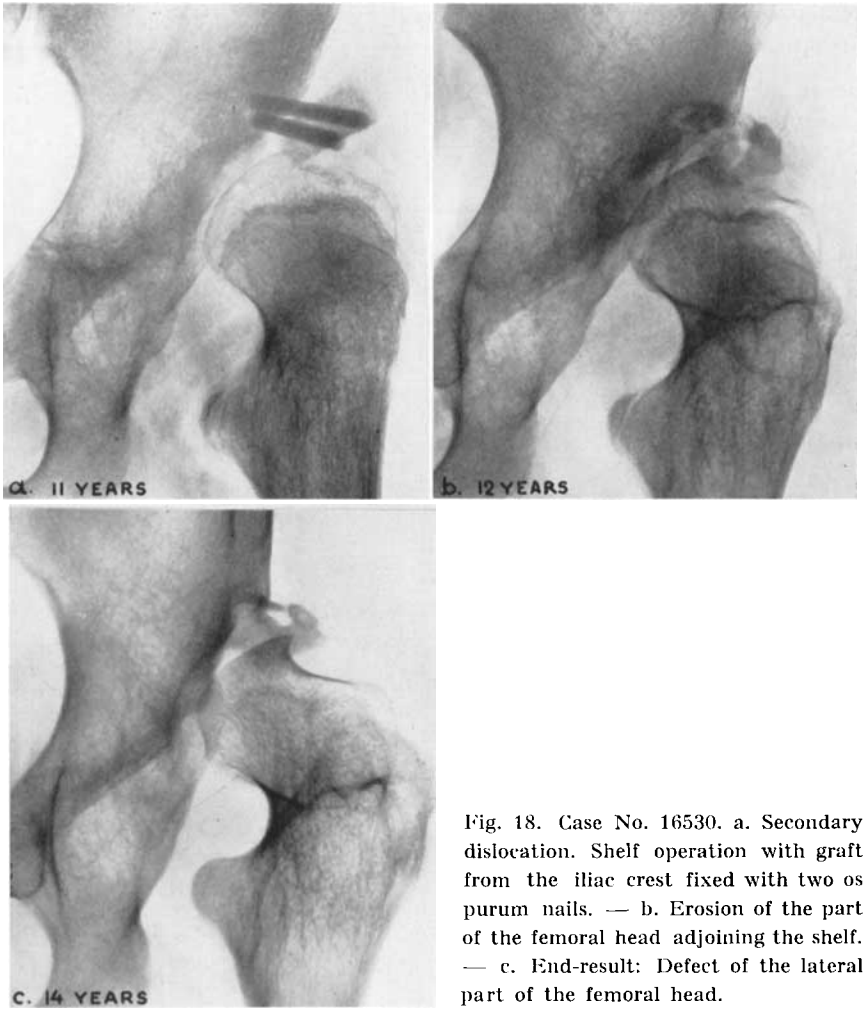


Fig. 18. Case No. 16530. a. Secondary dislocation. Shelf operation with graft from the iliac crest fixed with two os purum nails. — b. Erosion of the part of the femoral head adjoining the shelf. — c. End-result: Defect of the lateral part of the femoral head.

not operated on revealed one case with a similar picture of joint injury (No. 1419/39). Reduction treatment had been completed when the patient was three years old, and after-examination at the age of ten years disclosed pronounced articular destruction. In another case (No. 4693/44), subtrochanteric cuneiform osteotomy was done in the contralateral hip joint six weeks after shelf operation. An arthritis-like condition developed in both hips (Fig. 17, left). The operation could not have been the cause of the joint damage in these two cases. Probably a joint injury incurred at reduction later underwent an acute exacerbation. This assumption is supported by the fact that cases of primary subluxation do not exhibit this picture of rapid destruction of the joint.

The present material included nine cases with a course that resembled the foregoing. All of these cases were not similar, however.

Case No. 31034. Reduction was done at the age of ten years at the same time as the operation.[1] One year later the joint space was found to be narrow and the contours were diffuse. It was undoubtedly the late reduction that caused the joint damage.

Case No. 16530. Operation was done at the age of 11 years, after-examination at 23 years. Motion was normal before the operation. Within a year the joint showed considerable erosion with absorption of the part of the femoral head outside the acetabulum and under the shelf. The X-rays gave a definite impression of a shelf pressed too hard against the femoral head. (Fig. 18.)

The remaining cases are listed in Table XIX.

Table XIX. Cases with Early Postoperative Osteoarthritis.

Case No.	Type	Operation and after-examination ages	Downward reflection of roof	Motion before operation	Post operative course	Remarks
26193 right	Pronounced subluxation	15—16 years	0	poor	rapid osteo-arthritis	Arthrodesis
26193 left	Pronounced subluxation	15—18 years	0	poor	rapid osteo-arthritis	Cyst in acetabular margin at operation
26331	Pronounced subluxation	12—20 years	0	poor	erosion of the femoral head	Dislocation 2 mos. after operation
34576	Pronounced subluxation	13—16 years	0	poor	rapid osteo-arthritis first year	Shelf too high. Erosion of head before operation
379/41	Moderate subluxation	12—20 years	+	poor	osteo-arthritis 11 mos. after operation	—
841/43	Moderate subluxation	13—19 years	+	poor	osteo-arthritis 4 mos. after operation	Ankylosis
4693/44	Pronounced subluxation	16—17 years	0	poor	rapid osteo-arthritis first year	Rapid osteo-arthritis in side not operated on

[1] Reduction is no longer performed in children over five years due to the unsatisfactory results of the procedure above that age.

Fig. 19. Case No. 379/41. a. Secondary moderate subluxation. — b. Shelf operation: The acetabular roof is slightly pried down. — c. Shelf partially absorbed; there are signs of a joint lesion: erosion of the femoral head and narrowing of the joint space. — d. Osteoarthritis with lateral defect of the femoral head has developed.

Only in two of the cases listed in table XIX could the operation possibly have damaged the joint. Roentgen showed that the roof had been broken down to such an extent that it gave the appearance of an intra-articular fracture (Fig. 19 and Fig. 20). All the cases had four features in common:

a) Previous treatment for dislocation.
b) Age at operation: 13 to 16 years.

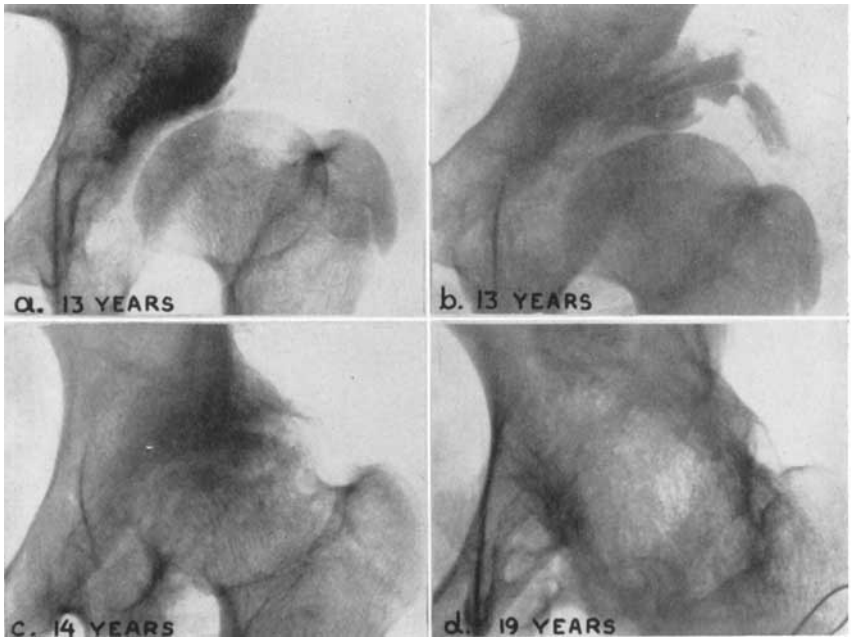


Fig. 20. Case No. 841/43. a. Secondary moderate subluxation. — b. Shelf operation with incomplete downward reflection of the acetabular roof. — c. Diffuse contours and narrowing of the joint space indicates joint lesion. — d. End-result: Ankylosis.

c) Pronounced subluxation. The two exceptions were the cases with downward reflection of the roof, and both of them belonged to the moderate subluxation category.

d) Limitation of movement before operation.

The last factor suggests damage to the joint. In one case (No. 34576), a later examination of the X-rays showed that even before the operation there had been a small area of erosion on the femoral head, indicating beginning arthritis.

Destruction of the joint took place in another case also (No. 30782). The patient was a three-year-old with dislocation, which had recurred after reduction. Reduction was done once more at the age of four years, this time together with an operation in the form of downward reflection of the acetabular roof. Postoperative roentgen revealed some downward reflection of the margin. After this operation, the femoral head and the acetabulum underwent necrosis, and redislocation occurred. There is nothing in the case history to explain this unusual course of events.

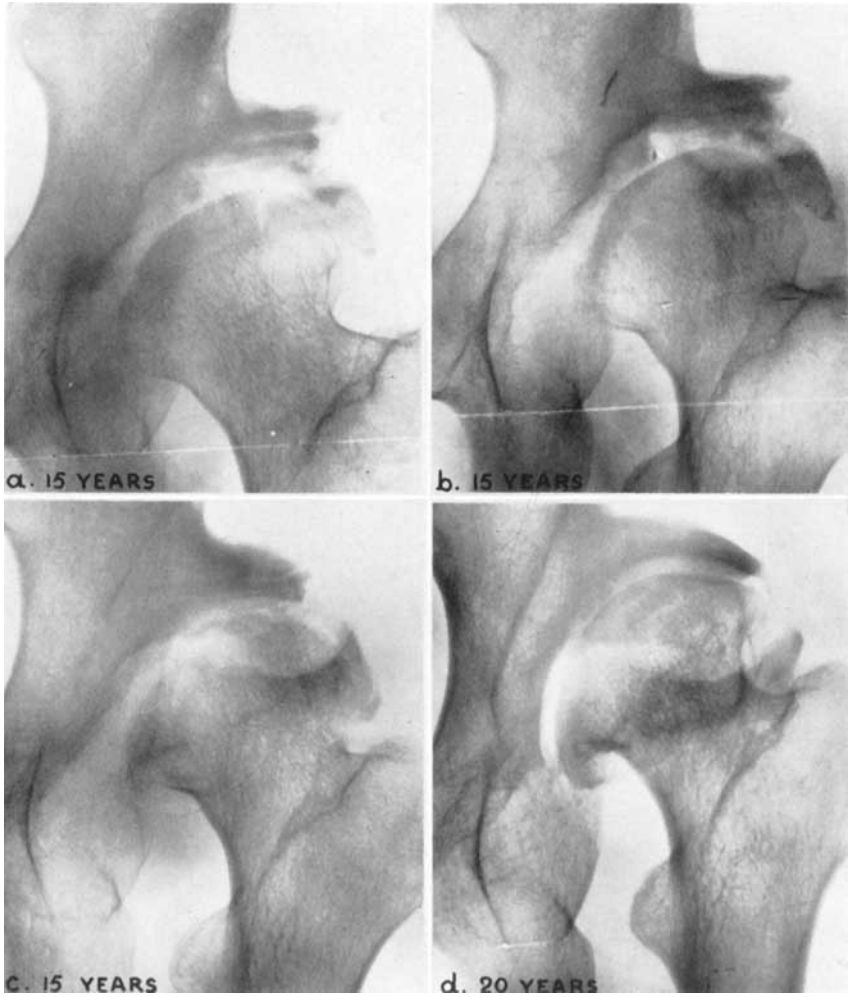


Fig. 21. Case No. 9666. During the year after shelf operation the femoral head became dislocated, pushing the shelf upward.

9) **Early Displacement of the Head of the Femur after the Operation.** In the general review of the material, it was noted that in some cases the femoral head was displaced outward during the first few years after the operation; it may also have returned to its old position soon after reduction was attempted. In a few cases, however, considerable further outward displacement and even dislocation occurred during the first postoperative year (Fig. 21). This happened in six cases, listed in Table XX.

Table XX. Cases with Early Postoperative Displacement of Femoral Head.

Case No.	Type	Operation and after-examination ages	Operative indication	Shelf	Postoperative course
9666	Moderate subluxation	14—24 years	pain	good	dislocation with upward displacement of shelf during first year
26331	Pronounced subluxation	12—20 years	displace-ment	poor	dislocation during first months
146/36	Dislocation	14—29 years	pain	poor	dislocation within one year
1871/36	Primary moderate subluxation	6—13 years	displace-ment	poor	subluxation within one year
3246/38	Moderate subluxation	7—14 years	displace-ment	good	pronounced dislocation within first months
3747/43	Slight subluxation	3—9 years	Displace-ment	poor	dislocation within six months; shelf turned upward

The displacement in the last case in the table can be explained by the fact that the operation was done soon after the dislocation treatment; the shelf was unable to act as a deterrent. In the other five cases the outward displacement happened so soon and was so pronounced that one suspects that the operation favoured the causes of dislocation. Meantime, I was unable to find proof that this was the case. In three of the cases the oblique tendon of the rectus femoris was extirpated, and in three cases this point was not mentioned. Nor was it mentioned whether the joint capsule had been partly dissected free from the wing of the ilium in order to bring the shelf nearer the femoral head; a weakening of the joint capsule might possibly increase the risk of dislocation. It is also conceivable that the muscles around the joint were so weakened that the stability of the joint was decreased. Since we do not know how a subluxation joint becomes stabilized, it is impossible at this time to discuss the problem of whether the displacement in the foregoing cases was a complication of the operation or a manifestation of the pathologic conditions in the joints.

Problems of Surgical Technic

In the foregoing chapters the shelf operation was treated with reference to results and risks. The technical problems of the operation will now be discussed on the basis of the present material.

I. Incision

All the patients in the present material were operated on with the *Smith-Petersen* incision. After-examination revealed that distinct atrophy of the tensor fascie latae and the gluteus medius could be palpated in some cases, generally in the form of flattening, rather than the normal bulge on contraction, or of a shallow depression. In some cases, however, a muscular defect in the form of an indentation could be palpated.

One hundred and forty-four hips were examined in this way. The muscles revealed nothing abnormal in 50 cases, or 34.7 per cent, moderate atrophy in 70, or 48.6 per cent, and appreciable defects in 24, or 16.7 per cent.

At the follow-up I also examined the active abduction motion with the patient in the lateral position. In this way I was able to note the range of motion within which the patient was able to fix the limb. The Trendelenburg test was also checked. These two methods are informative with regard to the function of the abductors. I reviewed suitable cases in order to investigate whether there was any parallelism between palpation findings, active abduction and the Trendelenburg test (Table XXI). The degree of subluxation influences the function of the abductors, and, therefore, I only included the mildest forms up to slight subluxation. The cases in which outward displacement occurred after the operation were eliminated, as were the osteoarthritic cases.

With normal musculature, the active abduction range was normal in 76.9 per cent and the Trendelenburg in 84.6 per cent.

Table XXI. Abduction of Hip and Trendelenburg's Test in Normal and Defective Abductor Muscles.

	Abduction			Trendelenburg's Test		
	Good	Slightly limited	Limited	Negative	Uncertain	Positive
Hips with normal abductor muscles (13 cases)	10	1	2	11	1	1
Hips with palpable muscular defect (12 cases)	4	2	6	7	4	1

With muscular lesion, the figures were 33.3 per cent and 58.3 per cent, respectively. There was thus no absolute parallelism. This is explained by the very relative methods of investigation. Both Trendelenburg test and active abduction are greatly influenced by the weight of the body and of the leg. Nor did I take into consideration possible exertion before the examination or the patient's endurance.

In some of the cases with moderate changes, the palpation findings could be interpreted as atrophy resulting from inactivity. However, there were obvious signs of muscular damage or displacement after the operation in a not inconsiderable number of cases.

Meantime, if a more extensive intervention is required with downward reflection of a bone flap and possibly of the acetabular margin also, considerable dissection of the operative field is necessary. With the *Smith-Petersen* incision there is, of course, a danger of muscle damage. However, this incision provides such excellent access to the operative field that it cannot be ignored. *Ollier's* incision gives good entry to the upper acetabular margin, and it is easy to check with roentgenograms that the muscular insertions, visualized as the apex of the trochanter, have healed into place after the operation. Furthermore, if the subluxation is pronounced, the trochanter can be displaced downward, as stated by *Mau* (1932). Finally, the *Ollier* incision has the advantage of not involving the tensor fascie latae muscle. On the other hand, downward reflection of the bone flap cannot be accomplished with the same visibility as with the Smith-Petersen incision. Furthermore, a special incision must be made in order to extract the bone grafts.

II. Palliative Operation with Downward Traction of the Femoral Head

The femoral head was drawn down in only three of our cases with damage to the femoral head in two.

As already pointed out, the shelf operation gives such poor results in dislocation that one is compelled to advise against it.

III. Determination of the Site of the Shelf

It appears from the present material, as well as from the literature, that the shelf is sometimes situated too high. This is especially true of the secondary cases. I consider that roentgen supervision during the course of the arthroplasty is a most important factor. The position of the shelf and of any downward reflection of the acetabular margin should be verified before closing.

IV. Downward Reflection of the Acetabular Roof

Obviously a steeply sloping roof provides inadequate support for weight-bearing. Downward reflection of the roof to the horizontal plane must be an adequate counter-measure.

Two requirements must be met to justify the operation.

1) The acetabular roof must exhibit definite sloping. At the age of four to five years, roentgenograms of reduced cases may show considerable sloping of the acetabular bone-roof, while arthrography shows the cartilage roof, i.e. the true roof, to be normal.

2) The downward reflection of the roof, which in reality represents an intra-articular fracture, must not injure the joint.

Evaluation of the first point is often inaccurate. Some cases are operated on, simply because the bone roof is oblique or because the retention seemed to be insecure after reduction.

The risk of joint injury is very seldom discussed. *Scholder* (1930) mentioned the risk of intra-articular lesions in connection with one of his cases.

In the following I shall examine the results in our material with reference to the advantages and risks of downward reflection.

At this point I should like to mention an important factor in the evaluation of results. Roentgenographic verification that the intended downward reflection of the roof or of the margin has actually been accomplished should be done in all cases. This detail is not discussed in the literature. If the end-result is good, it is attributed to the operation.

Further, it is impossible to express numerically the degree of downward reflection of the acetabular roof, since the diffusely outlined margin prevents exact measurements. In our cases it is only a question of downward reflection of the margin, and here measurement of the angle is of no interest. Therefore, I was only able to determine whether

downward reflection had been accomplished and to note the end-results in the various cases (Table XXII).

Table XXII. Late Roentgen-Anatomic Results with Downward Reflection of the Acetabular Margin.

Group	No. of cases	Probable improvement	Uncertain improvement	Worse	Osteo-arthritis
Under eight years					
Prevention	7	4	3	0	0
Unstable retention	3	2	0	1 (necrosis)	1
Displacement ..	3	3	0	0	0
Over eight years					
Prevention	4	3 (age 8 years)	0	1 (age 12 years)	1
Displacement ..	2	1 (age 8 years)	0	1 (disloc.)	0
Pain 8—15 years	2	0	0	2 (age 13 years)	2
Pain over 15 years	1	1 (age 17 years)	0	0	0

It appears from the table that downward reflection of the acetabular margin was seen in 22 hips, with consequent improvement of the anatomic conditions in 14 hips. The improvement consists chiefly of a more harmonious junction between the acetabular roof and the shelf (Fig. 22). In three hips in which the acetabular margin grew out under the shelf, it is uncertain if the break-down was of any importance. Four cases showed joint damage, in one case in the form of total necrosis of the head and in two in the form of distinct pressure damage to the femoral head. In the fourth case the damage may have been caused by rapidly developing osteoarthritis of the type seen in secondary cases between the ages of 12 and 15 years. The necrosis case is difficult to explain. The operation was aimed at downward reflection of the whole acetabular roof, and it may be that the femoral head was exposed to such strong pressure that necrosis set in.

It may be concluded from our cases that downward reflection of the acetabular margin combined with shelving gave rise to a good anatomic result in patients under eight years. In the older cases, however, there was a risk of joint damage. The fact that the risk was smaller in the younger cases is probably explained by the thick cartilage roof having prevented dislocation of the fragment reflected down. It is impossible, on the basis of our material, to fix an upper age limit after which there is a risk of joint damage. In the eight-

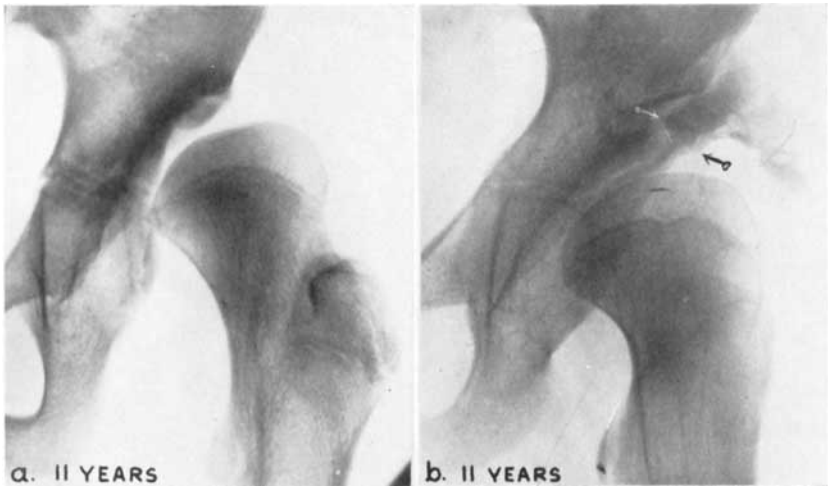


Fig. 22. Case No. 2047/38. a. Secondary moderate subluxation. — b. Shelf operation with downward reflection of the acetabular margin. — c. End-result is good, with the shelf at the level of the bone roof.

years-old group, downward reflection was done in three cases without joint damage. Downward reflection was not done in any of the nine to ten-years-olds, and only one eleven-year-old was submitted to the procedure. This would indicate that the acetabular margin may safely be pried down in patients up to and including the age of eight years. From twelve years on the risk of osteoarthritis is so great that downward reflection of the acetabular margin should be avoided. The material permits no conclusions concerning the age group nine to eleven years. Meantime, downward reflection can probably be done with safety in cases in which there is still a thick cartilage roof.

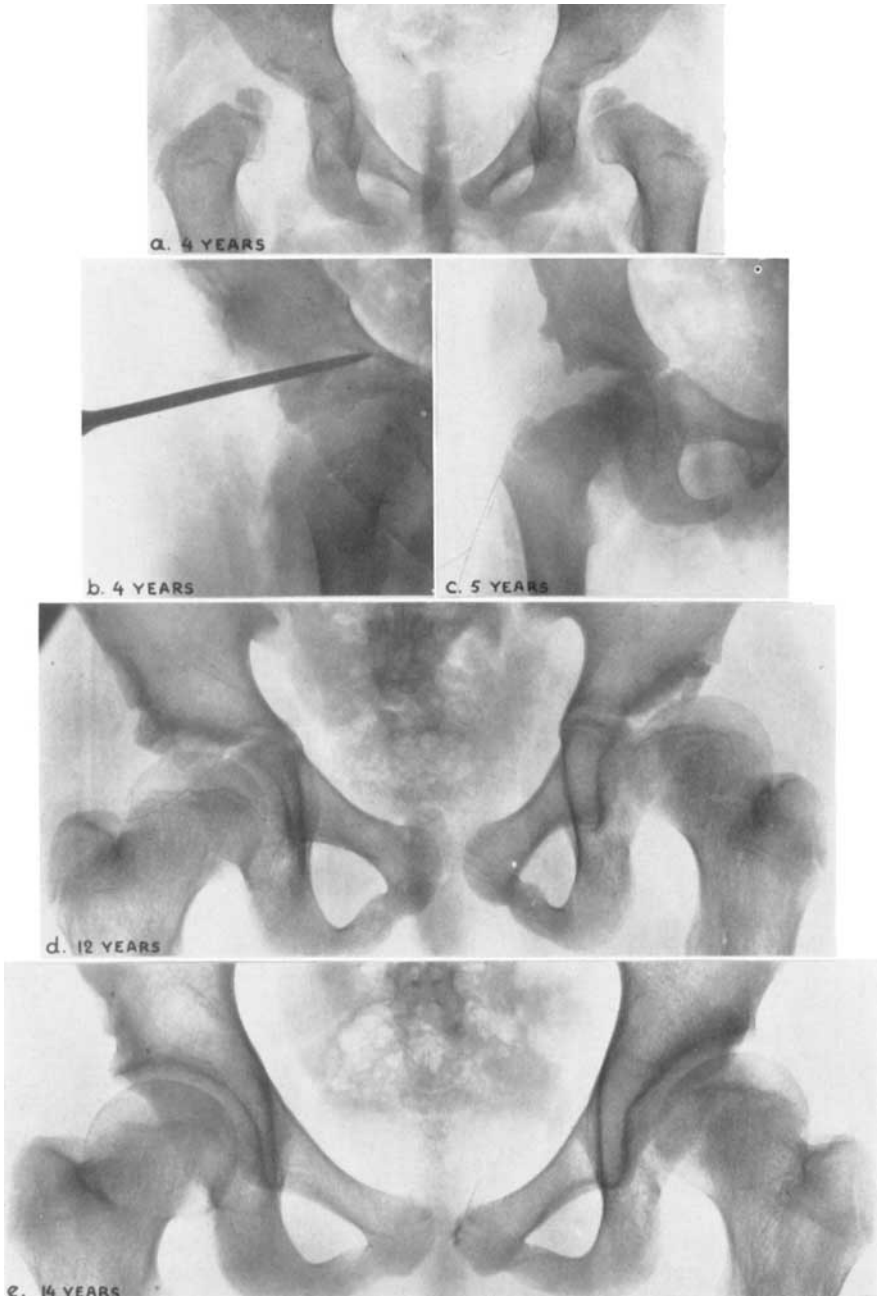


Fig. 23. Case No. 4519/41. a. Redislocation on right side. - b. After reduction the acetabular roof is pried down. — c—e. Good end-result.

Downward reflection was successful in four primary cases, all of them under nine years. It should, therefore, be stressed that the material permits no conclusions concerning older primary cases. Effective downward reflection of the entire acetabular roof was done only in one case, and no evaluation can therefore be made of this method either (Fig. 23).

To turn to the Trendelenburg test, this is an expression of the force with which the hip joint is fixed in abduction. As a pennate muscle with great strength and little range of action, the gluteus medius muscle is very sensitive to any shortening between origin and insertion. In upward subluxation of the hip joint, the force is diminished and the abduction angle in which the hip joint is fixed grows correspondingly smaller. Effective downward reflection of the acetabular roof might be imagined to restore the distance between origin and insertion and thereby explain a negative Trendelenburg. This is the reason that many workers interpret the Trendelenburg test as evidence that the downward reflection of the acetabular roof has succeeded. I may mention that *Ponseti* (1946) considered that the lengthened lever arm which develops when the femoral head is subluxated outward increases the pressure on the abductors to the point that they are unable to fix the joint. In our cases in which the margin was pried down but the acetabular roof was not reconstructed, one could not expect an improvement in the Trendelenburg symptom. In the cases in which the Trendelenburg test was positive before the operation, it remained unchanged thereafter. On the other hand, three cases with negative Trendelenburg became positive after the operation.

In conclusion, let us consider the technic of downward reflection.

Judging from the reports of the operations in our material, downward reflection of the acetabular roof was attempted relatively consistently during the first years. Gradually, however, the method was abandoned. *Wiberg* also stressed this point in 1951. Attempts at downward reflection often failed and at best only the margin could be pried down. In this way we have two groups, one including the cases in which the acetabular margin was pried down and the other covering the cases in which downward reflection failed.

A survey of the material reveals that the acetabular margin was pried down in 23 cases, while, judging by the lack of evidence in this respect shown by the postoperative roentgenograms, the procedure failed in 23 cases.

In consequence of these strikingly poor results, we have gradually come to confine the procedure to enlargement of the articular margin. Meantime, the problem is important from the point of view of surgical

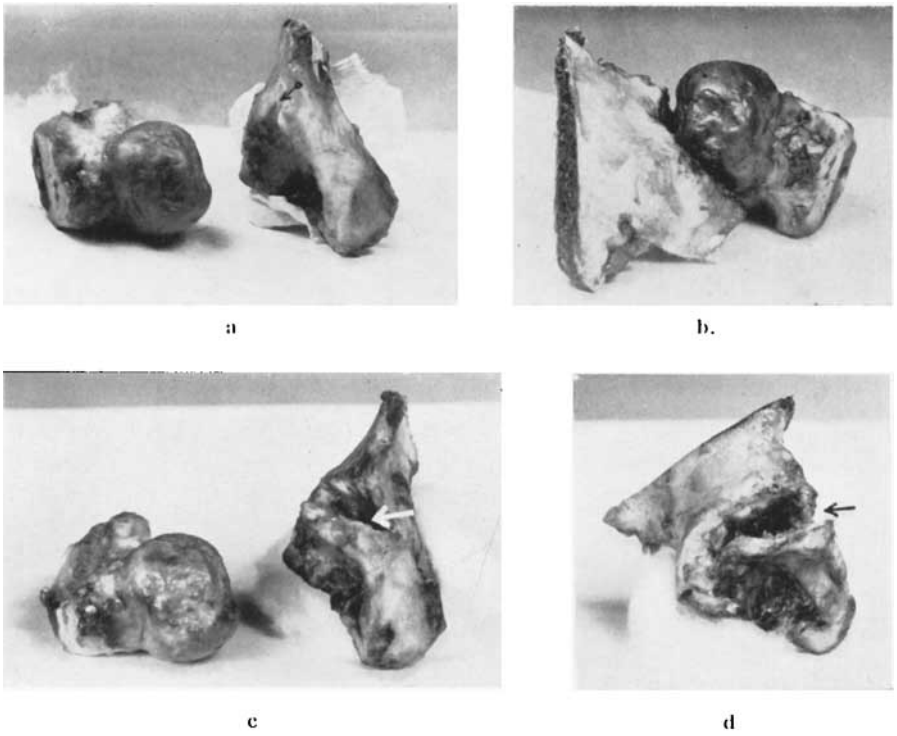


Fig. 24. Autopsy specimen of a case of congential dislocation of the hip joint. a. Frontal view of the joint cavity. Arrow indicates the furrow in the upper acetabular margin. — b. Cranial view of the hip joint. The acetabular roof covers the posterior part of the femoral head only. — c. The acetabular roof has been reflected downward, owing to chiselling being done both from the lateral and the frontal (arrow) aspect of the roof. — d. Side view of the joint cavity. Arrow indicates the anterior margin of the downward reflected roof.

technic. In the first place, the question arises why no change can be seen on the X-ray when the surgeon himself has been under the impression during the operation that he was able to pry the roof down. As we perform the operation, a bone flap is first chiseled down from the wing of the ilium, and the cancellous bone is thereby exposed in the area above the joint. The chisel is then inserted from the lateral aspect as nearly as possible parallel with the roof. Next we try to pry the roof down, with the point of the chisel forming a fulcrum. In this way a wide crack is made in the cancellous bone, giving the impression that the roof is pressed down. This impression is further strengthened when one presses the shaft of the chisel well down below the horizontal line. Meantime, a crack may develop by the cancellous bone being compressed under the chisel and without the roof having

been pressed down. The pronounced lowering of the shaft of the chisel can be achieved merely by pressing the point of the chisel up into the cancellous bone.

I had the opportunity to investigate the technic of downward reflection in an autopsy specimen. The patient was a three-year-old girl with bilateral dislocation of the hip. The specimen consisted of the part of the pelvis around the joint and of the proximal section of the femur. The muscles, capsule and obstructive connective tissue of the joint were removed, leaving the specimen as it appears in Fig. 24. As will be noted, the joint was very shallow. The acetabular roof consisted of a bracket-like projection under the spina iliaca anterior inferior. Behind the projection one could see a furrow in the lateral acetabular margin running in a cranio-caudal direction. The poor support afforded the head of the femur can be seen in the figure.

Downward reflection was attempted as follows: The joint was fixed in a vise. A chisel was inserted deeply about half a centimeter above the joint from the lateral aspect. An attempt to break down the roof only resulted in the point of the chisel working its way up into the cancellous bone. Not until I went in from the front, under the insertion of the rectus femoris muscle, was I able to pry the roof down without trouble. This bears out experience with open reduction combined with remodelling of the acetabulum. In this operation the joint is opened, the head is dislocated, and the chiselling and downward reflection can be accomplished relatively easily in the most efficient fashion. When shelving, the surgeon can only see the lateral part of the ilium above the joint, which makes the operation considerably more difficult. The only possible supervision of the position of the chisel is by roentgenograms. In practice, however, it is found that even insertion of the chisel at the right level and both from the lateral and the anterior aspect is no guarantee of success.

In order to accomplish the considerable downward reflection of the roof that is required for stability, i.e. almost down to the horizontal plane, the joint must be opened, and the femoral head dislocated so that the surgeon can see what he is doing throughout the course of the operation. This, however, represents a much more extensive operation, which can only be justified by a considerable improvement in results. It is doubtful whether the advantage so gained justifies the greater risk involved.

The following case report illustrates a factor which may have a deleterious effect on the results in downward reflection of the whole roof.

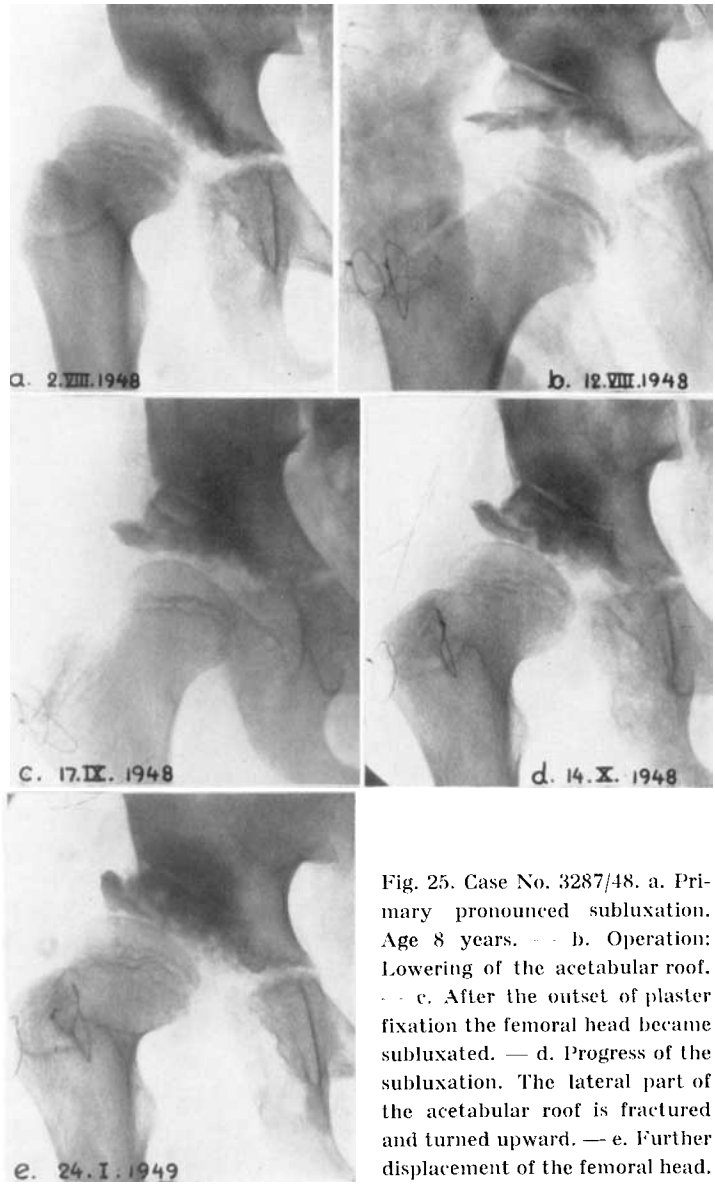


Fig. 25. Case No. 3287/48. a. Primary pronounced subluxation. Age 8 years. — b. Operation: Lowering of the acetabular roof. — c. After the outset of plaster fixation the femoral head became subluxated. — d. Progress of the subluxation. The lateral part of the acetabular roof is fractured and turned upward. — e. Further displacement of the femoral head.

The patient in question was an eight-year-old boy with unilateral primary subluxation of the hip (Fig. 25). Roentgen examination revealed that the head slipped into the acetabulum in good order on abduction. The joint was so deep that downward reflection of the roof alone could be expected to produce a relatively normal picture. In order to make sure of the result, arthrotomy was done and the

femoral head was dislocated, whereupon the acetabular roof was pried down under ocular supervision and was then fixed in place as usual with two substantial wedges from the iliac crest. A plaster cast was then applied with the joint in abduction in order to relieve the pressure on the acetabular roof. The cast was removed after five weeks and was replaced by traction in abduction for a further 18 days. It was found, however, that the femoral head forced up the downward reflected roof at the same time as the roof fractured and was displaced outward. The femoral head was then able to return to its old position. To prevent this complication, the joint must be fixed in such a way as to divert pressure from the roof, i.e. it must be fixed in pronounced abduction. Furthermore, this position must be maintained for approximately three months. Such a long period of fixation, in turn, may lead to rigidity of the joint, which requires lengthy after-treatment.

The more extensive operation and the lengthy after-treatment mentioned above may possibly yield a better anatomic result. However it is doubtful if the functional result will also be better. The risk of joint damage is probably greater. Hitherto, no material is available upon which to base an evaluation of the method in question.

Model Experiments Illustrating the Distribution of Load in the Normal, Dysplastic and Subluxated Hip Joint

With a material which includes dysplasia and varying degrees of dislocation, the question arises whether a method like the shelf operation has any prospect of influencing the distribution of load in the hip joint. The problem is a simple one if all that is required is prevention of displacement. In cases of dysplasia or of a stable subluxation joint in which no displacement occurs after the treatment, one is justified in wondering if any load can be transferred to the broadened acetabular margin via the capsule. I have not been able to find any investigations on the distribution of load in the hip joint in the literature.[1] There seems to be no way of solving the problem mathematically, since it is impossible to calculate the effect of the elastic cartilage as a load equalizer. Therefore, the only possibility seemed to be experiment with models, and in this connection the photoelastic method appeared suitable. The investigation was conducted with the help of Docent *R. Hiltscher,* Chief of the Photoelastic Laboratory of the Royal Institute of Technology.

The photoelastic method is based on the circumstance that a transparent, solid, isotropic body will become optically anisotropic under load, i.e. bi-refringent. The anisotropic state can be demonstrated by polarized light, which, in a parallel light beam, passes the plane model at an angle of 90 degrees. The light then passes an analyzer, the polarization plane of which is at right angles to the polarizer. If the model is free from stress, the polarized light passes through the model but is extinguished in the analyzer and the field remains dark. If the model is stressed, it becomes optically anisotropic. The light wave will be divided into two waves, each of which will oscillate parallel with the principal stress planes. The speed of propagation through the model of the two rays mentioned above will depend on the magnitude

[1] Pauwels (1949) reported on the distribution of load in the hip joint, but did not state how he arrived at his figures.

of the principal stresses. In this way a phase difference between the waves will take place, and, since they have the same polarization plane after passing the analyzer, interference phenomena may occur. The wave may now be extinguished or remain unchanged, according to the stress, whereupon fringes of constant phase difference will be seen. The number of fringes will increase with stress. If white light is used, the fringes are coloured. Their colours represent the complementary colours of the extinguished wave length. The order of interference can be determined from the colours (*Hiltscher* 1948, *Mönch* 1949).

As described above, the method only reveals the distribution of stress in a plane model, and thus represents an approximation of the three-dimensional problem.

To determine the pertinent facts about the magnitude and angles of forces and the form of the model, I measured the specimens and assembled the data about dimensions and weight from the literature.

A. The Normal Joint and the Dysplastic Joint

Half a pelvis together with the proximal part of the femur was sawed out. The pelvis was then put in such a position that an imaginary frontal plane through the femur was parallel to a frontal plane through the antero-superior iliac spine and the symphysis, i.e. the position of the femur in relation to the pelvis was the same as in the upright position. The specimen was thereafter sawn in two in a frontal plane through the center of the femoral head (Fig. 26). This specimen was then drawn on transparent paper so as to portray the contours of interest to the investigation (Fig. 27). The tendons of the contracted gluteus medius and minimus were assumed to have the directions as drawn in Fig. 27 and their angles of tension were then drawn accordingly. A single hypothetical abductor muscle was then drawn in a position corresponding to the parallelogram of forces. Weight-bearing is studied with the patient standing on one leg. The data as to weight were taken from a case described by *Fischer & Braune,* according to *Stauss* (1938), or 58.6 kg. The length of the leg was assumed to be 93 cm. When equilibrium is achieved, the three forces will meet at one point (Fig. 28 a). The diagram reveals the joint load to have a direction of four degrees. At the same time, the forces at equilibrium form a triangle of forces. From the latter, the joint load was found to be $G = 146$ kg (28 b).

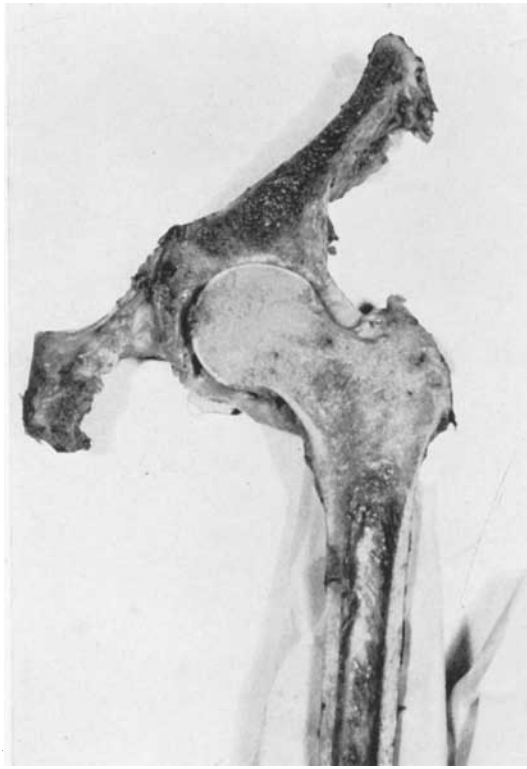


Fig. 26. Frontal plane of an autopsy specimen of a normal hip joint.

Fig. 27. a. A sketch in outline of the hip joint in fig. 26. The insertion tendon of M. gluteus medius runs in the middle of the muscle and that of the M. gluteus minimus on the lateral surface of the muscle. M. gluteus minimus inserts on the frontal and medial aspect of the trochanter (Sollberger). Its direction of pull is accordingly drawn from Linea glutea superior to the medial side of the trochanter. The resultant muscle force has been drawn according to the proportion, medius : minimus, 2 : 1 (Fick). — b. Drawing of the plane model of bakelite.

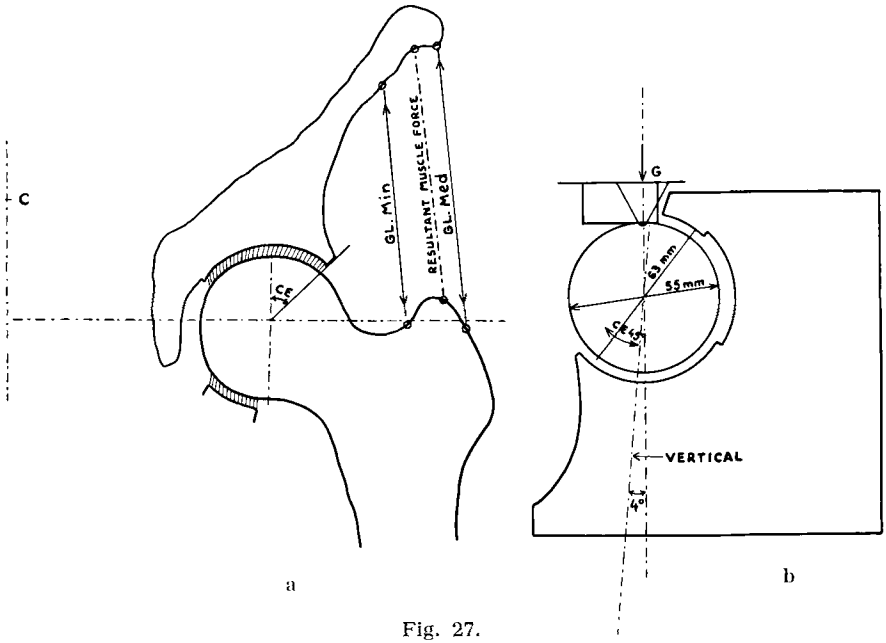


Fig. 27.

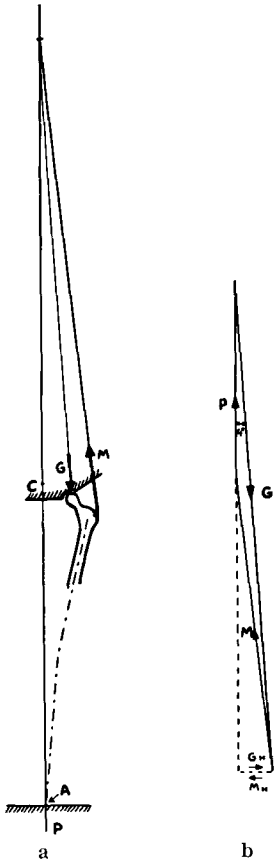


Fig. 28. a. Drawing showing the direction of forces when standing on one leg. The centre of gravity is assumed to be situated in the midline vertical over the foot *A*. *P* = Body weight. *G* = Joint load. *M* = Muscle force. — b. Triangle of forces gives the following values. Body weight *P* = 58.6 kg. *G* = 146 kg. *M* = 88 kg. M_H = 11.8 kg (the horizontal component of the muscle force.)

Fig. 28.

A simplified model of the plane section through the joint was constructed of bakelite one centimeter in thickness. A rubber plate 4.5 mm in thickness was used as a cartilage substitute. In order to reproduce reality as closely as possible, a brand of rubber with a modulus of elasticity of 30 kg/cm² was selected on the basis of the following:

The moduli of elasticity for corresponding materials are:

Bone E_B = 200 000 kg/cm² (*Rauber* according to *Hirsch* 1944)

Bakelite E_{Ba} = 30,000 kg/cm² *(Hiltscher)*

Cartilage E_{Ca} = 100 kg/cm² (*Hirsch* 1944)

Rubber E_R = 30 kg/cm² *(Hiltscher)*

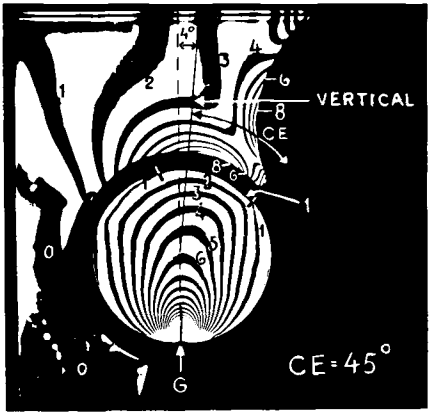
The ratios between the moduli of elasticity are thus

$$\frac{E_B}{E_{Ca}} = \frac{200{,}000}{100} = 2{,}000$$

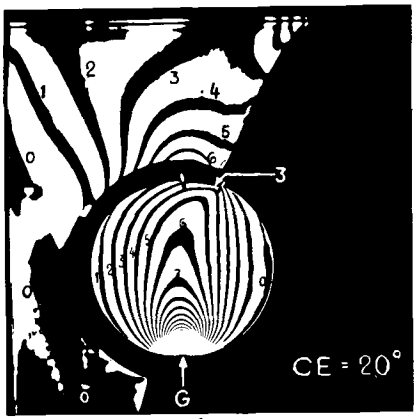
$$\frac{E_{Ba}}{E_R} = \frac{30{,}000}{30} = 1{,}000$$

The deviation can thus not be considered of any practical significance.

The experiment was then made in a loading frame with a load of 200 kg on the "femoral head" at an angle of four degrees to the vertical. The load was chosen arbitrarily because it gave clearer pictures and because it was not my aim to make precise measurements of the stress. The experiment was made with three different CE-angles: 45, 30, and 10 degrees (Fig. 29).



a.



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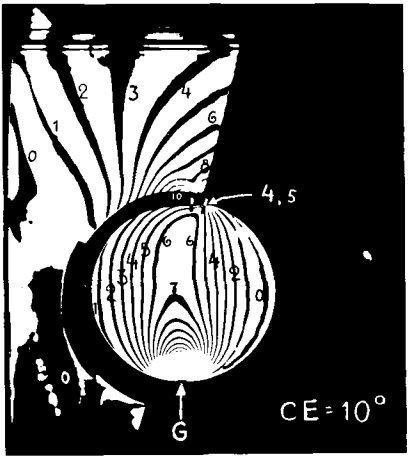

c.

Fig. 29. Photoelastic models with stress in normal and dysplastic "hip joints". a. CE-angle = 45 degrees. Stress of the first fringe order distributed over a long distance (between the white streaks). — b. CE-angle 20 degrees. Stress of the third fringe order over a short distance close to the "acetabular margin". — c. CE-angle 10 degrees. Stress of the 4.5 fringe order over a very short distance close to the "acetabular margin".

The investigation reveals the following:

1. As the CE-angle is reduced, the head of the femur is forced out of the acetabulum. Stability cannot be maintained with a CE-angle of less than 10 degrees. Muscular force would be required to keep the femoral head in the acetabulum, or else the limbus and the joint capsule would have to take over some of the weight-bearing function.

2. If the fringes are constant along the acetabular margin, the stress will also be constant. It appears from the various experiments that the area of constant stress on the femoral head grows smaller and is displaced laterally with increasing dysplasia. At the same time, the stress increases in the ratio 1, 3, 4.5 (fringe order) to the same degree that the dysplasia grows more pronounced. These figures represent the approximate increase in stress.

B. The Subluxated Joint

No specimens were available to continue the investigation on the distribution of stress in the subluxated hip joint. I therefore selected a roentgenogram of a joint of this type and made a drawing of the acetabulum and the femoral head. In this way, the only change that occurred in the experiment was in the slope of the acetabulum and in the size of the femoral head (Fig. 30). In reality there would also be a

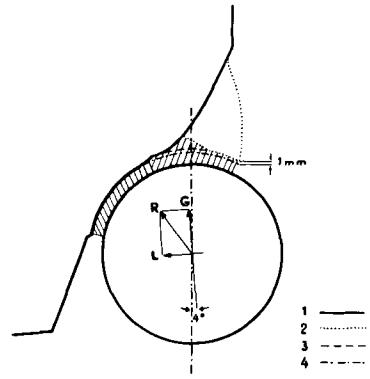

Fig. 30. Drawing representing different experiments on a plane model of a subluxated hip joint. G = Joint load. L = "Ligament". R = Resultant force. 1. Subluxated hip joint. 2. Shelf one mm high and too high medially. 3. Shelf one mm too high. 4. Shelf at the level of the roof.

discrepancy in the position of the trochanter in relation to the center of the femoral head and to the distance between the origins of the muscles and the midline, and probably also in the angle of the joint load to the vertical. The figure shows that the joint load causes the femoral head to slip out of the acetabulum. A device that would act as a ligament and keep the femoral head in place was therefore constructed. This pseudo-ligament consisted of a metal band, attached on one side to the center of the femoral head in one axis and medially to the loading frame. It could be relaxed and tensed with screws. The experiments were then made both without the shelf and with the shelf in different positions. The cartilage was replaced with the same kind of hard rubber as in earlier experiments. However, a somewhat softer type of raw rubber was used between the shelf and the femoral head, in order to reproduce the soft parts of the joint capsule and the scar tissue generally present *in vivo*.

The experiments gave a direct picture of the stress on the material at a given point. From this could be seen indirectly the site at which the load on the "femoral head" was greatest. We could thus make deductions as to the relative distribution of load, but we could not measure precisely its order of magnitude, partly because the effect of friction is unknown.

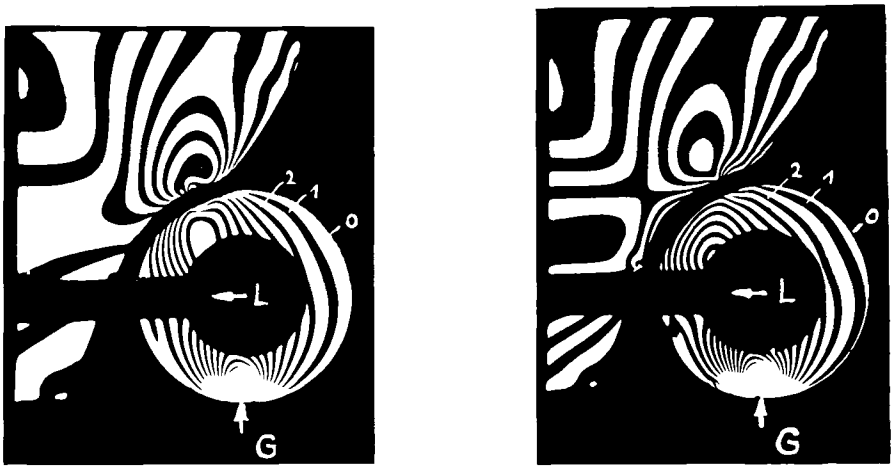

Fig. 31. Subluxated "hip joint". a. Slightly tightened "ligament". — b. Strongly tightened "ligament".

The following experiments were made without any shelf:

1. The "ligament" was slightly tightened to allow some degree of outward displacement. The figure shows stress of the fifth fringe order over a short distance (Fig. 31 a).

2. The "ligament" was strongly tightened with no outward displacement. There was stress of the fourth fringe order over a slightly longer distance as compared with Fig. 31 a (Fig. 31 b).

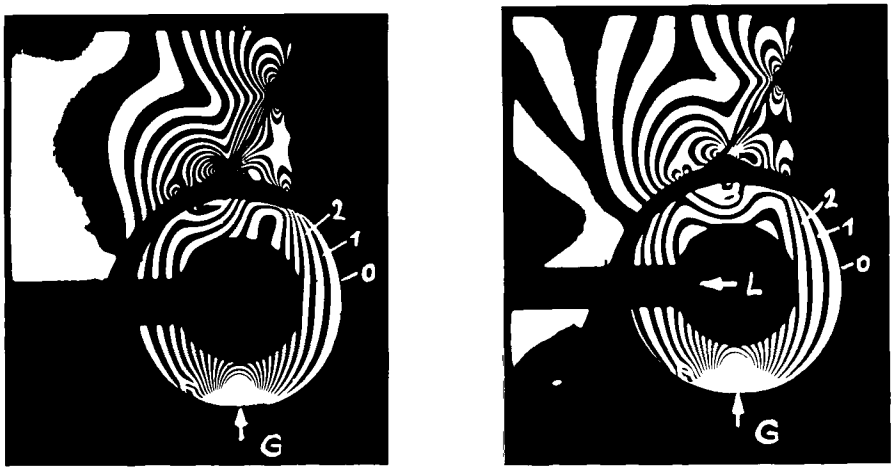

Fig. 32. Shelf one mm high and too high medially. a. The "ligament" is not tightened. — b. The "ligament" is tightened.

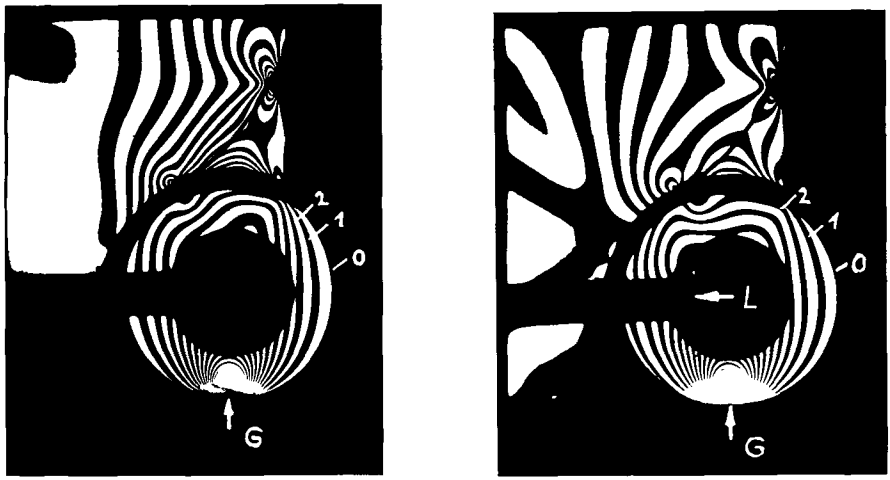

Fig. 33. Shelf one mm too high. a. The "ligament" is not tightened. — b. The "ligament" is tightened.

The following experiments were made with a shelf:

3. Shelf: 1 millimeter high and too high medially. The "ligament" was not tightened. The greater part of the load was transferred to the apex to the shelf. The stress was of the fourth fringe order (Fig. 32 a).

4. Shelf: 1 millimeter high and too high medially. The "ligament" was tightened. The load was divided between the articular surface (third fringe order) and the shelf (second fringe order), but the load was

Fig. 34. Shelf at the level of the roof. a. The "ligament" is not tightened. — b. The "ligament" is tightened.

unevenly distributed. The load on the shelf was thus diminished as compared with Fig. 32 a (Fig. 32 b).

5. Shelf: 1 millimeter too high. The "ligament" was not tightened. The main load was on the shelf (approximately 2.5 fringe order). The distribution of load on the shelf was thus more even as compared with Fig. 32 a (Fig. 33 a).

6. Shelf: 1 millimeter too high. The "ligament" was tightened. The load on the shelf was somewhat less (approximately 1.8 fringe order) and the articular surface was more heavily loaded, but the distribution of pressure was still somewhat uneven (Fig. 33 b).

7. Shelf: ideal position. The "ligament" was not tightened. The load and stress were evenly distributed over a long distance, but mostly on the shelf (Fig. 34 a).

8. Shelf: ideal position. The "ligament" was tightened. The load was mainly on the articular surface, but was fairly evenly distributed over a long distance (Fig. 34 b).

The experiments with models thus revealed that progressive dysplasia leads to an increasingly concentrated stress and load laterally on the "articular surfaces". They further showed that, with a CE-angle of less than ten degrees, a muscular or ligamentary force, acting in a medial direction, is required to prevent lateral displacement of the femoral head. The experiments with a "sloping acetabular roof" disclosed pronounced stress on the articular surfaces, concentrated on a shorter stretch when the medial force was weaker.

As might be expected, the experiments with a shelf showed that the joint surface was most heavily loaded when the "ligament" was tightened. The shelf, in turn, was most heavily loaded when the "ligament" was not tightened. The load was unsatisfactorily distributed both when the shelf was situated too high medially, with the apex bearing the whole burden, and when the entire shelf was slightly too high. In the latter case, the shelf was somewhat more evenly loaded. Finally, it was seen that an ideally situated shelf gave the best distribution of load, although the shelf was still more heavily loaded than the "articular surface".

The experiments illustrated the conditions of loading in given situations, which do not exactly correspond with the conditions *in vivo*. They do, however, clarify the forces and stresses in normal and pathologic hip joints and are therefore of considerable theoretical interest.

The following objections may be raised:

1. The experiments are only applicable to a simplified model in one plane.
2. In reality there is scarcely any friction between the cartilaginous surfaces, while in the experiments there was considerable friction between the rubber and the experimental material.
3. As already mentioned the numerical bases of the subluxation experiments did not correspond with reality.

It is interesting to note that there is considerably greater stress in the "acetabular roof" than in the "femoral head". This is illustrated in Figure 29, where the stress in the roof with a CE-angle of 45 degrees was of the eighth fringe order, but increased to the tenth fringe order with a CE-angle of ten degrees, while the stress in the femoral head rose from the first to the fourth and a half fringe order. This considerable difference in stress is explained by the circumstance that the roof was exposed to bending stress at the same time, while there is no bending but only stress in the femoral head.

This phenomenon may explain the appearance of absorption changes in the acetabular roof, as an initial sign of excessive stress on the bony tissues. The first stages of osteoarthritis might thus, under certain circumstances, be imagined to occur in the immediate neighbourhood of the joint.

On the basis of the foregoing experiments with models, the appearance of osteoarthritis in a dysplastic joint could be explained as a result of an increase in the stress in the acetabular roof, instead of an incongruence in the hip joint.

Further clarification of this point would require the following:

1. Specimens on which the anatomy of a subluxated joint could be estimated.
2. A method that would permit of three-dimensional experiments with models.

Meantime, it may be said that from the mechanical point of view, the experiments with models revealed that an ideally situated shelf provides the best distribution of load, as well as the least stress on the material, due to the fact that the stress is most equitably distributed.

Summary

The writer studied the effect of the shelf operation in the cases of congenital dislocation, congenital subluxation and dysplasia of the hip treated at the Orthopedic Clinic of *Karolinska Institutet,* Stockholm.

The material consists of 173 patients, representing 213 operations. 167 patients were given a follow-up examination (96.3 per cent). Exclusion of unsuitable cases left 159 patients representing 196 operations (91.3 per cent). The observation time ranged from 2 to 15 years. In most cases a buttress was constructed above the head of the femur by turning down a flap of bone from the ilium. In some cases the acetabular margin also was pried down.

The material was first divided into two groups.

I. Secondary cases—i.e. residuals after treatment for congenital dislocation of the hip.
II. Primary cases—i.e. congenital dysplasia and subluxation of the hip.

Each of these two groups were divided into two age groups.

A. Operation up to 8 years of age.
B. Operation over 8 years of age.

These sub-groups were further broken down according to therapeutic indication.

1. Prevention
2. Displacement
3. Unstable retention
4. Pain
5. Fatigue
6. Osteoarthritis.

The evaluation of results depended upon the purpose of the operation.

I. The purpose of the operation was to check displacement of the head of the femur.

1. Good result: good anatomic result; no displacement of the head of the femur.
2. Moderate result: good anatomic result, but further displacement of the head of the femur after the operation had been checked by the shelf.
3. Uncertain result: good anatomic result, but the articular margin had grown under the shelf.
4. Poor result: poor anatomic result.

II. The purpose of the operation was to relieve symptoms.

1. Good result: good anatomic result; freedom from symptoms without special precautions.
2. Moderate result: good anatomic result; improvement without special precautions.
3. Uncertain result: good anatomic result; improvement or freedom from symptoms, but the patient takes precautions.
4. Poor result: poor anatomic result, or no improvement.

Segregation of the uncertain cases in a special group makes it easier to evaluate the effect of the operation.

The significance of the degree of displacement to the result is discussed. The different types from the roentgen-anatomic point of view are classified as follows:

1. Dislocation
2. Subluxation
   a. Slight subluxation
   b. Moderate subluxation
   c. Pronounced subluxation
3. Dysplasia

The foregoing classification and evaluation led to the following conclusions:

A. Under 8 years

1. **Prevention:** the operation is indicated in cases of moderate and high subluxation.
2. **Displacement** of the head of the femur: the operation is indicated when displacement of the head of the femur has been diagnosed.

3. **Unstable retention:** Redislocation in connection with the reduction treatment is not an indication for shelf operation. The cause of the unstable retention must first be investigated.
4. **Pain:** in this age group very few cases were operated upon because of pain. The operation is probably of value in primary cases.

B. Over 8 years

1. **Prevention:** The operation is probably effective in secondary cases (8 to 14 years old).
2. **Displacement:** The operation is indicated in order to check further displacement.
3. **Pain:**

a. *age 8 to 15 years.*

In secondary cases the operation should only be done after a long period of expectance in order to avoid operating on cases liable to develop an early osteo-arthritis.

Only one primary case was operated on.

b. *age over 15 years*

The operation should not be done in secondary cases owing to the bad results.

In primary cases the results are sufficiently good to justify operation.

4. **Fatigue:** this symptom alone does not indicate operation.
5. **Osteoarthritis:** the operation is of no value for the alleviation of pain due to osteoarthritis.
6. **Dislocation:** the results were so bad that operation is not indicated.

A series of secondary cases not operated on were studied with regard to the risk of displacement of the head of the femur and to late ossification of the acetabular roof. It appears that the risk of displacement of the head of the femur in the age group under 8 years is small in secondary cases of dysplasia (10 per cent), greater in slight subluxation (33.3 per cent), and considerable in moderate subluxation (90.1 per cent). Late ossification of the acetabular roof and growth of the acetabular margin occurred in mild cases of subluxation not operated on up the age of 10 to 12 years. This supports the opinion expressed earlier that dysplasia and slight subluxation are not indications for an immediate preventive operation. These patients should be under

regular observation, bearing in mind the possibility of the joint developing normally without operation.

The symptom of pain is discussed. It is stressed that this symptom is not solely due to instability caused by dysplasia or subluxation of the hip. It appears that pain is more frequent in hips where the head of the femur is deformed. Further, it is stated that epiphysitis of the head of the femur had developed during the reduction treatment in most of the cases with deformed head of the femur. Thus, prevention of epiphysitis is just as important a problem as prevention of subluxation. From the diagnostic point of view, attention is called to the fact that involvement of the lumbar nerve root may simulate disease in the hip joint. By comparing cases with the shelf in good position with cases in which the shelf is placed too high, it appears that a well-placed shelf may eliminate pain.

From the roentgen-anatomic point of view it appears that a strong shelf with sclerotic cortex takes over part of the weight-bearing function. Absorption of the shelf, on the other hand, is connected with poor location of the shelf in the age group under 8 years. The tendency to absorption was much less pronounced in the older patients.

Among the *complications,* the risk of early osteoarthritis in secondary cases from 13 to 16 years of age is emphasized.

Regarding *surgical technic,* muscular lesion was observed in some cases in connection with the Smith-Petersen incision. However, this incision provides such excellent access to the operative field that it cannot be disregarded.

The importance of roentgen control during operation is stressed.

The prying down of the acetabular margin can be done without risk at least up to eight years. In older cases there is risk of joint lesion.

The technic of downward reflection of the whole acetabular roof was studied in an autopsy specimen. The difficulties are great, and the writer is of the opinion that reliable downward reflection of the acetabular roof can only be achieved under open control, i.e. the capsule must be opened and the femoral head dislocated.

Model experiments were conducted according to the photoelastic method in order to study weight-bearing conditions in the hip. Increasing stress and lateral loading could be observed in models representing increasing dysplasia of the hip joint and sloping acetabular roof. The best distribution of the weight-bearing function was obtained with a well-placed shelf as compared with a shelf that was too high medially or slightly too high in general.

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