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Treatment of Legg-Calvé-Perthes Disease

Assessment of Therapeutic Results with Particular Reference to the Value of Traction in Bed

By

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Preface

The present study was carried out in the Seaside Hospital, Refsnæs. My thanks go to the management for the good working conditions which I have enjoyed and for financial aid towards the publication.

I should like to thank also the staff in the Seaside Hospital, Refsnæs, and in the Finsen Institute, Copenhagen, for their ever ready help in the course of the study. In particular, I want to thank my X-ray assistant, Mrs. *Agnethe Back*. The reading and measurement of the numerous films would not have been possible without Mrs. *Back's* unfailing interest and understanding of the problems involved.

For the statistical calculations and discussions concerning statistical problems I am indebted to *Svend Sørensen*, M.A. (econ.).

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Introduction

In 1909–1910, almost simultaneously, Jaques Calvé, Arthur T. Legg, Georg Perthes, and Henning Waldenström described a new syndrome which affected children and which was caused by pathological changes in the femoral head.

As the nature of this disease was unknown, it was named, during the subsequent years, after one of these four authors. In English-speaking countries it is now generally known as Legg-Calvé-Perthes disease (LCPD), and this term will be used in the present publication.

The description of this new syndrome meant that these cases—which had previously been interpreted and treated as tuberculosis—could now be distinguished as a disease *per se* of a far more benign course than tuberculosis of the hip joint. The long-lasting and difficult treatment which had been used previously in the belief that the condition was a tuberculous manifestation, was now superfluous and could be replaced by a far gentler management.

But then it changed to the other extreme. The patients were left practically untreated—apart from periodical short-lasting relief from weight-bearing when the children had pain ("symptomatic treatment"). It was believed that the disease ran a completely regular course, regardless of any therapeutic measures.

This point of view was also accepted in Denmark.

The first reports on LCPD in Denmark came from Sundby Hospital, Copenhagen, in March 1914 (Flemming Møller) and from the Seaside Hospital, Refsnæs, in September 1914 (Michelsen). During the subsequent decades the patients in this country too received only symptomatic treatment or none.

Gradually, however, it was realized, in Denmark as well as in other countries, that the prognosis of untreated LCPD was not as favourable as assumed. True, the majority of patients were symptom free immediately after the lesions had healed, but the X-ray film showed that often the head was considerably deformed—flat, mushroom-shaped—

and later many cases developed severe secondary osteoarthritis of the hip causing severely disabling symptoms.

More active measures appeared to be indicated, and in the course of the 1930'ies better results from long-lasting non-weight-bearing—in some cases with traction—were reported from England (Danforth 1934, Eyre-Brook 1937).

In Denmark it was suggested by Hans Friderichsen, as early as 1933, that the patients be treated by long-lasting bed rest. This form of treatment was adopted in 1940 at the Seaside Hospital, Refsnæs, where LCPD had been treated only symptomatically since 1914.

In 1952 the results of this treatment were analysed by Helbo and compared with those of symptomatic—or no—treatment in a series whose main part had been published by Flemming Møller in 1924.

Helbo concluded that long-lasting relief from weight-bearing was a definite advance compared with symptomatic treatment. He did not state his opinion as to which form of long-lasting relief from weight-bearing was to be preferred.

This problem was tackled by Mose in 1964.

He analysed 2 series treated by long-lasting bed rest in the Seaside Hospital. Refsnæs, and the Hospital for Physical Medicine and Rehabilitation, Hornbæk, during the period 1953–1957. The treatment had not been entirely identical, as a more intensive physical therapy and exercise therapy had been used in Hornbæk. The results obtained in these two series were then compared with those of ambulatory relief from weight-bearing by a Thomas walking brace in two orthopaedic departments in Jutland (Sønderborg and Kolding).

Mose concluded that long-lasting relief from weight-bearing by recumbency afforded definitely better results than ambulatory relief from weight-bearing by a Thomas walking brace. The difference was statistically significant.

As the results appeared to be the better the more effective the relief from weight-bearing, we started combining the long-lasting recumbency with traction applied to the legs in the Seaside Hospital, Refsnæs.

By now, it ought to be possible to assess the results of this traction therapy. However, when the author started analysing the result, he came across problems which had to be solved, if the assessment was to be reliable.

In the two studies mentioned above, Helbo's and Mose's, the assessment had been done by different principles—clinical and radiological—so that a direct comparison of the results from these two studies mutually and with those obtained by traction proved impossible.

First and foremost, then, it was necessary to arrive at the most rational method for assessing the results achieved in the treatment of LCPD. By application of this method first to the assessment of the traction series and then to series treated by other methods it ought to be possible to obtain a reliable evaluation of the different therapeutic methods.

It was this task which the author set himself in the present study.

It is based in large measure upon the reports of Helbo and Mose, primarily because these two monographs are *far more detailed* and *better substantiated* than papers published in periodicals in the usual form and of the usual extent. Both are accompanied by brief case histories for each individual patient. This renders it possible to assess critically the authors' conclusions and analyse the published materials from different angles.

Moreover, a considerable part of both series is derived from the Seaside Hospital, Refsnæs, so that the present author is thoroughly familiar with the performance of the treatment and has access to all the X-rays obtained in the course of the treatment and later during the follow-up.

All these factors make the two studies particularly well-suited to form—together with the subsequent study performed in the Seaside Hospital, Refsnæs—the basis of the present study which may, in fact, be considered a continuation of Helbo's and Mose's.

As their reports dealt with a number of problems of *no* interest in this connection, they will not be reviewed *in toto*. Those parts of the two monograph which are of interest will be reviewed gradually as they become of topical interest to the present subject.

Assessment of Therapeutic Results

The medical literature abounds in reports on attempts at evaluating the result of some form of treating LCPD. These papers will not be reviewed here, but the reader is referred to Goff, Helbo and Mose. Only a brief survey will be given of the principles used in the assessments.

Some authors have restricted themselves to a purely *clinical assessment* (*e.g.* Masse), but this involves considerable difficulties. As a rule, it is desired to assess a therapeutic result relatively soon after the treatment has been completed—*e.g.* at the end of a year or two. At this juncture, which may be called the *time of primary healing,* the clinical symptoms in the majority of patients are very slight and the clinical signs only demonstrable by thorough investigation. Any numerical analysis of such mild symptoms and signs must carry considerable inaccuracy, and therefore the result must depend very much upon the care devoted to the task by the investigator.

Other studies—probably the majority—are based upon assessment of the *X-ray appearances* at the time of primary healing. This preliminary radiological result of the treatment may be assessed when the healing has advanced so far that the X-ray appearances have become stationary, showing a normal—or near-normal—bony structure and uninterrupted outlines of the osseous components of the joint. By the most common therapeutic methods, this stage is attained a year or two after completion of the treatment, in some cases earlier, but in others several years later.

Some authors restrict themselves to a mere estimate of the X-ray appearances. This, like the clinical estimate, is extremely inaccurate (Flemming Møller, Sundt, Goff). Others draw their conclusions from *measurement of the flattening of the epiphysis* which, of course, is more tangible (Eyre-Brook, Sjövall, Helbo). This method is considerably more accurate when the procedure of Mose is employed: By an objective measuring method, the "spherical" heads are distinguished from the irregular, angular ones and thereafter the epiphyseal flattening in the spherical heads is measured. It serves no purpose to measure the epiphysis in the irregular, angular heads, and such measurement cannot be performed in a sensible way (Mose).

Herndon & Heymann have tried to improve the radiological measuring methods by measuring also the deformity of the acetabulum and of the femoral neck after the treatment. However, this method is so complicated, including so many poorly defined measurements, that its performance can only be inaccurate and its significance is difficult to evaluate (*vide infra*).

Jonsäter measured the height and width of the head on arthrographic exposures, but this method suffers from the same disadvantage as Herndon and Heymann's: It is inaccurate, as it is difficult to state the exact site where the head is broadest. Therefore, the measurement of the height of the head will become inaccurate. As a measure of its shape it is, on the whole, insufficient.

As will gradually appear from the following, several weighty objections may be raised to all these clinical and radiological methods of assessment. Owing to these imperfections there is a complete lack of agreement between the therapeutic results reported in the literature. The number of successful results of apparently the same therapeutic method varies in the reports by the various authors from *a few* to 100 per cent (Mose). These disagreements are not due exclusively to difficulties connected with and imperfections of the studies performed at the time of primary healing. The explanation is, largely, that the results are not directly related to the final clinical result, but serve merely as a basis for a tentative long-term prognosis.

If a method for treating LCPD is to be assessed, the problem is to predict—a year or two after the treatment has been completed—which symptoms the patient is likely to have at the end of 25 years or more, when secondary osteoarthritis really sets in. It is the frequency of these late symptoms which decides whether or not a therapeutic method may be called successful, while the symptoms at the time of primary healing are of relatively little importance.

However, such a prediction has proved at least as difficult and subjective as the evaluation of the condition at the time of primary healing

The object of the present study, then, was:

(1) to find a more accurate objective method for assessing the *condition at the time of primary healing.*

For this purpose there can be no question of anything but *ra-*

diological assessment, as clinical assessment cannot afford a sufficiently differentiated and objectively reliable evaluation.

(2) if possible, to find a *correlation* between the *radiological appearances at the time of primary healing* and the *late clinical symptoms,* so that at this early stage it is possible to assess the risk of osteoarthritis in a given series.

It is this last-mentioned item which is the most important one from a practical clinical point of view—and in fact the main object of the present study. At the same time, however, it is that part of the task which is most difficult—and at present perhaps impossible—to solve. The presupposition of its solution is previous knowledge of the *entire* radiological and clinical course of LCPD after some form of treatment, from the time that the diagnosis was made, throughout the treatment period until primary healing—and *after that for a minimum of 25 years.* Only thereby is there a chance of getting an idea of which features of the primary radiological appearances determine the subsequent clinical course. This knowledge, then, may be used for assessing the primary results of *other* therapeutic methods.

Investigations of this nature have been extremely sparse. The two most detailed ones are by Helbo and Sundt.

Helbo has reported a follow-up examination of 52 patients at least 25 years after the onset of LCPD. These patients were either *untreated or had received only symptomatic treatment.*

Out of the 52 patients 5 have to be left out, as they are unsuited for the investigation.

Among the remaining 47 the radiological status at the time of primary healing was as follows:

5 had healed, showing "spherical head".
29 had healed, showing "greatly flattened head".
13 had healed, showing "irregular, angular head".

These radiological characteristics represented the result of a mere estimate.

At follow-up it was found that *no* patient with "spherical" and *all* patients with "irregular" heads had developed osteoarthritis. Out of the 29 patients with "greatly flattened heads" 19 (66 per cent) developed osteoarthritis, while 10 did not.

Helbo concluded that the *radiological shape of the head* at the time of primary healing played a decisive role in the development of secondary osteoarthritis: Slight deformity did not lead to osteoarthritis, while in the event of greater deformity the risk is considerable—increasing with the severity of the deformity. Of course the *wear on the joint* is a factor too, but according to Helbo's studies of less importance than the deformity.

Sundt had an appreciably larger series, viz. 153 patients (172 hip joints). The majority of his patients too were in fact untreated. He after-examined 137 patients – 153 hip joints, 69 joints more than 25 years after the onset of the disease.

At an estimate he divided these hip joints into 4 groups according to the shape of the head at the time of primary healing: (1) spherical, (2) ovoid, (3) cylindrical, (4) quadrangular.

The radiological status of the 69 after-examined hip joints at the time of primary healing had been:

(1) spherical head	6 hip joints
(2) ovoid heads	25 hip joints
(3) cylindrical heads	36 hip joints
(4) quadrangular heads	2 hip joints

At follow-up, *none* of the best group and all of the poorest group had osteoarthritis. Out of the second group (ovoid) 48 per cent (12/25) and out of the 3rd group (cylindrical) 72 per cent (26/36) had osteoarthritis. This result corresponds in all essentials to Helbo's.

These two studies may then be briefly summed up as follows:

The number of patients after-examined 25 years after the onset of the disease is quite large—about 100 patients. However, the radiological description of the status at the time of primary healing proved to be *based merely on an estimate* in both series, without any attempt at a more accurate assessment. Therefore, on the face of it, it would not seem possible to use these two studies as a basis for a more detailed description of the relation between the radiological appearances at the time of primary healing and the risk of osteoarthritis.

This is not saying that the studies concerned are of no interest—on the contrary.

Both authors arrived at the same general conclusion:

The more the hip joint—in this case the head of the femur—differs from the normal shape, the greater is the risk of osteoarthritis.

This may sound like a platitude, but in fact it is the general basis for all radiological assessments in the present study—and therefore seems to be worth stressing.

However, such a general basis for assessment is of little assistance when the intention is to predict, in a given series, at the time of primary healing which patients—and how many—are going to develop osteoarthritis at a later date.

But if we have *two* series, treated by different methods, and if we are able to *measure* the deformity of the hip joint with accuracy, it is possible to form, on the basis of the dictum: the greater the deformity the greater the risk of osteoarthritis, an estimate of the *relative* risk of osteoarthritis in the two series, *i.e.* to establish which of the two therapeutic methods is more effective—and possibly to obtain a measure of the difference.

Maybe it is also possible, by a more detailed mapping of individual series—at the time of primary healing as well as after a long follow-up period—to arrive at a prognostic assessment in a single case material.

Our first object, then, is to arrive at relevant, well-defined radiological criteria as to how much a joint which has been affected by LCPD differs from the normal *shape* of the hip joint.

But before dealing with the X-ray appearances under normal and pathological conditions, it seems reasonable to recapitulate the *anatomical* characteristics of the normal hip joint.

NOTES ON THE NORMAL ANATOMY OF THE HIP JOINT

The hip joint connects the femur with the pelvis and is a *ball-and-socket joint.*

The *joint surface of the femur* in adults makes up 2/3–3/4 of a spherical surface.

That part of the femur which is covered by the joint surface is called the head of the femur.

In adults down to the age of 14–16 years the head of the femur consists exclusively of bony tissue. In children from the age of 14–16 and downwards the head consists partially of cartilage—the younger the individual the more the cartilage.

The head is formed by two parts: the *epiphysis* and the diaphyseal part of the head called the *metaphysis.* These two components are separated by the epiphyseal line (epiphyseal plate) or—in adults—by its traces in the osseous structure. The demarcation of the head from the neck on the surface of the femur is the edge of the joint surface which does *not* form a circle at the junction to the neck, but a slightly

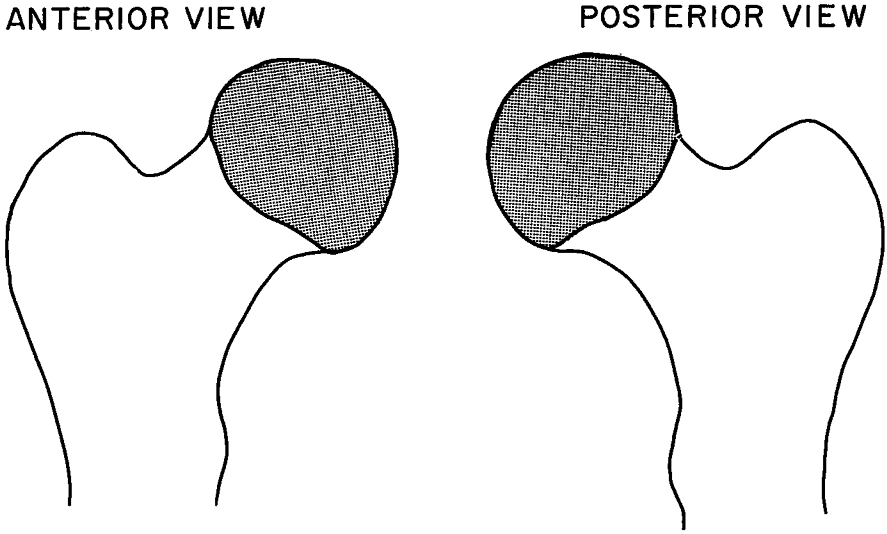


Figure 1. A normal femoral head. The edge of the joint surface is undulating.

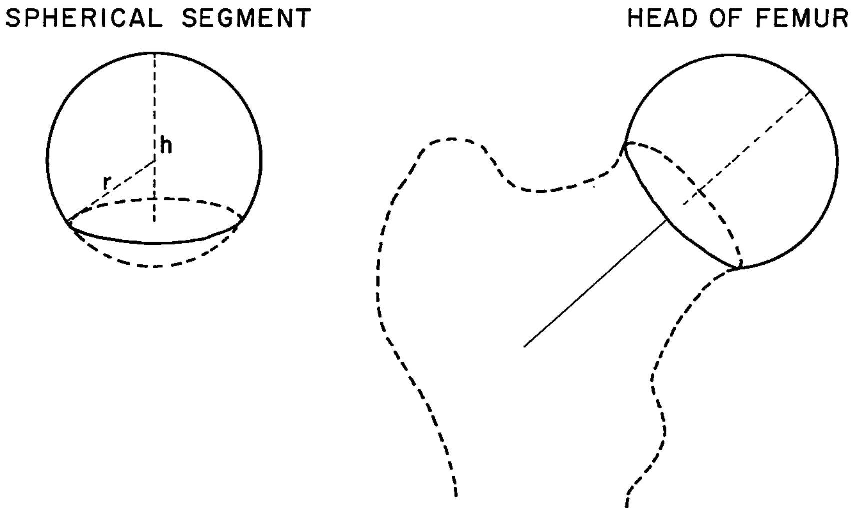


Figure 2. The head of the femur may be described as a spherical segment.

undulating line which extends most distally on the anterior and posterior aspects of the neck, while medially and laterally it is more proximal (Figure 1). However, the undulating line which demarcates the joint surface does not differ much from a circle. The head may, therefore, be described as a spherical segment—*i.e.* a body delimited by 2 surfaces—one spherical surface and one plane—intersecting each other in a circle (Figure 2).

The proximal joint surface of the hip joint is made up by the cartilage-lined socket of the pelvis, the *acetabulum*. The articular cartilage, however, does not line the entire acetabulum, only the facies lunata, as medially there is a tongue-shaped notch, the acetabular notch.

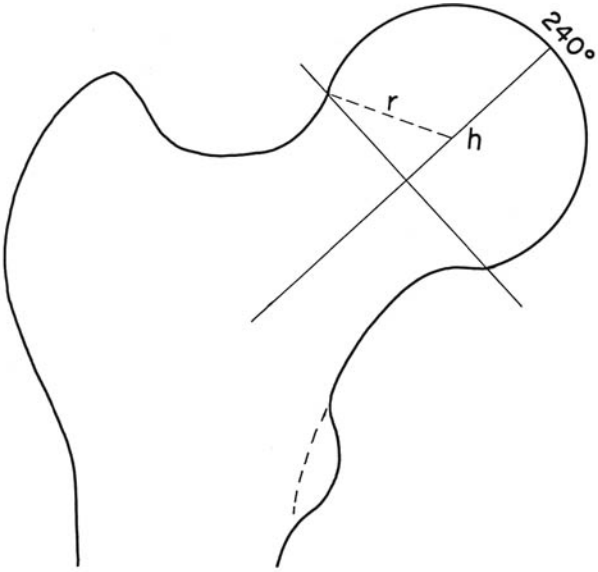
The acetabulum is hemispherical and therefore cannot cover the entire head of the femur whose surface makes up 2/3–3/4 of a spherical surface. The non-covered areas of its articular surface are situated antero-laterally.

But, as already mentioned, the factor of interest when assessing the results of treating LCPD is not the normal anatomy, but its *radiological appearance.*

THE NORMAL X-RAY APPEARANCES

X-rays visualize only the *bony head*. In adults and in children down to the age of 5–6 years its outlines make up the *arc of a circle,* 220–240°, which has the same radius when photographed in two views. A line joining the end points of the circular arc at the junction to the neck forms the *radiological base of the femoral head* (Figure 3). Of course, this line is to some extent constructed, as the edge of the joint surface is not projected as a straight line across the neck, but as an undulating line. However, it does give an approximate idea of the demarcation of the head from the neck. In the lateral view (Lauenstein's projection) it is rather more distal than in anteroposterior views, as the joint surface extends farthest down towards the neck anteriorly and posteriorly (Figure 7). When, for instance, in working out a measuring method, the head is to be defined, it is most practical to use the line drawn on anteroposterior views which are generally used in assessing therapeutic results. However, the lateral view might just as well be used.

In anteroposterior views the joint surface extends *laterally* to the lateral end of the epiphyseal line—in young children to its distal edge —in older children and in adults occasionally to a point somewhat proximal to the lateral end of the epiphyseal line (Figure 14). In the latter case, the junction of the convex joint surface and the concave contour of the neck is usually distinct. When, in the following, the baseline is used for comparative measurements of various femoral heads, it will be drawn in *all* cases through the lateral end of the epiphyseal line or the distal edge of its lateral end. Owing to the undulat-



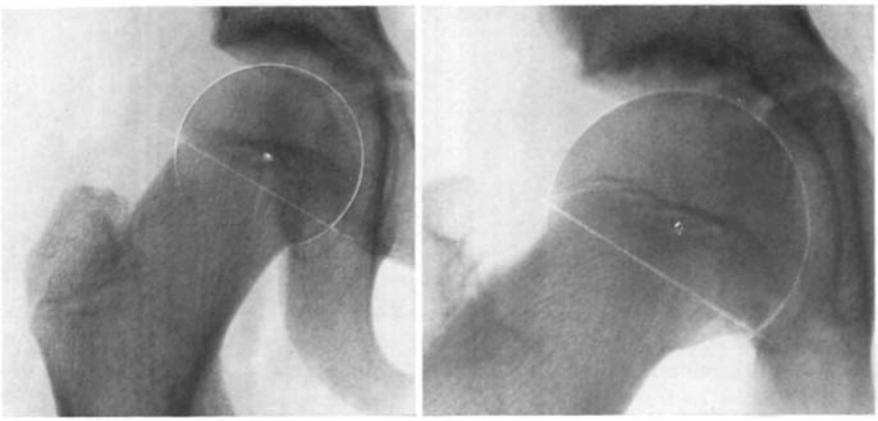


Figure 3. On the X-ray film the normal femoral head is demarcated by:
(1) a circular arc of about 240°.
(2) a line through the end points of the circular arc:
"the baseline" (9 7/12 ♂, 14 2/12 ♂).

ing shape of the edge of the articular surface, this gives the best possible impression of the demarcation of the femoral head—and thereby of the articular surface (Figure 4). In comparing the diseased and the sound side the most important factor is that the baseline be passed through the same points on both sides.

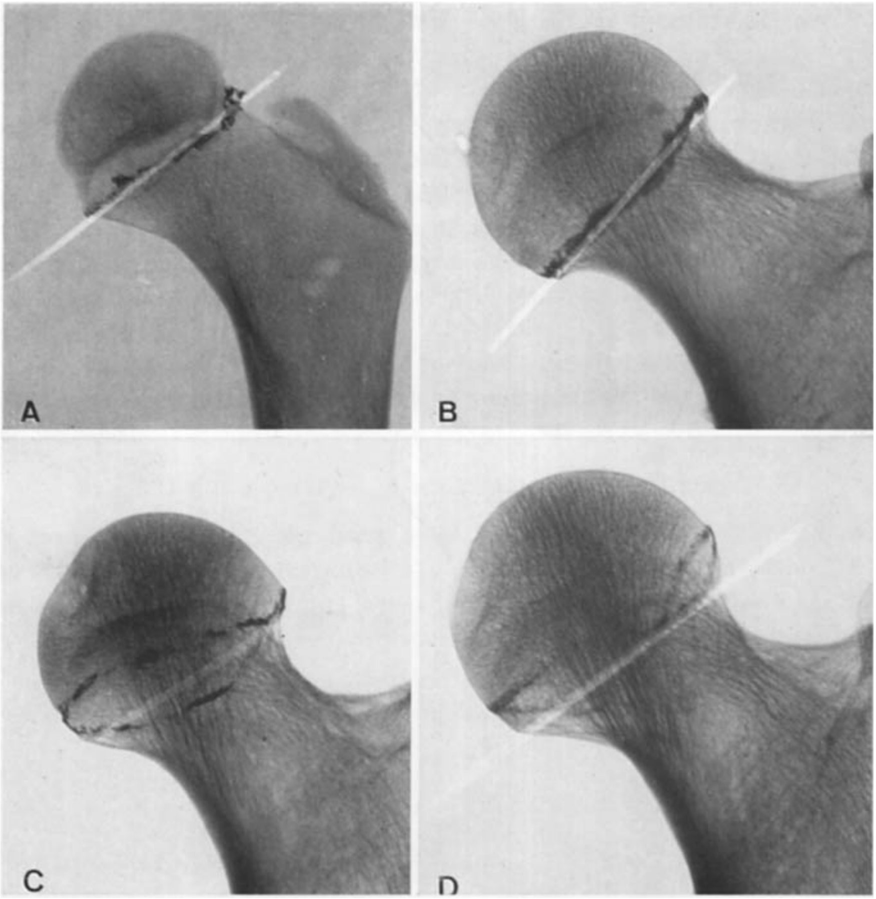
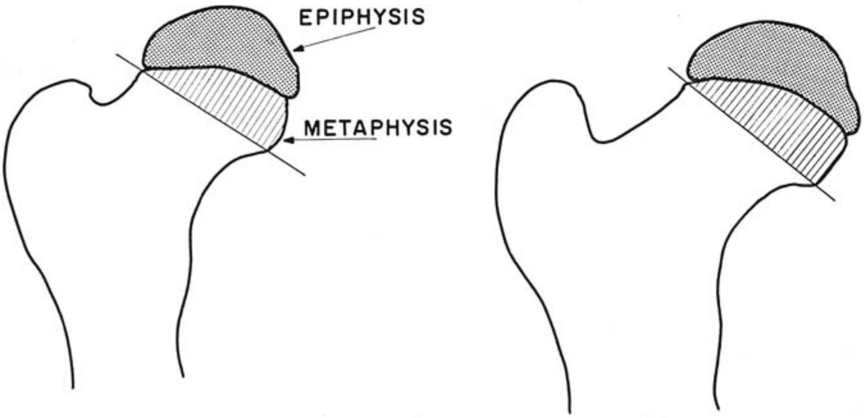


Figure 4. Edge of joint surface and baseline. X-ray film of bones on which the edge of the joint surface of the femoral head is marked by a constrasting paint. The baseline is drawn on the X-ray film as stated in the text (1 child (A), 3 adults). The baseline cannot be traced with as much accuracy in adults as in children, since in adults the epiphyseal line is visible only as an indistinct trace in the bone. As a rule, it is drawn too far distally (d), because during puberty the edges of the epiphyses are prolonged distally.

Medially the joint surface extends to the level of the bottom limit of the tear drop figure, and as a rule the junction of the convex joint surface and the concave contour of the neck is not difficult to trace.

Since, in the following, the baseline will be used in the various measuring methods, it is of course very important that it should be *well-defined.* This demand is fulfilled by the baseline described as



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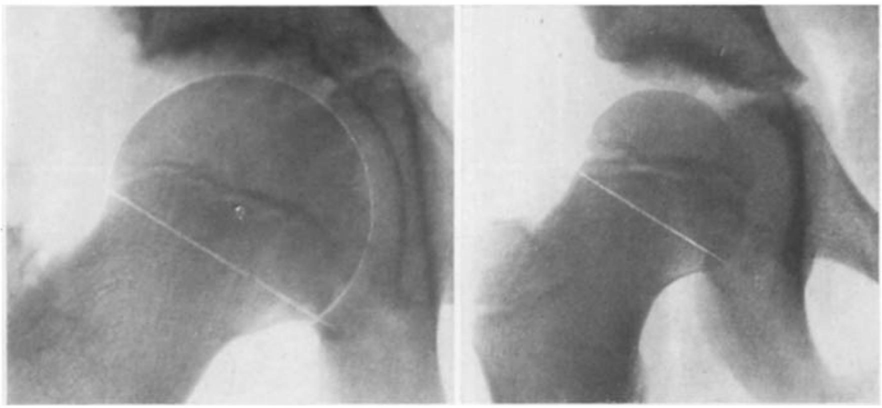


Figure 5. Normal femoral heads. Epiphysis and metaphysis.
(X-ray films ♂ 14 2/12 years, ♀ 8 8/12 years).
(I traced from Klein et al.: Slipped Capital Femoral Epiphysis. Springfield, U.S.A., 1953, Figure 44. II traced from Lanz & Wachsmuth: Praktische Anatomie I, Berlin, 1938, Figure 116).

far as is possible with a radiologically determined line. At any rate it is just as well-defined as the epiphyseal line—if anything better, that is when the femur is in 20° internal rotation so that the neck is parallel with the film.

The *circular arc,* which forms the periphery of the head, has its centre approximately in the middle of the head—*i.e.* at a distance of about 1/3–1/2 radius from the baseline.

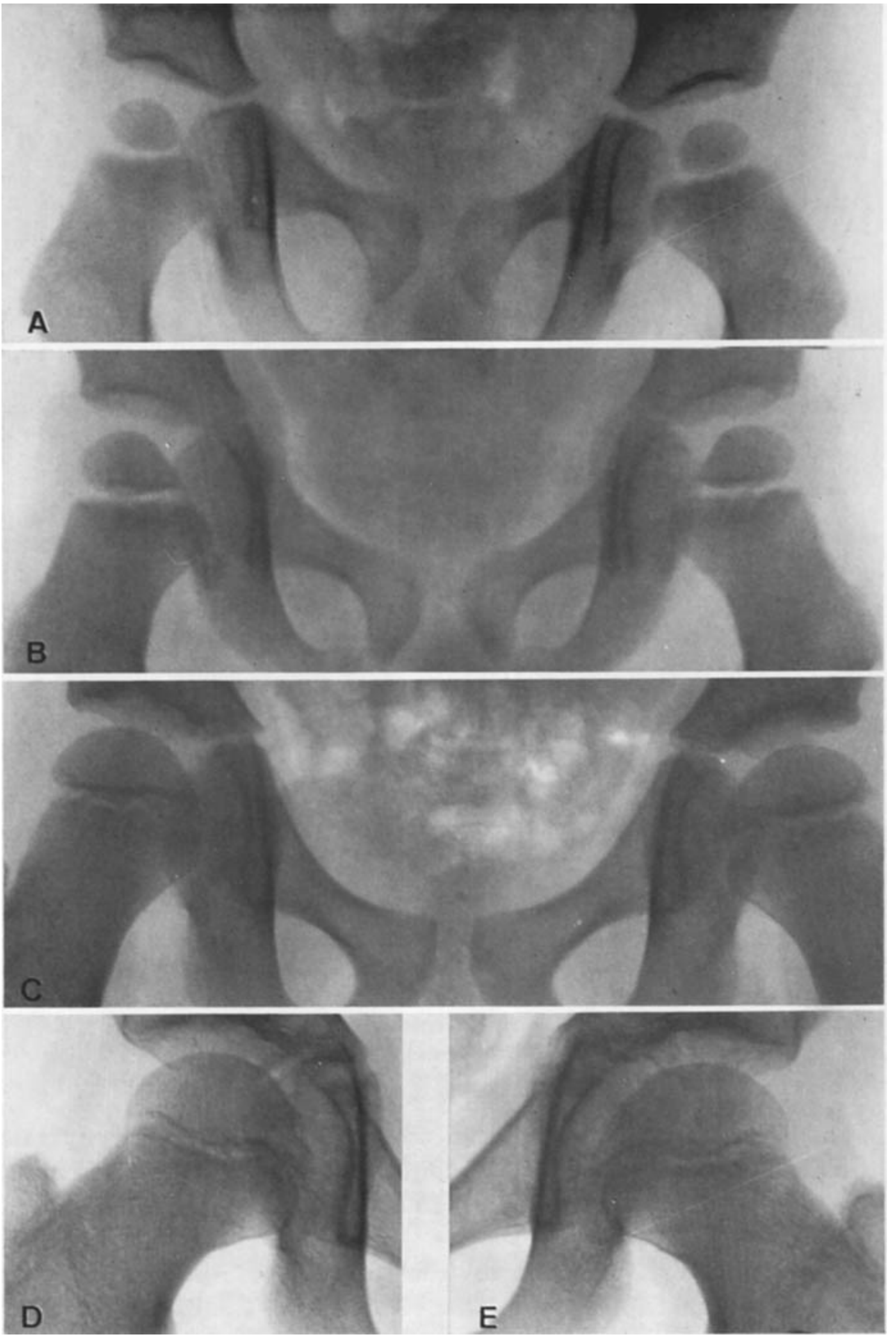


Figure 6. Normal pelves and hip joints. Epiphysis and epiphyseal line in various age groups. (♂ 2 1/12, ♂ 3 10/12, ♀ 5 7/12 and ♀ 8 years).

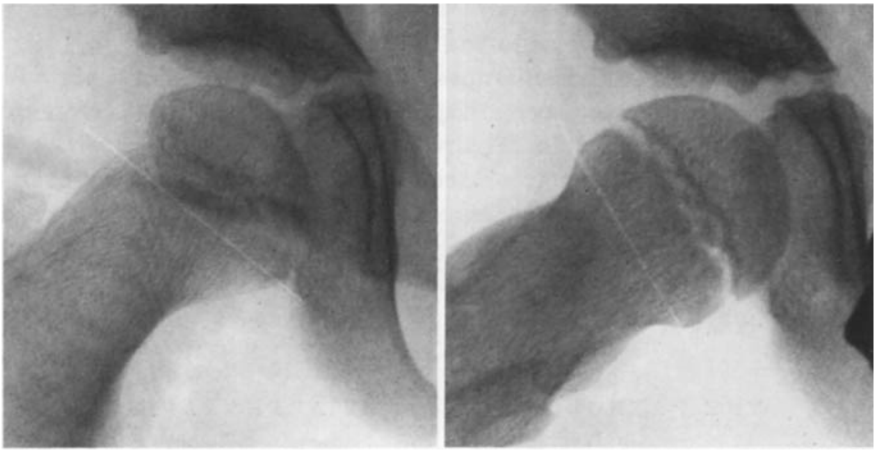


Figure 7. Normal hip joint
The metaphysis is visible as a rectangle in the lateral view.

On the X-ray film too the bony head consists of two parts separated by the epiphyseal line: the *epiphysis* and the *metaphysis*. The line which represents the base of the head is approximately at right angles to the axis of the neck, while the base of the epiphysis is more horizontal. Therefore, the metaphysis stands out like a wedge (triangle) whose base is medially and tip laterally oriented (Figure 5).

However, this applies only to age groups in which the epiphyseal line forms a *straight line,* viz. from approx. 5 to 12 years of age.

Above the age of 12 the epiphyseal line manifests itself as an upward convex line, the edges of the epiphysis bending down in a tip laterally as well as medially. Medially this tip may completely cover the medial surface of the metaphysis so that above this age the epiphysis may form the only base for the articular cartilage.

Below the age of 5–6 years the epiphyseal line is wider—and at the age of 2 years or below no actual epiphyseal line is visualized. The small round ossification center is completely separated from the metaphysis by a broad space corresponding to the cartilage in the non-ossified part of the femoral head. In this age group, therefore, the epi- and metaphysis do not form an entity with an unbroken contour (Figure 6A).

At the age from 3–5 years there will be the beginning of an epiphyseal line, but as the outline of the epiphysis is still double-convex the epiphyseal line now stands out as a downward-convex line. The epiand metaphyseal contour is now more uninterrupted, but does not yet make up part of a circle as in the older age groups.

All this applies to the anteroposterior view. In the lateral view the metaphysis, during the age group 5–12 years, is a small rectangle just distal to the epiphysis (Figure 7).

The outlines of the normal acetabulum are seen, at ages over 5 years, as a clear semicircle concentric with the articular surface of the head. It is most clear and sharp upwards, lateral to the acetabular notch, but in its medial part too the contour is quite well-traced as a continuation of the circular arc.

THE PATHOLOGICAL X-RAY APPEARANCES

A description of the pathological *X-ray picture* can only be rendered in relation to what is known—or felt to be known—about the *pathological antomy.*

The following description, therefore, will be given with constant reference to and comparison with the *pathological anatomical course.*

LCPD is generally considered as *a disease localized primarily to the capital epiphysis. In untreated cases this leads to flattening and widening of the epiphysis. The object of treatment is to prevent this process*—but as a rule it is only partially successful.

The other changes observed in the hip joint, viz. changes in the shape of the remaining parts of the head (metaphysis) and of the acetabulum, widening of the neck, the general increase in growth of bone around the joint, merely represent the reaction of the surrounding osseous components to the deformation of the epiphysis.

This should not lead anyone to believe that these *secondary changes* consist exclusively in *passive* adaptation to the flattened epiphysis. As far as the head is concerned there is certainly a question of compensatory processes striving to remedy the effect of the flat epiphysis upon the shape of the head, making it differ as little as possible from normal.

The acetabulum, on the other hand, adapts itself more passively to the final result of epiphyseal flattening + the compensatory growth processes in the head, so that the joint surfaces acquire the same shape—perhaps concentric—with a joint space of uniform width. It is often stated that *subluxation* of the head in the acetabulum is an important sequel of LCPD. This subluxation is said to manifest itself in the way that a larger part of the capital joint surface than normal is

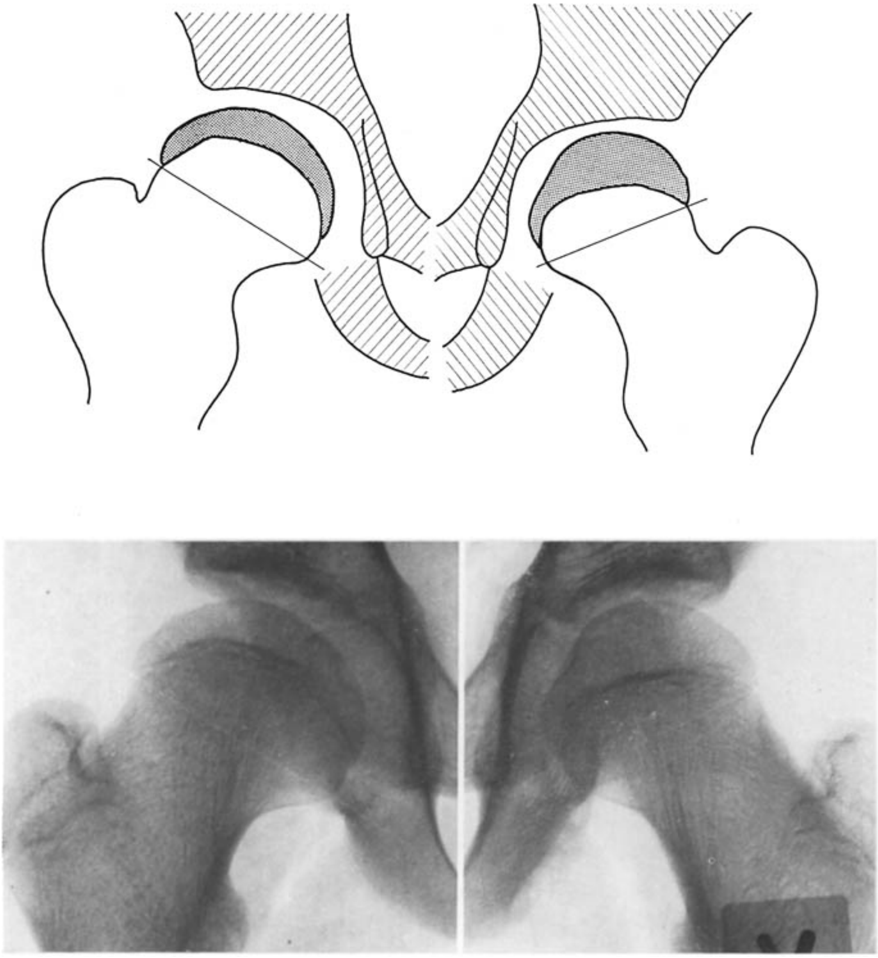


Figure 8. 12-year-old ♀. Sequelae of right sided LCPD.
Right capital epiphysis the shape of a new moon.

situated outside the lateral edge of the acetabulum. However, this need *not* be a sign of actual subluxation; it may be due merely to a disproportion between an enlarged femoral head and a relatively small acetabulum. Subluxation is present only if the joint space is wider medially than laterally. This is no uncommon finding *during the course of* LCPD, but as a rule it disappears after healing—at any rate if a fairly effective relief from weight-bearing has been carried through.

In the event of very severe deformities of the head *after* the course

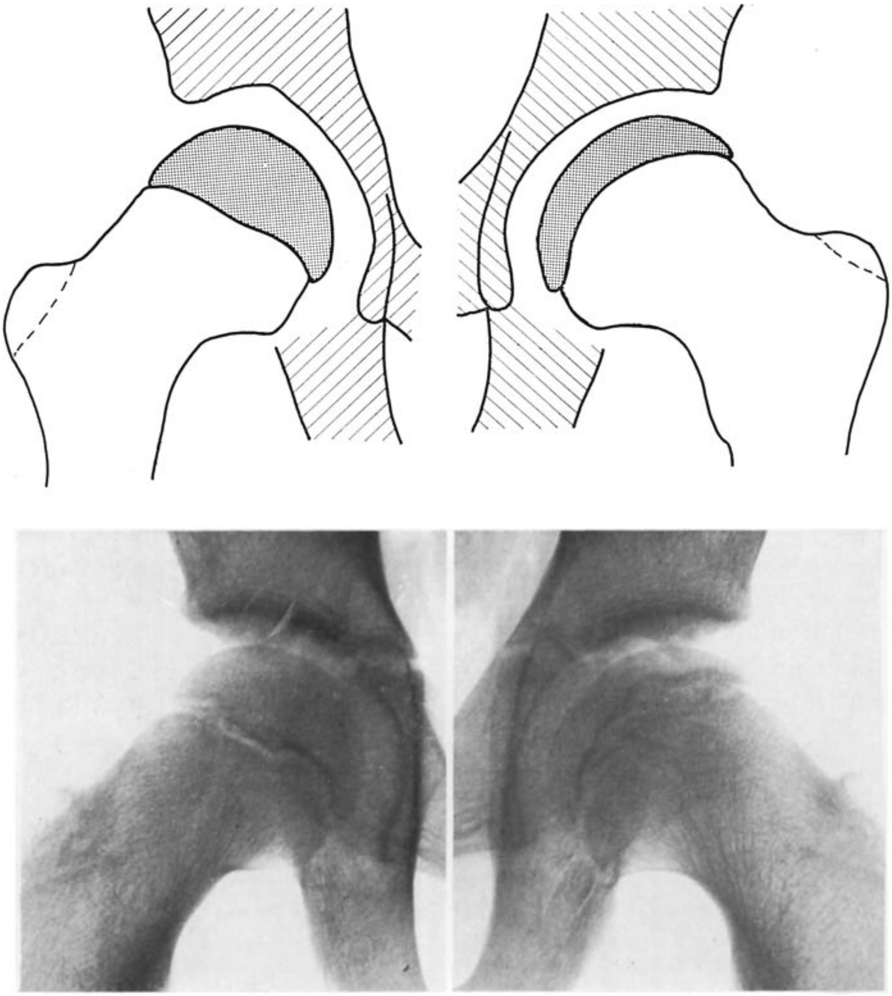


Figure 9. 10-year-old ♂. Sequelae of left-sided LCPD. Left capital epiphysis the shape of a new moon.

of LCPD there *may* be something like a subluxation, but in these cases its importance is quite subordinate to the deformity of the head.

The changes in the *neck* consist primarily in an arrested longitudinal growth—evidently due to damage to the function of the growth zone (epiphyseal line). Measurements show that there is rarely a question of actual shortening. In the second place, there will be widening—the rate of periosteal newformation of bone obviously not coming to a

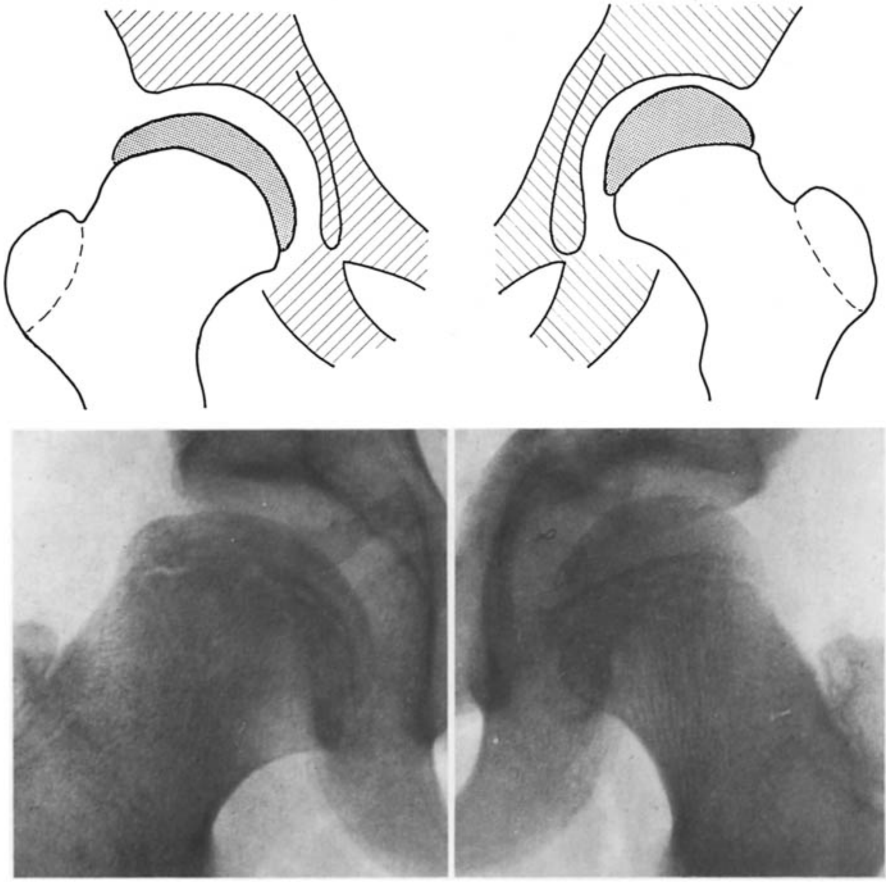


Figure 10. 9-year-old ♀. Sequelae of right-sided LCPD. Right capital epiphysis the shape of a new moon.

stop, but being increased. This happens in cases where the head shows great widening, presumably as a kind of secondary adaptation. The widening of the neck is of no importance *per se* in the development of osteoarthritis. Relative shortening of the neck may impair walking during the time after primary healing, but it does not appear to cause osteoarthritis—at least its role in this respect is inferior to that of the simultaneous marked widening of the head.

In brief, neither subluxation nor the secondary changes of the acetabulum or neck are in my opinion important prognostic factors.

The sequelae of LCPD are localized primarily to the head—and consequently the changes of the head are what has to be evaluated in

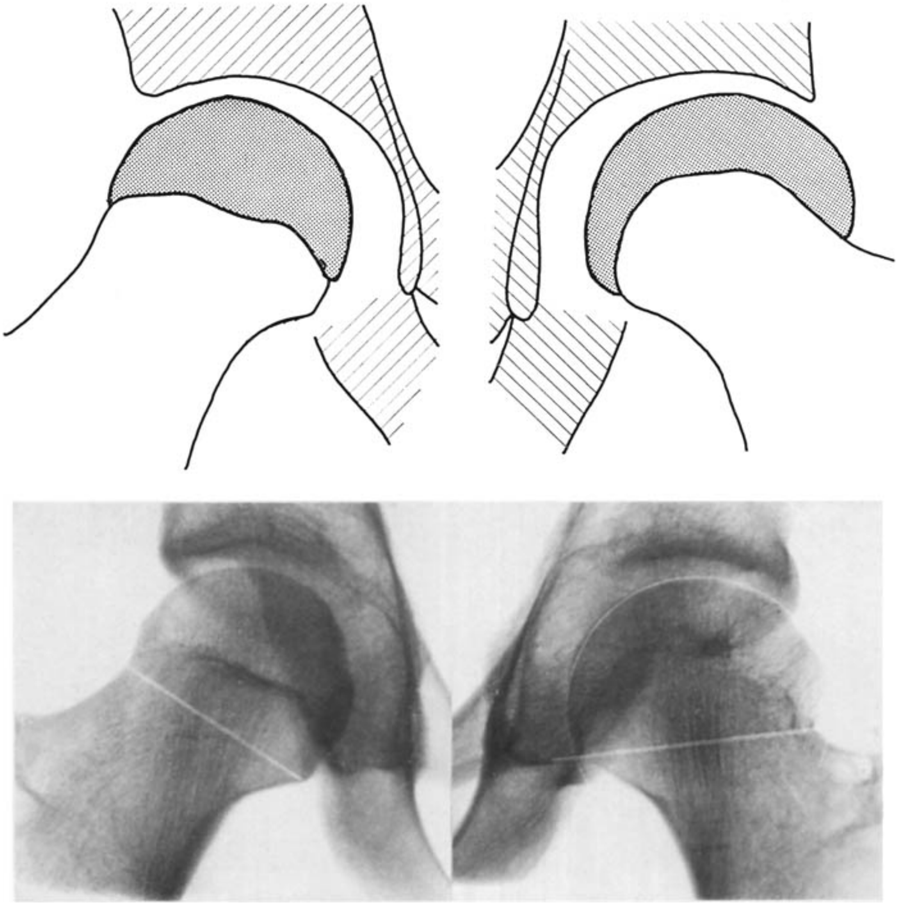


Figure 11. 13-year-old ♀. Sequelae of left-sided LCPD.
Left capital epiphysis the shape of a new moon, caput magnum.

assessing the primary result of a treatment—exactly the same conclusion at which Helbo and Sundt arrived on the basis of their studies.

Of course, one *may* try to record any changes in the position of the head in the acetabulum and the apparent shortening of the neck. However, these phenomena are nearly always combined with severe changes of the head and are therefore of subordinate interest.

But what happens in the head of the femur?

The primary change is flattening and widening of the epiphysis. If this consisted merely in the height of the epiphysis being reduced and its width increased, the remainder of the head adapting itself

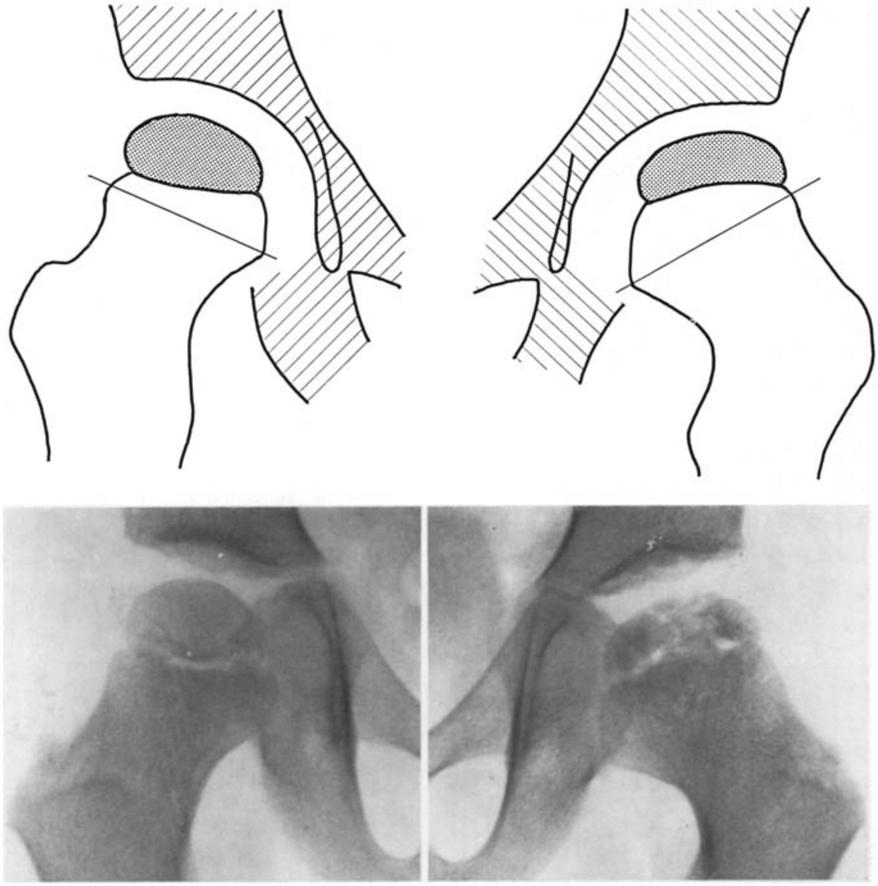


Figure 12. 5-year-old ♂. Left-sided LCPD. "Metaphyseal console".

accordingly, the flattening of the epiphysis would directly determine the shape of the head, and measurement of the epiphyseal deformity would afford a direct impression of the shape of the entire head.

But as stated above this is not so. The epiphysis does not merely become flatter and wide. It also "curves", so that on the X-ray film it assumes *the shape of the new moon* with the convexity upward. This counteracts the flattening of the head, its circular contour is preserved, still being about 220–240° with its centre at the approximately normal place in the head. The metaphysis grows up into the concavity of the new moon, *i.e.* it grows larger, and the epiphyseal line now manifests itself as an upward convex line (Figures 8, 9, 10).

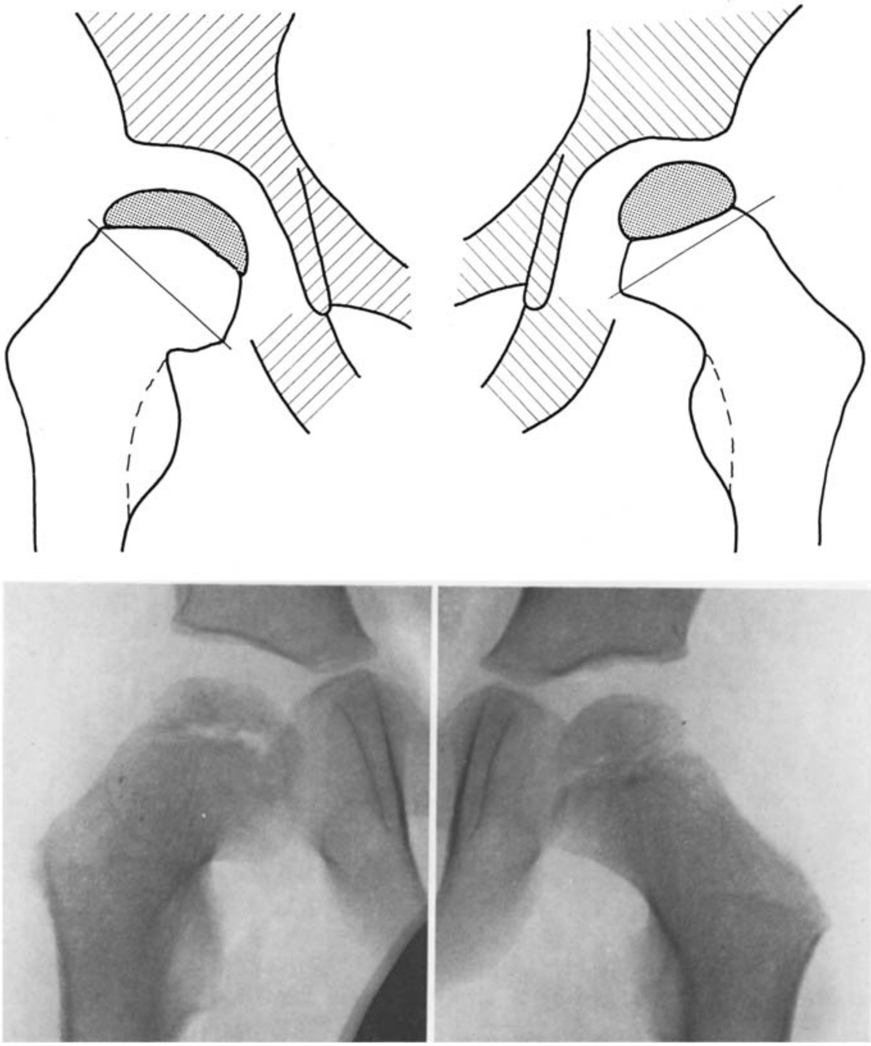


Figure 13. 5-year-old ♂. Right-sided LCPD. "Metaphyseal console".

If the epiphysis increases *greatly* in width, it cannot—despite its curving—be contained within the normal contour of the head. This would lead to flattening of the head, if the head did not acquire a larger surface by *diffuse growth* which gives room for the flat, wide curved epiphysis without the head as a whole getting flat and wide (Figure 11).

It seems reasonable to interpret the growth of the metaphysis up into the concave "new moon" and—at least partially—the diffuse growth of the head as *compensatory reparative* processes which, despite the flattening of the epiphysis, strive to maintain the normal shape of the head. This *may* be completely successful, although the epiphysis is visible only as a narrow sickle across the surface of the head. In such particularly successful cases the head presents itself as a moderate *"caput magnum"* of an entirely normal shape.

But in such instances a measure which merely represents the flattening of the epiphysis does not by any means give an impression of the shape of the head.

This form of compensation for epiphyseal deformity occurs mainly in the higher age groups, from 8 years and upwards. Another form may be observed in the age range 5–8 years. In this age group the epiphysis becomes flatter and *smaller*. It does not get appreciably wider, and therefore it is more rarely new moon-shaped. The metaphysis compensates for the small, flat epiphysis by increasing in size and forming a large *metaphyseal "console"* below the small epiphysis (Figures 12, 13). This preserves the normal shape of the head which is now made up mainly of the metaphysis. The head does not increase appreciably in size, unless the epiphysis also widens.

In cases having a metaphyseal console measurement of the epiphyseal flattening also gives no impression of the shape of the head.

Thus, in a considerable number of cases these reactions on the part of those components of the head which are outside the epiphysis can maintain the head in its approximately normal shape.

However, if the flattening of the epiphysis becomes *too* pronounced, things get more difficult.

In such cases it is impossible to compensate for the epiphyseal flattening which therefore will affect the shape of the head, making it on the whole flatter and wider. True, the circular contour of the head on the X-ray film is preserved, but the radius of the circle gets longer and the centre of the circle moves down toward the neck. The circular arc no longer makes up 220–240°, but approaches a semicircle (180°) or gets even smaller when the centre moves down *into* the neck (Figure 14).

If the epiphyseal flattening becomes even more pronounced, the circular contour of the head can no longer be maintained. The contour gets more curved at the edge and in the case of great flattening quite *irregular* and *angular* (Figure 16).

However, it must be pointed out that it is not only the degree of

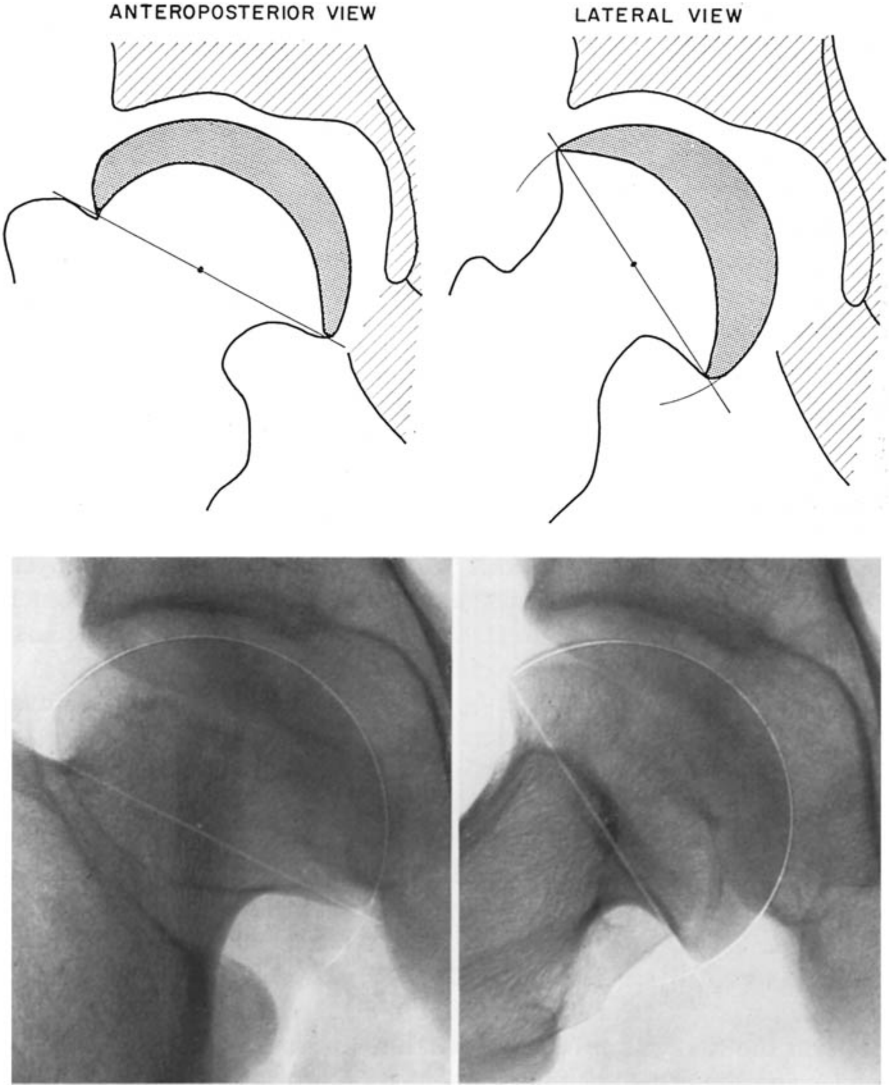


Figure 14. 17-year-old ♂. Sequelae of right-sided LCPD.
"Spherical" femoral head with a long radius and a short, broad neck.

epiphyseal flattening which decides whether the compensatory processes can maintain the normal shape of the head. This compensation also depends to a great extent upon whether the *metaphysis* is able to increase in size and adapt itself to the flat epiphysis. There are cases in which the metaphysis evidently lacks this ability for growth, so that even a slight flattening of the epiphysis is accompanied by a corresponding flattening of the entire head.

The lacking ability of the metaphysis for growth can only mean that the newformation of bone along the epiphyseal line has ceased or is greatly reduced. But this affects not only metaphyseal growth; the longitudinal growth of the neck of course ceases too. The result is the well-known picture of a *wide, flat head* on a *short, wide neck* (as the *periosteal* transverse growth of the neck does not cease!).

In other words, this typical deformity must be interpreted as a sign that in these cases the epiphyseal line has "closed" at an early stage of the disease. This justifies two conclusions:

In the first place: The worst thing that can be done during the treatment of LCPD is early *drilling* through the neck and epiphyseal cartilage up into the epiphysis. This will accelerate the closure of the epiphyseal line and prevent the compensatory osseous processes from exerting their influence—*i.e.* to preserve the shape of the head despite epiphyseal flattening.

In the second place: It is not surprising that the therapeutic results in LCPD are the poorer the closer the patient has approached puberty (Mose). In this age group the epiphyseal line is about to close and the epiphyseal cartilage does not possess the growth energy needed for eliciting a brisk compensatory growth of bone. The poor results in this age group are not due to greater flattening of the epiphysis, but to lacking compensatory osseous growth along the epiphyseal line.

Concerning the *factors and processes* active during the course of LCPD which together determine the *radiological* appearances, it may then be said:

The end result after treatment of LCPD is determined by 2 factors:

(1) the epiphyseal flattening,
(2) the processes in the remainder of the head which strive to compensate for this flattening.

It is the *total effect* of these two factors which determines the shape of the entire head of the femur as seen on the X-ray film at the time of primary healing.

The flattening of the epiphysis is determined partly by the severity of the disease and partly by the ability of treatment to prevent this flattening, *e.g.* by relief from weight-bearing. In comparing several series of *approximately the same severity*, therefore, the epiphyseal flattening is a *fitting indicator of the therapeutic efficacy*.

As series reported from this country will be of largely the same degree of severity a method measuring the epiphyseal flattening will afford a good index of the therapeutic efficacy, but not of the prognosis which depends upon the shape of the femoral head.

A method which measures the shape of the entire head, on the other hand, will afford important prognostic data, at least concerning the *relative* prognosis on the basis of the dictum: The greater the deformity of the head, the greater the risk of osteoarthritis.

The shape of the head may be measured in various ways.

First *directly*, *i.e.* so that the result of the measurement directly expresses the shape of the head. To my knowledge, no such measurement has been devised.

In the second place measurement of the capital shape may possibly be done by *indirect* methods. Thus, *a priori* it cannot be ruled out that a fairly constant, fixed relation exists between epiphyseal flattening and the shape of the entire head, so that the results of a method measuring epiphyseal flattening *may* be used as a measure of the shape of the entire head (Mose). However, this does not appear very likely according to what has been stated above. An orientation as to whether such a relation exists at all and—if so—concerning its magnitude, may be procured by comparing the results obtained by measuring the epiphysis and the shape of the head in a given series.

If such a relation exists, it must then be investigated, whether it exists also in other series and whether in these series it is of the same magnitude.

This is quite an undertaking, and even so one can never be *sure* that such a fixed relation between epiphyseal flattening and capital shape is present in *all* series under *all* circumstances. An indirect measuring method is always uncertain, and a method which directly measures the shape of the head is therefore undoubtedly preferable—if such a method can be devised!

In the following the various available—and any new—measuring methods will first be applied to a given material to ascertain whether they are applicable in practice and to assess the information obtainable by these methods.

Thereafter, the result of such a preliminary study is hoped to be applicable for a reliable assessment of the value of *different* therapeutic methods.

The material selected for the preliminary study consists of 79 patients with unilateral LCPD, treated in the Seaside Hospital, Refsnæs, during the period 1953–1957. All patients referred to the hospital during this period were included, regardless of the treatment they received.

The great majority of patients were treated by relief from weight-bearing on the affected hip, *i.e.* prolonged bed rest (about 18 months), followed by ambulatory relief from weight-bearing, *i.e.* crutches and Snyder's sling for about 6 months (relief from weight-bearing for an average of 25.8 months). The assessment was not performed until primary healing had occurred.

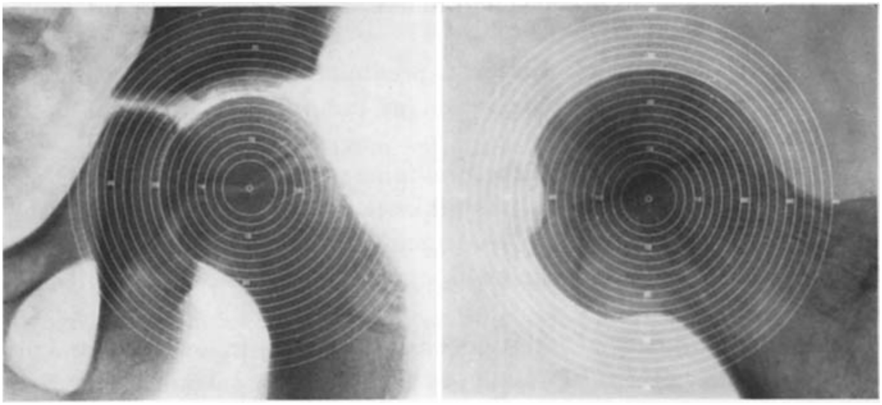
This series is identical with that described in Knud Mose's paper, and in the following it will be called the "bed rest series" unlike other series to be mentioned later treated without bed rest or with traction in bed.

This series has now been assessed independently by the author in every detail. But let me state that wherever Mose and I have used the same measuring methods and calculations, the results differ only negligibly.

A more detailed description of this series—its origin, definition, sex ratio, and age distribution, etc. was given in Mose's thesis. In the present paper, I shall give only a tabulation of the patients' age at the initial symptom and the stage of the disease when treatment was started (Table 1).

From this series it was first endeavoured to pick out a group in which the prognosis could be said to be definitely *poor*. The remaining cases then make up a group in which the prognosis is at least *better* than in the first group—in some of the cases even quite good.

The grouping was done on the basis of the radiographic findings. First, the X-ray films were arranged—on the basis of a pure estimate —in a long row, starting on one side, *e.g.* on the left of the viewer, with near-normal heads, the capital deformity increasing towards the other end (on the right). This row was then divided into 2 groups, one in which the articular surface of the affected head after the treatment still made up part of a spherical surface, varying from three-



a b

Figure 15. Mose's circular plate.

quarters of a spherical surface having approximately the same radius as the sound head to a considerably smaller part of a spherical surface with a longer radius—and another group in which the articular surface of the affected head had become irregular and angular.

Of course, this grouping can be done on the basis of a mere estimate, just by viewing the X-ray films, but a more exact, objective method was highly desirable.

A transparent plastic plate scored with circles was suggested by Goff as a valuable aid in estimating the shape of the head. Now, Mose has used a similar plate for a more exact assessment:

A transparent plate with a system of concentric circles with a 2 mm difference in radius, from 6 to 40 mm, is placed on top of the X-ray film (Figure 15). If one of the circles is applicable for covering the outline of the head in the anteroposterior view and the same circle covers the outline in the lateral view, the head is spherical, *i.e.* its surface is a major or minor part of a spherical surface. The plate also gives information regarding the size of the radius of this spherical surface (a 2 mm variation is permitted).

If none of the circles can cover the capital outlines, the case is assigned to the other group, *i.e.* that of irregular, or angular heads.

It may be mentioned that according to Mose's experience—and mine—there are actually no elliptic capital contours. As a transition between the definitely spherical and the irregular heads there may be very flat ones, the greater part of their surface being nevertheless spherical, having a circle-shaped silhouette, *i.e.* a circular arc which is

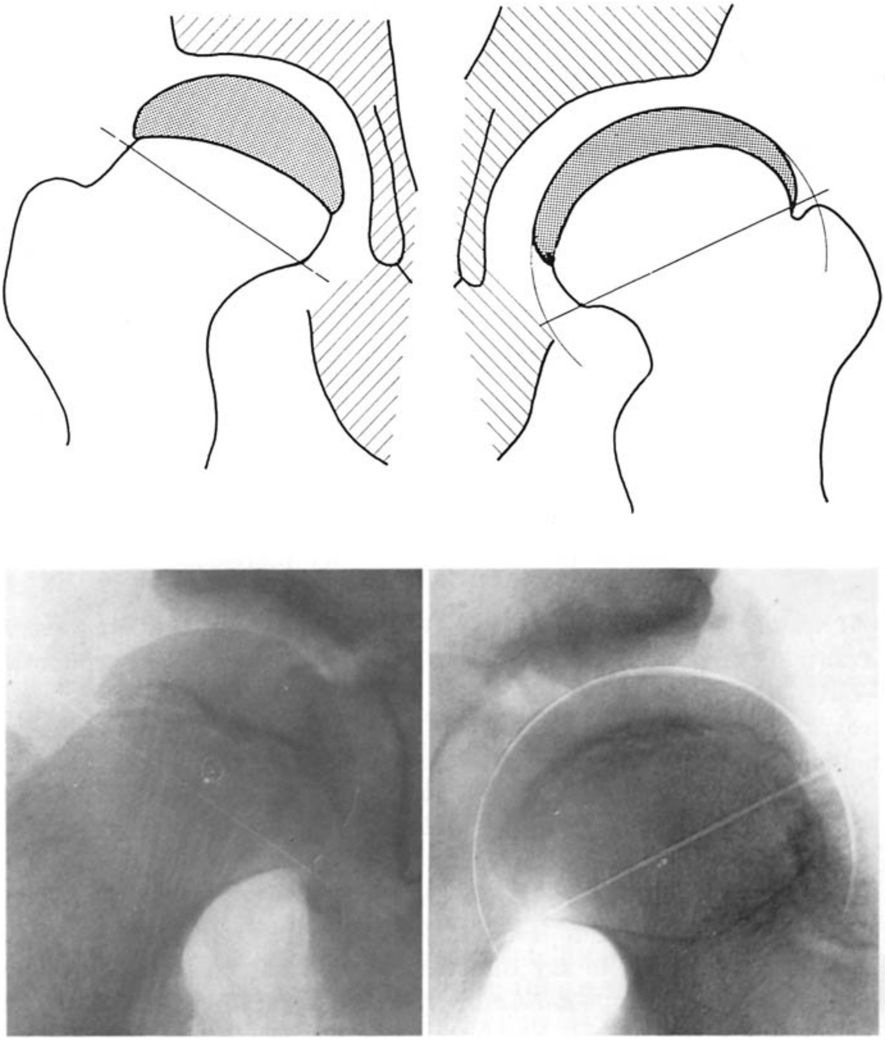


Figure 16. 12-year-old ♂. Sequelae of LCPD.
Transitional variety between "spherical" and irregular femoral head.

small in degrees having a long radius, and a centre situated in the neck, while the edges have greater curvature, and thus a shorter radius (Figure 16).

Such heads should always be classified as irregular, but the grouping may be difficult. However, they occur only in small numbers.

It might be imagined also that the grouping into spherical and non-spherical would give rise to difficulties in the young age groups—below 4 years—in which even the normal head does not show an uninterrupted circular contour on the X-ray film. However, this difficulty has never been encountered in practice, as the therapeutic results are never assessed until 3–4 years after the onset of the disease.

On the whole, the division into the two groups is very reliable, and Mose's application of Goff's plate means a considerable advance in the evaluation of the therapeutic results in LCPD.

We have now distinguished one group of patients in whom the femoral heads, after the disease has run its course, are so deformed—irregular and angular—that the risk of osteoarthritis must be very great.

The prognosis in the remaining cases—the group with spherical heads—is more difficult to establish.

Let us imagine again that the X-ray films for this group are arranged—according to a mere estimate—in a row starting on the left with the near-normal heads, the capital deformity increasing towards the right.

If we view this row, it is evident that the cases on the left have a favourable prognosis, while those on the right have a poorer prognosis—but it is impossible to decide the limit between a good and a poor prognosis by a mere estimate. This requires at least a measuring method which gives an objective measure of the shape of the head.

But even though such measurements were available, it would be impossible—as already mentioned—to decide directly which deformities are going to give rise to osteoarthritis and which not.

However, some guidance is to be had.

Just as irregular heads indubitably spell a poor prognosis, it may probably be justified to say that when a relevant measuring method shows a head of a shape *within the normal range*, the prognosis ought to be good.

But no such measuring method is available—as yet.

In order to obtain one, it was my object first to try whether, in a given series, a method measuring the *epiphyseal flattening*, might, perhaps indirectly, afford information about the shape of the head. Should this fail, it was intended to try to arrive at a method which *directly* measures the shape of the head.

In the introduction I mentioned a number of the methods used so far for assessing the therapeutic results: Measurement of the epiphys-

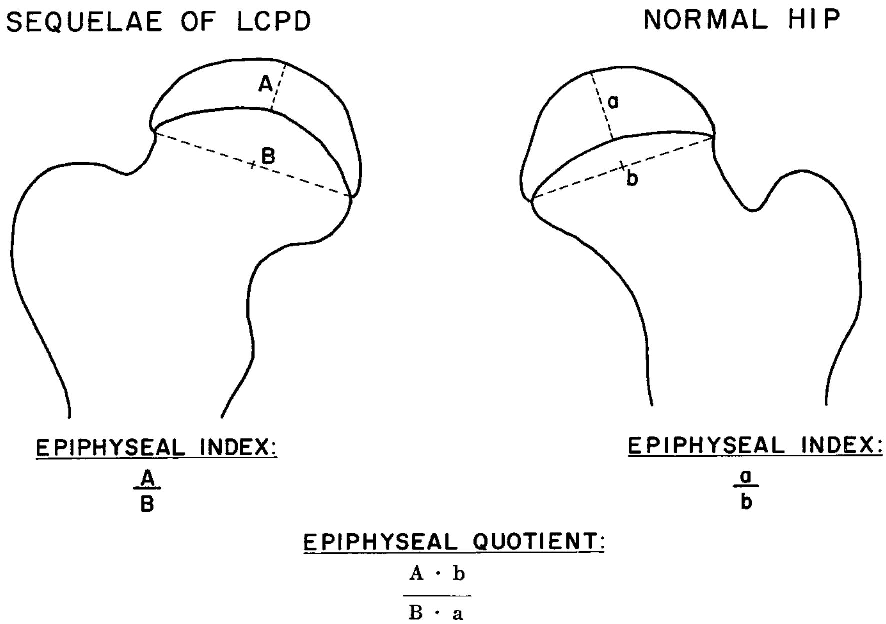


Figure 17. Calculation of epiphyseal quotient.

eal index (Sjövall), epiphyseal quotient (Eyre-Brook), Herndon & Heymann's comprehensive quotient, and Jonsäter's caput index.

Measurement of the epiphyseal quotient is the method which gives the most reliable information about epiphyseal flattening—and which is based upon the most well-defined measurements. Furthermore, Mose has once measured the epiphyseal quotient in the present material, and repeated measurement—carried out independently by another investigator—will, if the results show agreement, be a weighty argument in favour of the accuracy and reliability of the method.

The epiphyseal quotient is found by first dividing, on the affected side, the greatest height of the epiphysis by its width at the epiphyseal line. This gives the epiphyseal index of the affected side. This index is then divided by the epiphyseal index on the sound side, multiplied by 100, which gives the epiphyseal quotient (Figure 17).

When the epiphyseal quotients are calculated in a series of normal hips (of the same age distribution as the present series) the values generally range from 90–100, while a smaller number are between 85–90. *The normal minimum value must be said to be 85* (the epiphyseal quotients were measured on X-rays of 80 normal hips. The lower index is the numerator).

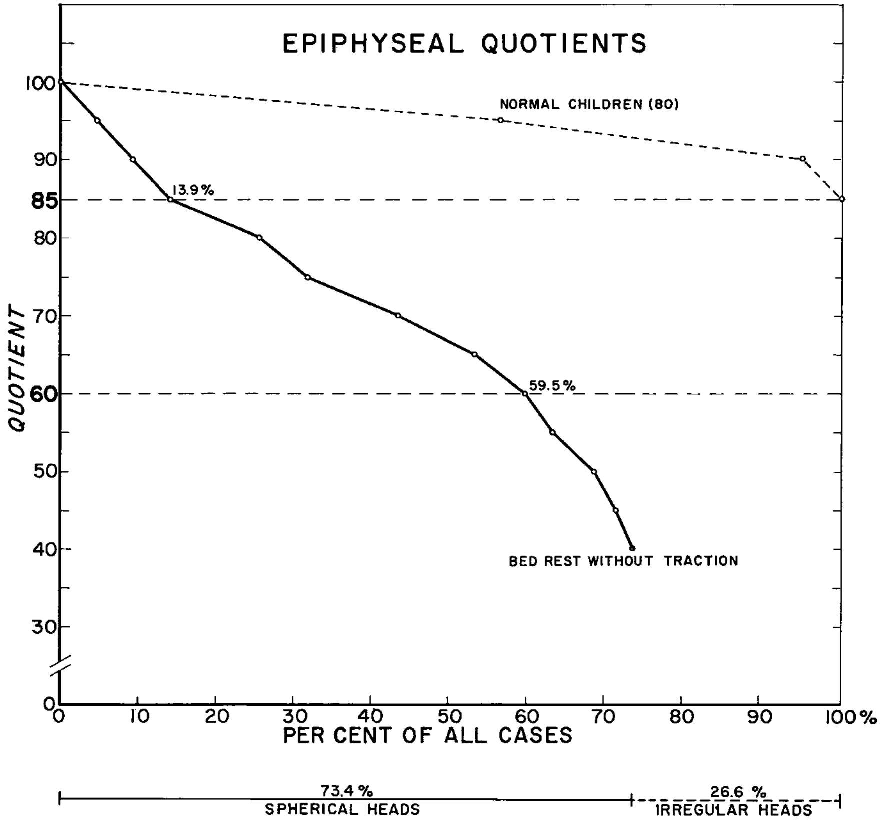


Diagram 1. Epiphyseal quotients *(bed rest without traction. Refsnæs 1953–57, 79 pts.). Epiphyseal quotients plotted along the ordinate. The number of patients, in per cent, plotted, according to decreasing epiphyseal quotient, along the abscissa. That part of the abscissa which is within the right end point of the curve signifies the number of patients with spherical heads (73.4 per cent), that part which is outside this point the number of patients with irregular heads (26.6 per cent). The broken curve indicates the epiphyseal quotients in 80 normal children. (Table 4[1]).*

The result of calculating the epiphyseal quotient in the "bed rest series" may be seen from Diagram I.—From this diagram it may be seen that only about 14 per cent of the patients have an epiphyseal quotient exceeding 85—the normal minimum.

If the epiphyseal quotient were a direct expression of the shape of the head, this would be an extremely poor result!

But it is not. The compensatory processes in the head lend far more than 14 per cent of the patients an approximately normal head.

This was also realized by Mose. Indeed, he states that careful inspection of the X-ray films showed that *all patients whose epiphyseal quotients exceeded 60 had a normally or near-normally shaped head.* In other words, there was a striking disagreement between the relatively low epiphyseal quotients in the greater part of the series and the large number of well-shaped heads.

Mose, accordingly, established the rule that all patients whose epiphyseal quotients exceeded 60 could be defined as a group having such well-shaped heads that the result had to be called "good".

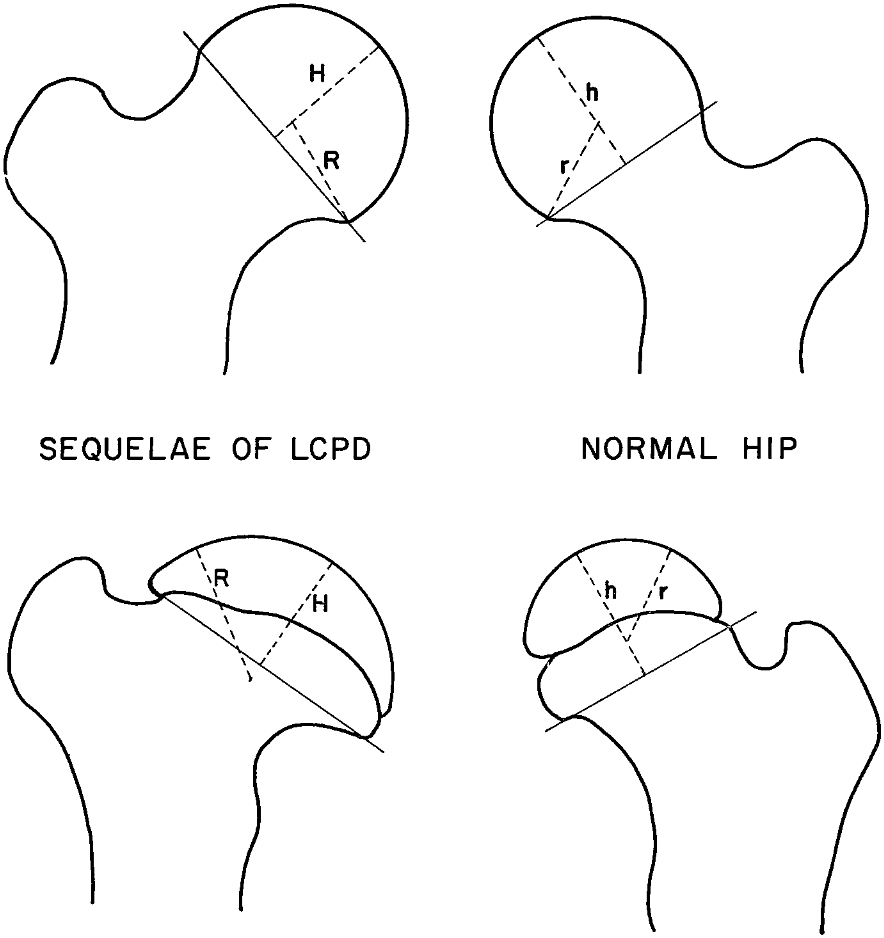
This rule, which I shall call *"Mose's rule"*, was thus set up in the attempt at getting an indirect measure of the capital shape by measuring epiphyseal flattening.

As is apparent from the diagram about 60 per cent of the patients had an epiphyseal quotient exceeding 60.

Herndon & Heymann were struck by the same disagreement between the low epiphyseal quotients and the surprisingly well-shaped heads. But they tried to arrive at a measuring method which is more in agreement with the shape of the head by combining the epiphyseal quotient with another 3 quotients relating to factors which also change in the course of LCPD: head-neck quotient, acetabular quotient, and acetabulum-head quotient. However, none of these 3 quotients proved to alter materially during the course of the disease, or at least far less than the epiphyseal quotient. Obviously, when an average of the epiphyseal quotient and 3 near-normal quotients is calculated, the values found will be closer to normal than the epiphyseal quotients alone and therefore in better agreement with the relatively large number of well-shaped heads.

Herndon & Heymann also found that 60 per cent of the patients treated (for a relatively short period) with bed rest and traction followed by ambulatory non-weight-bearing, had a comprehensive quotient exceeding 80, corresponding to a result which at an estimate must be called "excellent" and "good". Evidently, they feel that now there is a reasonable agreement between measuring method and estimate.

It is not clear why it is better to use a comprehensive quotient and a limit of 80 than the epiphyseal quotient alone and a limit of 60. There is nothing to indicate that Herndon & Heymann's other 3 quotients include particularly the shape of the head in the measuring method. The comprehensive quotient is in all essentials merely a fortuitous numerical reduction of the epiphyseal quotient.



JOINT SURFACE INDEX:

$$\frac{H}{2R}$$

JOINT SURFACE INDEX:

$$\frac{h}{2r}$$

JOINT SURFACE QUOTIENT:

$$\frac{H \cdot r}{R \cdot h}$$

RADIUS QUOTIENT:

$$\frac{R}{r}$$

Figure 18. Calculation of joint surface quotient *and* radius quotient.

In brief: Mose's as well as Herndon & Heymann's assessment of which heads—and thereby joints—may be called "good" etc. is based exclusively upon simple, direct inspection of X-ray films and is thus, in fact, a mere estimate.

Others have used different estimates. Katz, for instance, states that the epiphyseal quotients must exceed 75 for the result to be called "good" (Katz': "satisfactory"), while Mose's "good" group goes right down to an epiphyseal quotient of 60. Possibly, both these figures are correct—or reasonable—for *the respective series,* but it is possible also that the difference is due merely to different personal estimates as to what is considered "good". This shows, however, that the epiphyseal quotient is a frail basis for assessing the shape of the head—and thereby the prognosis. On the other hand, nobody will deny that it is an excellent measure of the ability of treatment to prevent epiphyseal flattening.

It is necessary, therefore, to arrive at a method which gives a more direct measure of the shape of the head.

The head is defined as that part of the femur which is covered by the joint surface. The shape of the head, therefore, is determined by the shape of the joint surface.

Normally the joint surface is shaped as 2/3–3/4 of a spherical surface demarcated from the surface of the neck by a slightly undulating line which, however, without major error may be described as a circle. In other words, the head may be considered a spherical segment and the joint surface as its curved surface. The area of the joint surface, expressed as a fraction of a whole spherical surface having the same radius is then $\frac{2 \pi r h}{4 \pi r^2} = \frac{h}{2 r}$ in which h is the height of the spherical segment and r the radius of the spherical surface. This quantity is called the *joint surface index.* h and r—and thus also the joint surface index—may be measured on the X-ray film (Figure 18).

During the course of a LCPD the head as a whole becomes deformed —flattened. In cases where the joint surface preserves its character as a spherical surface, it will—when measured as a fraction of a whole spherical surface—be diminished, *i.e.* the joint surface index decreases with increasing flattening. In these cases the joint surface index affords a well-defined measure of the shape of the entire head: 3/4 sphere, 1/2 sphere, etc., *i.e.* a spherical segment whose surface is 3/4–1/2 of a whole spherical surface.

The joint surface index on the diseased side may be compared with that on the unaffected side by dividing the former by the latter. This gives the *joint surface quotient:* $\frac{H \times r}{R \times h}$ in which the capital letters indicate the measurements on the diseased side and the small letters the measurements on the sound side. This quotient is an accurate, objective measure of the alteration in the shape of the head during the course of LCPD. It is stated multiplied by 100, and in 80 normal children it ranged from 100–85.

The shortcoming of the joint surface index and joint surface quotient is that these quantities remain entirely unchanged when H and R increase proportionally, *i.e.* when the head increases in size without changing in shape, or in other words when it develops into a "caput magnum"—which *may* be the only sequel of LCPD.

On the other hand, such an increase in capital size affects the radius of the head—which will of course become longer than on the sound side.

However, the length of the radius is not influenced only by a pure increase in growth. When, during an LCPD the head preserves its spherical shape, but gets flatter, the centre of the joint surface will move down towards, possibly into the neck. That is, the length of the radius will *also* be increased by flattening of the head.

This is important, because it makes it possible to employ the length of the radius for a more accurate assessment of the therapeutic results: The fact is that the flattening of the head is usually accompanied by a very considerable increase in growth.

Just as the joint surface quotient may be calculated from the joint surface index, it is possible to calculate a *radius quotient* by dividing the radius of the diseased side by that of the unaffected side—and multiply by 100. In 80 normal children this quotient ranged from 100 to 115 (Figure 18).

If this radius quotient is used for assessing a therapeutic result, it records the flattening *as well* as the increase in the size of the head, while the joint surface quotient records only the flattening. It is therefore not surprising that as a rule the radius quotient usually records a greater difference from normal than the joint surface quotient (cf. Appendix II).

Since, however, the increase in growth is presumably not of as much prognostic importance as the flattening, the radius quotient will probably be too pessimistic a prognostic indicator. As one cannot

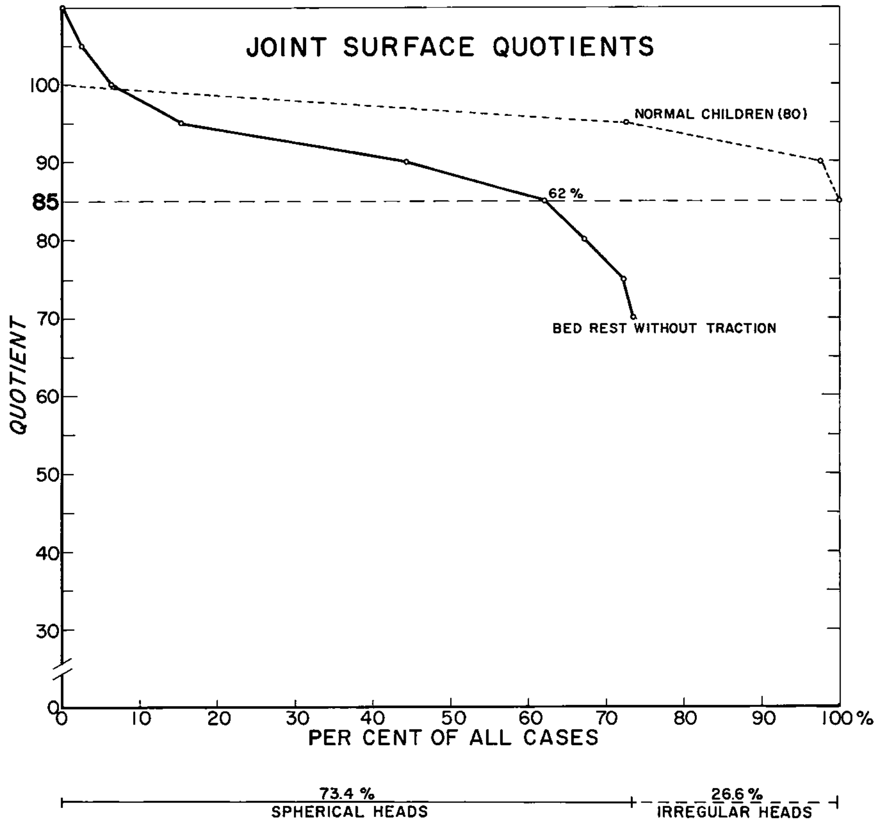


Diagram 2. Joint surface quotients *(bed rest without traction. Refsnæs 1953–57, 79 patients). Joint surface quotients plotted along the ordinate. The number of patients, in per cent, plotted according to decreasing joint surface quotient along the abscissa. That part of the abscissa which is within the right end point of the curve signifies the number of patients with spherical heads (73.4 per cent) and that part which is outside this point the number of patients with irregular heads (26.6 per cent). The broken curve indicates the joint surface quotients in 80 normal children. (Table 42).*

entirely disregard the increase in growth, the joint surface quotient is possibly too optimistic.

All considered, however, the joint surface quotient will probably be a better prognostic guide.

After these, more theroretical considerations, the two suggestions for new measuring methods will be tested in practice and their results compared with those found by measuring the epiphyseal quotient.

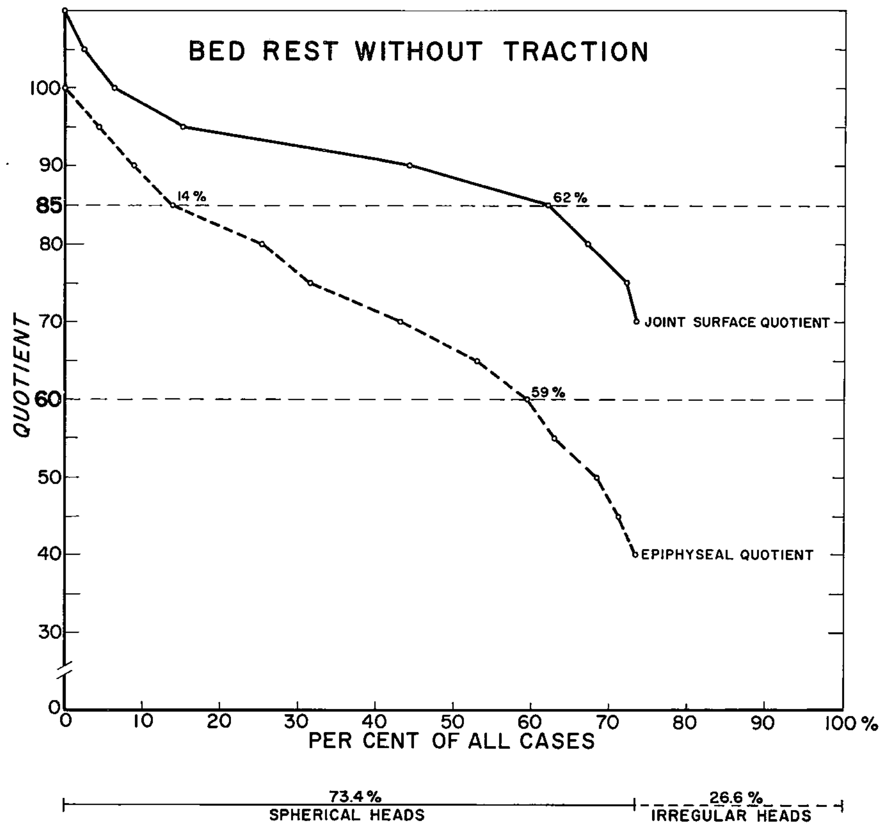


Diagram 3. Epiphyseal quotients *and* joint surface quotients *(bed rest without traction. Refsnæs 1953–57, 79 pts.). See legends to Diagrams 1 and 2. (Table 41-2).*

Diagram 2 shows the *joint surface quotients* of the material plotted in the same way as the epiphyseal quotients in Diagram 1.

The curve will be seen to differ greatly from that in Diagram 1: 62 per cent of the patients have joint surface quotients exceeding the normal minimum (which is 85 also for the joint surface quotient), while only 14 per cent of the patients have epiphyseal quotients above this limit (Diagram 3).

It will be noticed that the highest joint surface quotients are *in excess of 100.* This is because in certain rather mild cases of "caput magnum" withous flattening a slight increase in the joint surface index will occur on the affected side, as the head has evidently in-

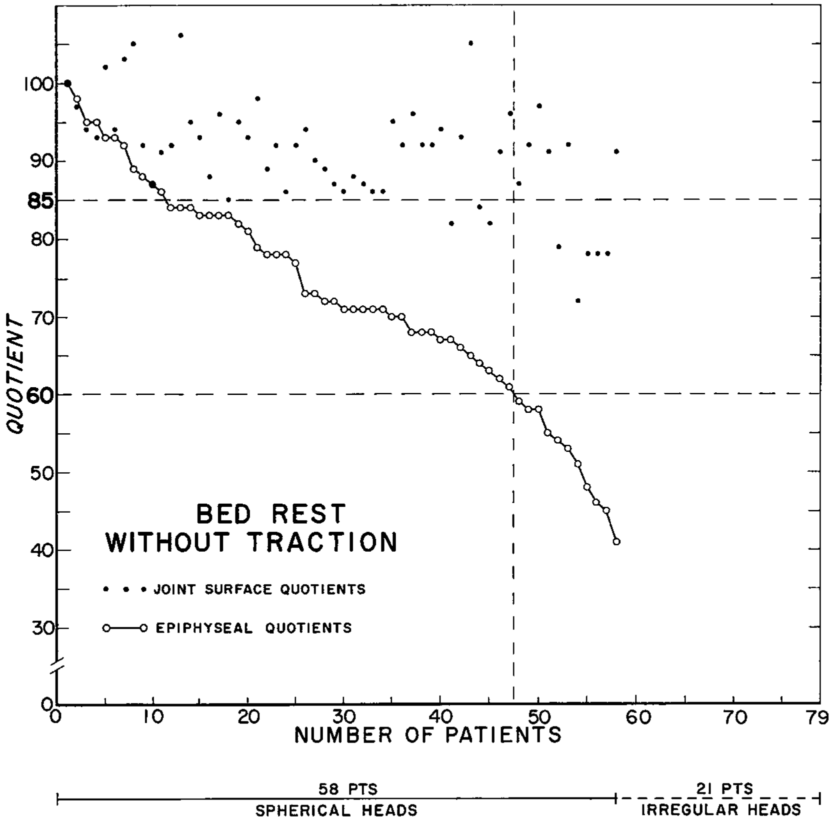


Diagram 4. Epiphyseal quotients *and* joint surface quotients *(bed rest without traction. Refsnæs 1953–57, 79 patients). The patients are plotted "singly" along the abscissa according to decreasing epiphyseal quotient. Epiphyseal quotients and joint surface quotients plotted along the ordinate. For each patient a circle for the epiphyseal quotient and a dot for the joint surface quotient. (Table 4[1-2]).*

creased in size in relation to the width of the neck, and the joint surface accordingly makes up a larger part of a spherical surface than on the sound side.

Mose's radiological estimate, viz. that 60 per cent of the patients have a normally or near-normally shaped head, then appears to have been confirmed by a purely objective measurement of joint surface quotients. This agreement may of course also be taken as a confirmation that the joint surface quotient is not only theoretically, but also in reality a measure of the shape of the head.

However, it must be mentioned that these values mean only that about 60 per cent of the patients have epiphyseal quotients exceeding 60 and that about 60 per cent have joint surface quotients within the normal range (above 85), and thus a practically speaking normal head. This is not saying that they are the same patients!

In Diagram 4 the patients are plotted *singly* along the abscissa according to decreasing epiphyseal quotient (not into per cent groups). For each patient the joint surface quotient is plotted as well. It will be seen that there is by no means a constant relation between the epiphyseal quotients—which indicate epiphyseal flattening—and the joint surface quotients, which afford a measure of epiphyseal flattening plus the compensatory processes and therefore—at least theoretically—of the shape of the head. In practically all cases the joint surface quotient is higher than the epiphyseal quotient, *i.e.* closer to the normal values—but in some cases the difference between the epiphyseal quotient and the joint surface quotient is slight, indicating that the processes which have endeavoured to compensate for the epiphyseal flattening have been of little effect. In other cases the difference is great, indicating a very effective compensatory activity.

By way of example, it will be seen that the patient who has the lowest epiphyseal quotient: 41, has a joint surface quotient of 91, *i.e.* a very well-shaped head within the normal range (Figure 10), while another patient with an epiphyseal quotient of 55 had a joint surface quotient of only 72, the lowest of all the joint surface quotients.

A total of 4 patients with epiphyseal quotients exceeding 60 had joint surface quotients below 85, while 6 patients with epiphyseal quotients below 60 have joint surface quotients within the normal range.

Considering (1) the theoretical basis of the joint surface quotient, (2) that—as expected—it is practically speaking always closer to normal than the epiphyseal quotient, and (3) the agreement found between the subjective estimate of the shape of the head, it seems justified to regard the *joint surface quotient as an expression of the shape of the head.*

It may then be said:

Mose's estimate that 60 per cent of the patients have well-shaped heads is correct—only they are not the same 60 per cent as those who have an epiphyseal quotient above 60.

Measurement of the epiphyseal quotient and the use of Mose's rule, then, do not lead to those patients who have a well-shaped femoral

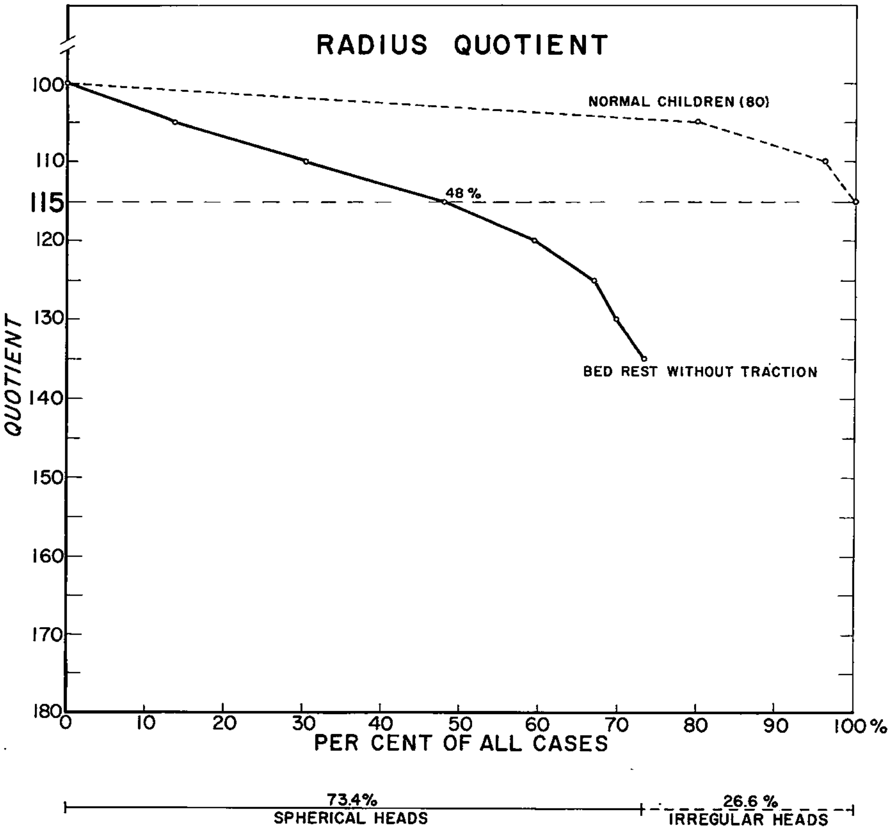


Diagram 5. Radius quotients *(bed rest without traction. Refsnæs 1953–57, 79 pts.). Radius quotients plotted along the ordinate. The number of patients, in per cent, plotted according to increasing radius quotient, along the abscissa. That part of the abscissa which is within the right end point of the curve signifies the number of patients with spherical heads (73.4 per cent), and the part outside this point the number of patients with irregular heads (26.6 per cent). The broken curve indicates the joint surface quotients in a number of normal children (80). (Table 43).*

head. This can be obtained only by measuring the joint surface quotient, which is a direct measure of the shape of the head, and picking out those patients whose joint surface quotient is within the normal range, *i.e.* above 85.

The epiphyseal quotient only expresses the flattening of the epiphysis. As this is determined to a marked extent by the efficacy of the relief from weight-bearing, the epiphyseal quotient is an *excellent*

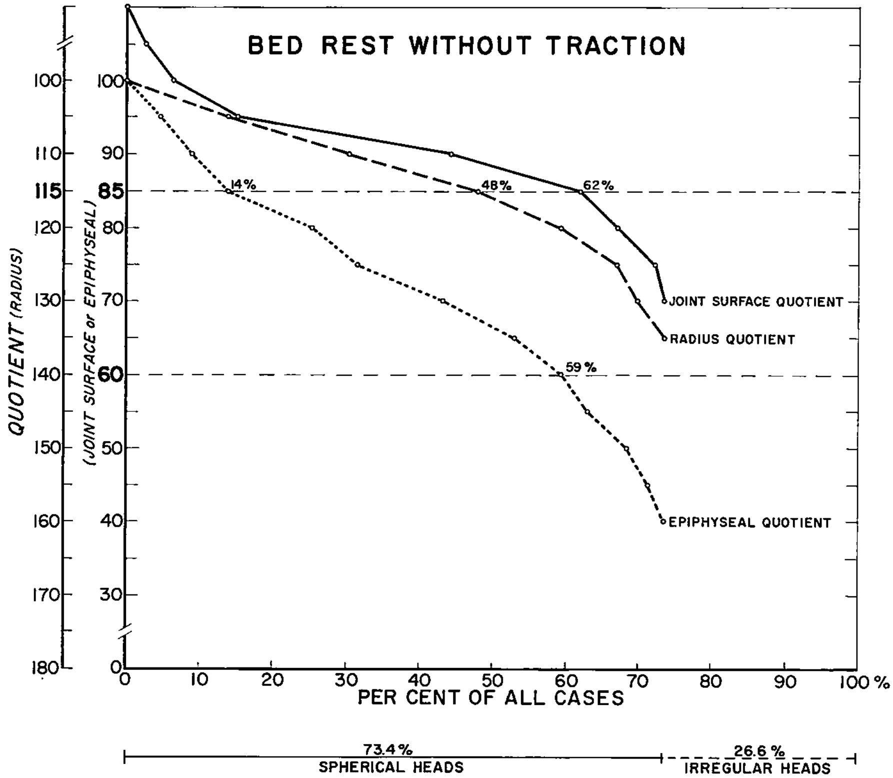


Diagram 6. Epiphyseal quotients, joint surface quotients, and radius quotients in patients treated with bed rest without traction. Refsnæs 1953–57 (79 patients). Cf. also legends to Diagrams 1, 2, and 5. (Table 41-2-3).

measure of the extent to which the treatment has been able to prevent epiphyseal flattening.

In brief: Measurement of the joint surface quotient and of the epiphyseal quotient afford different, but in both cases valuable information: the joint surface quotient regarding the *prognosis,* and the epiphyseal quotient regarding the *direct effect of the treatment upon the epiphyseal shape.*

Diagram 5 is a graphic representation of the *radius quotients* in the bed rest series—analogous with the representation of the epiphyseal quotients and joint surface quotients in Diagrams 1 and 2 (Diagram 6).

By this measuring method *only 48 per cent* of the patients were found to have radius quotiens below the normal maximum (115).

This value—48 per cent—is lower than found by measuring the joint surface quotients (62 per cent)—and is not in keeping with Mose's radiological estimate of the size of the group called "good" (60 per cent). This is a natural consequence of the influence upon the radius quotient of the flattening *as well as* increase in size of the head, while the joint surface quotient is influenced only by the flattening. Accordingly, measurement of the radius quotient is a stricter assessment of the therapeutic results and gives a lower proportion of successful cases (Appendix II).

In a radiological estimate the viewer is bound to attach most importance to those changes in the shape of the head which are due to flattening, while the increase in its size is less striking. Therefore, the radiological estimate will, very naturally, be in better agreement with the joint surface quotients.

The question is then, ultimately, whether the radius quotient or the joint surface quotient is a more reliable *prognostic* guide. As far as I can see it is more likely that the changes of the head due to flattening must be prognostically more important and that the increase in size must be subordinate—int. *al.* perhaps because it is compensated for during the patient's further growth. If this holds true, *measurement of the joint surface quotient gives the most reliable prognostic information.* This again means that about 60 per cent of the patients in the bed rest series—in agreement with Mose's radiological estimate—ought to have a favourable prognosis. As already pointed out, however, this cannot be decided with certainty until there has been occasion to measure the joint surface quotient and the radius quotient in a group of patients treated for LCPD, and then evaluate the clinical and radiological result at least 25 years later.

Such an investigation has not yet been carried out.

The total result of this section on measuring methods is then:

A grouping into cases with spherical and cases with irregular femoral heads is the necessary basis for any assessment of therapeutic results. This grouping sorts off the cases which have a poor prognosis—*i.e.* those which have healed with irregular heads. Thereafter, the remaining cases, *i.e.* the group of cases with spherical heads, may be further assessed by measuring the epiphyseal quotient, the joint surface quotient, and the radius quotient.

The epiphyseal quotient is neither a direct nor an indirect measure of capital shape—but of epiphyseal shape. The joint surface quotient, on the other hand, is a direct measure of the shape of the head, the radius quotient of its shape and size.

As it is the shape of the head which decides the prognosis, measurement of the joint surface quotient affords the best prognostic guidance.

In the present material there was agreement between the number of "good results" measured by the epiphyseal quotient and by the joint surface quotient—approx. 60 per cent by both methods. However, this agreement is only apparent: The value does not represent the same 60 per cent of the patients—and the selection resulting from the measurement of the joint surface quotient corresponded best to the term "good results", as the joint surface quotient is the most reliable prognostic guide.

This is not saying that measurement of the epiphyseal quotient is devoid of interest. On the contrary. This quantity may be considered an excellent—and sensitive—indicator of the effect of treatment upon the capital epiphysis.

Radiological Evaluation of the Various Forms of Treatment

This assessment was done on three groups of patients treated for unilateral LCPD: One with *traction in bed*, one with *bed rest without traction*, and one with *ambulatory relief from weight-bearing*.

According to the conclusion drawn in the last chapter, any assessment of the therapeutic results ought to include, as far as possible, all three measures: *epiphyseal quotient, joint surface quotient,* and *radius quotient*. Each measures well-defined—but mutually different—properties of the femoral head, so that the use of all three methods gives the most varied and detailed picture of the results. Any case healed with a spherical head may, in fact, be characterized by *3 figures,* viz. the results of the 3 above-mentioned measuring methods. Example: The case illustrated in Figure 8: 58–92–109.

However, this ideal can only be attained in the two first-mentioned series, not in the third. This is a series of patients with unilateral LCPD treated with ambulatory relief from weight-bearing and *reported by Mose.* The treatment consisted mainly in ambulatory relief from weight-bearing by using a Thomas brace, crutches and elevation of the opposite shoe for 17–26 months, average 25.2 months. *Any mention below of "ambulatory treatment" refers exclusively to this form of ambulatory treatment,* when nothing else is stated. Mose measured the epiphyseal quotients in this series, but I did *not* have occasion to measure the joint surface and radius quotients. Since it is important to compare the results obtained by ambulatory relief from weight-bearing with those of the other two forms of treatment, and since Mose's and my measurements of the epiphyseal quotient have proved to agree, I felt that it was reasonable to include this series in the study and to compare it with the other two as far as Mose's data permit.

However, the central point of the study is of course the comparison between those two series in which all 3 measuring methods can be applied.

Thus, the three series which form the basis of the present study were this *ambulatory* series described in Mose's thesis, the series treated with *prolonged bed rest,* and lastly a series of patients treated in the Seaside Hospital, Refsnæs, with *traction in bed.*

This traction series comprises 71 patients with unilateral LCPD treated in the Seaside Hospital, Refsnæs, from Jan. 1, 1958 to Jan. 1, 1962. *All* patients referred to that hospital and treated there for LCPD during these years were included in the analysis, regardless of whether or not they were treated with traction (57 patients out of 71 (or 80 per cent) were treated with traction and the others with bed rest alone). Thus, we are not dealing with a selected material. The treatment was as follows: One year of traction in bed followed by about 6 months in bed without traction, and thereafter about 6 months of ambulatory relief from weight-bearing (crutches and Snyder's sling). The patients were allowed out of bed and on crutches, when X-ray showed definite signs of incipient newformation of bone around and between the epiphyseal fragments.

The *traction* was a 1–1½ kg traction on both legs, applied for periods of 6 weeks interrupted by two-week periods without traction, but with close supervision of the condition of the joints, in particular the knee joint. In other words, this was fairly light traction whose main effect has presumably consisted in reducing or abolishing the muscle tonus and securing better immobilization.

When the treatment was changed to ambulatory, various physiotherapeutic measures were cautiously instituted to train the muscles and joints.

The final X-ray films were, in practically all cases, read at least one year after the completion of treatment. In *all* cases the outlines of the femoral head were uninterrupted and well-defined.

The *age distribution* and the *stage* of the disease when the treatment was started in all three series are listed in Tables 2 and 3.

These tables show that the traction series included a somewhat larger number of children under 4 years of age than the bed rest series. If the limit is set at 3 years, there is no difference. On the other hand, the patients treated with bed rest alone arrived for treatment at an earlier stage of their disease.

The cases who had ambulatory treatment are more favourable in both respects with a view to obtaining a good therapeutic result.

By way of introduction, Diagram 7 gives the results obtained by measuring the epiphyseal quotients in the 3 series. It is supplemented by the more simplified Diagrams 8 and 9.

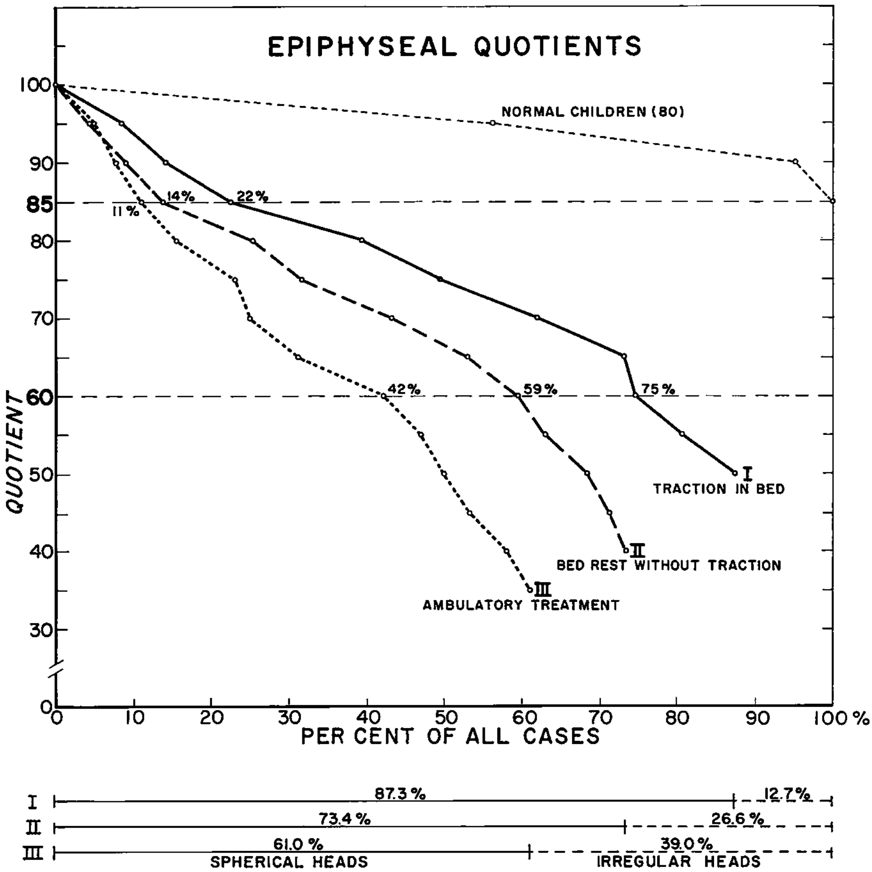


Diagram 7. Epiphyseal quotients in 3 series treated for LCPD by 3 different methods.

I. Traction in bed. Refsnæs 1958–62, 71 patients.

II. Bed rest without *traction. Refsnæs 1953–57, 79 patients.*

III. Ambulatory treatment (Mose), 64 patients.

The epiphyseal quotients are plotted along the ordinate. The number of patients, in per cent, plotted according to decreasing epiphyseal quotient, along the abscissa. That part of the abscissa which is within the right end point of the curve signifies the number of patients with spherical heads (87, 73, and 61 per cent), that part which is outside this point the number of patients with irregular heads (13, 27, and 39 per cent). (Tables 5^1, 4^1, 6).

In the following, the 3 series will be called the "traction series", the "bed rest series", and the "ambulatory series".

Curve III on Diagram 7 is based, as already mentioned, on Mose's measurements. However, the ambulatory series includes 7 cases in

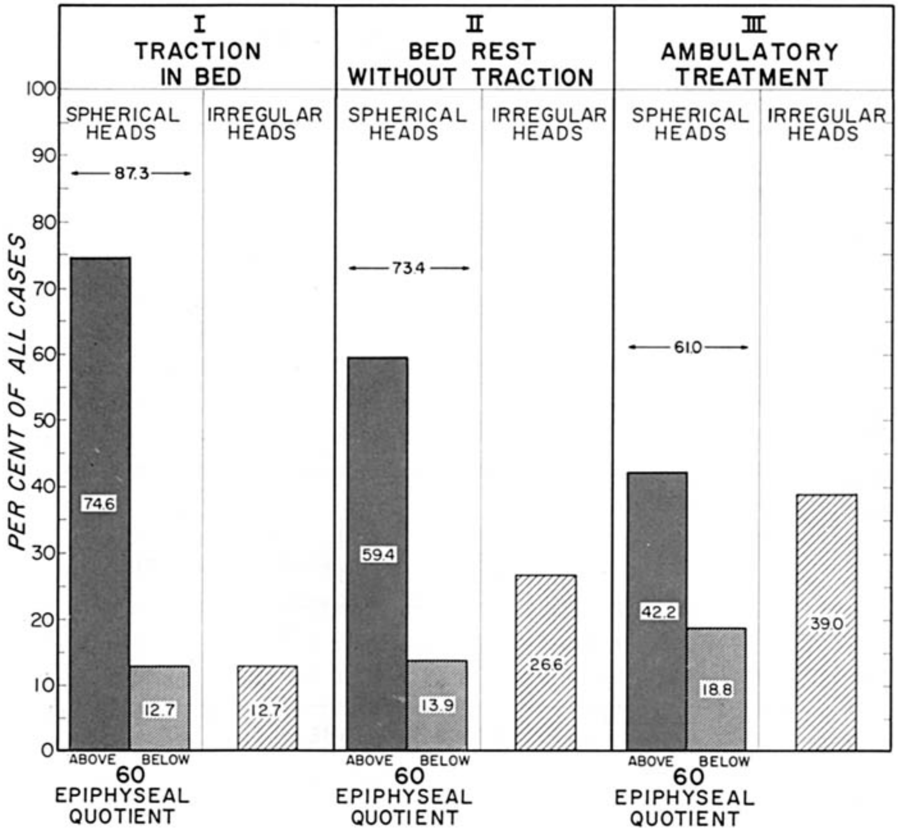


Diagram 8. Distribution of patients with spherical heads and with non-spherical (irregular) heads in series I–II and III and distribution of epiphyseal quotients above and below 60 in patients with spherical heads.

I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
III. Ambulatory treatment (Mose), 64 patients.
(Tables 5[1], 4[1], 6).

which the epiphyseal quotient could not be measured because there had been LCPD in the contralateral hip. Therefore, these 7 patients were excluded, and the series then is reduced from 71 to 64 patients.

The figures plotted on Diagram 7 on a level with epiphyseal quotient 60 represent the number of good results obtained by the application of "Mose's rule".

It is apparent that 75 per cent of the patients in the traction series had an epiphyseal quotient exceeding 60. This also applies to 59 per

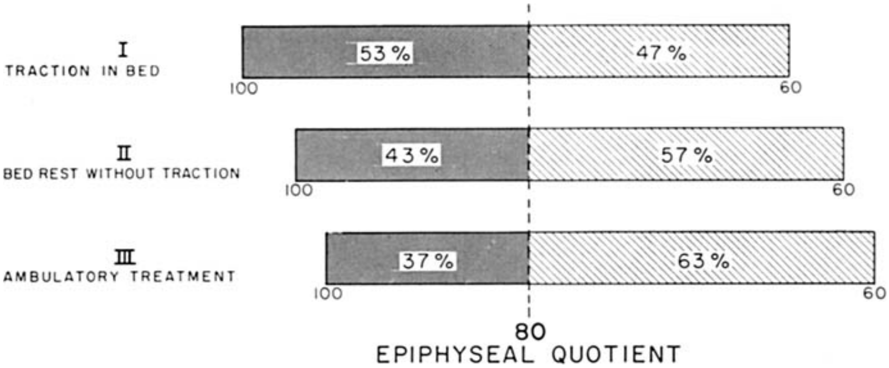


Diagram 9. Distribution of epiphyseal quotients above and below 80 among epiphyseal quotients above 60 in series I, II, and III.

I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
III. Ambulatory treatment (Mose), 64 patients.
(Tables 5¹, 4¹, 6).

cent of the patients in the bed rest series and 42 per cent of those in the ambulatory series. If the bottom limit for good cases is not set at epiphyseal quotient 60, but at 85 (the normal minimum), these figures are 22 per cent, 14 per cent, and 11 per cent respectively.

According to these figures, the epiphyseal flattening is considerably less marked in the traction series than in the bed rest series, and very considerably less marked than in the ambulatory series. This applies not only quantitatively, but also qualitatively—as is clearly evident from Diagram 9 (distribution of epiphyseal quotients exceeding 60).

As the major or minor flattening of the epiphysis may be taken to express the efficacy of treatment, the figures signify that traction is more effective than the other two methods in preventing epiphyseal flattening.

Now, the epiphyseal quotients have been measured in 3 series treated by 3 different methods. It would be of great interest also to measure the epiphyseal quotients in a series in which the patients had received *no treatment* or only *symptomatic treatment,* which according to Helbo does not give better results than "no" treatment.

However, a series of this nature is not available to me, but Helbo has reported one of 70 patients in which he measured the epiphyseal quotients.

The main difficulty of comparing these materials is that Helbo's

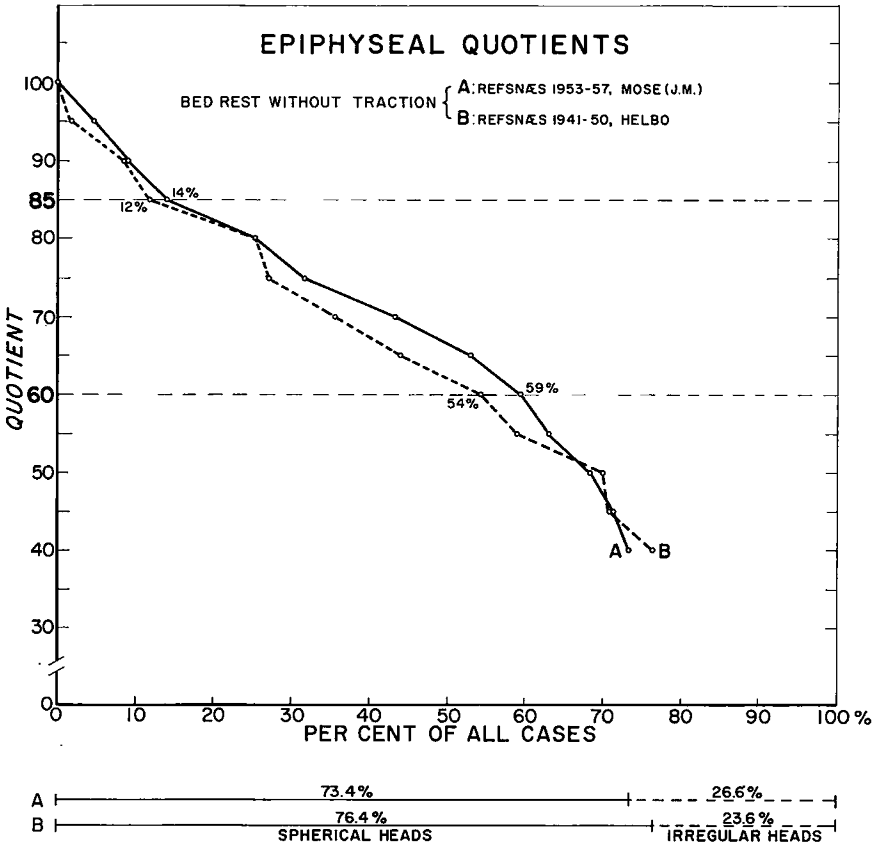


Diagram 10. Epiphyseal quotients in 2 series treated by prolonged bed rest without traction.
A. Refsnæs 1953–57, 79 patients. B. Refsnæs 1941–50, 59 patients. Epiphyseal quotients in A measured by J. M. Epiphyseal quotients in B measured by Helbo. Cf. also legends to Diagram 1. (Tables 4^1, 7).

cannot be divided into patients with spherical and non-spherical heads in the sense used by Mose. Helbo divided his patients into 3 groups according to the capital shape: spherical, greatly flattened, and irregular, but it is impossible to see whether these 3 groups correspond to Mose's good, fair, and poor groups.

Another difficulty is that of course it is impossible to know directly whether Helbo measured his epiphyseal quotients in the same way as Mose and I did in the present 3 series.

Accordingly, the difficulties of comparing Helbo's patients who received no or only symptomatic treatment with our 3 series would appear to be insurmountable.

However, there is a way out: Helbo has also reported on a relatively large series. *i.e.* 59 patients treated in Refsnæs for unilateral LCPD with prolonged bed rest during the period 1941–1950. He divided the patients of this series into the same groups as the untreated patients (patients with spherical, greatly flattened, and irregular heads) and measured the epiphyseal quotients.

When presupposing, *a priori,* that Helbo's concept "spherical" is identical with Mose's "spherical" head and that his epiphyseal quotients were measured as in our series, it would be expected that a curve drawn on the basis of Helbo's epiphyseal quotients in his bed rest series would very closely cover that representing our bed rest series (Diagram 1). It might perhaps be expected to be a little lower, partly because the bed rest in Helbo's material was not quite as prolonged as in ours and partly because the number of children under 4 years of age—among whom the most favourable results are obtained—is smaller in Helbo's series than in ours (14 per cent as compared with 25 per cent).

A look at Diagram 10 and Tables 4 and 7 shows that these expectations are fully confirmed—even strikingly so.

Although there *may be* some question of chance, we may conclude with fair certainty that *Helbo's concept "spherical" is in all essentials identical with Mose's* and that his epiphyseal quotients were measured as in our series.

Now, it is permissible to compare our three series with Helbo's patients who received symptomatic or no treatment.

The results are shown in Diagram 11 on which the curve representing Helbo's patients treated with bed rest is plotted as well, and in Table 8 (age and stage of disease at institution of treatment, cf. Tables 9 and 10). It is apparent that the results are extremely poor when the patients receive only symptomatic or no treatment, also when compared with patients treated by ambulatory relief from weight-bearing. Spherical heads were found in only 19 per cent of untreated patients, while they were found in 61 per cent of those treated with ambulatory relief from weight bearing and in 73 per cent of those treated with bed rest.

This result is so bad, that it cannot but make one sceptical. But when comparing *e.g.* with Sundt's results, we find that in his total series he had only 8 per cent which he designated as "spherical". This figure corresponds quite well to the number of cases in Helbo's series with

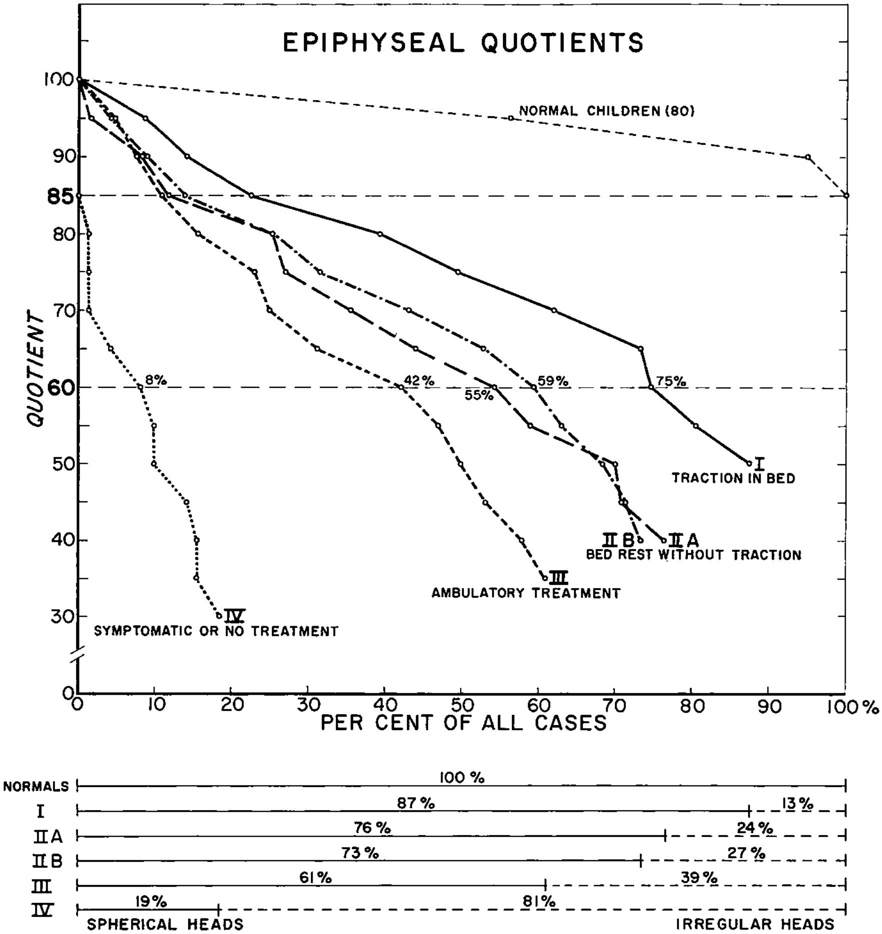


Diagram 11. Epiphyseal quotients *in 5 series treated by 4 different methods.*
I. Traction in bed. Refsnæs 1958–62, 71 patients, measured by J. M.
II. (A) Bed rest without traction. Refsnæs 1941–50, 59 patients, measured by Helbo.
(B) Bed rest without traction. Refsnæs 1953–57, 79 patients, measured by J. M.
III. Ambulatory treatment, 64 patients, measured by Mose.
IV. No or only symptomatic treatment, 70 patients, measured by Helbo.
(Tables 5[1], 7, 4[1], 6, 8).

epiphyseal quotients exceeding 60, *i.e.* corresponding to Mose's "good" group. When calculating the total number of cases designated as "good" in Mose's list (p. 56 in his thesis) compiled from the literature on results obtained without treatment, we find that they make up only 13 per cent of all treated patients. This is in quite good keeping with the

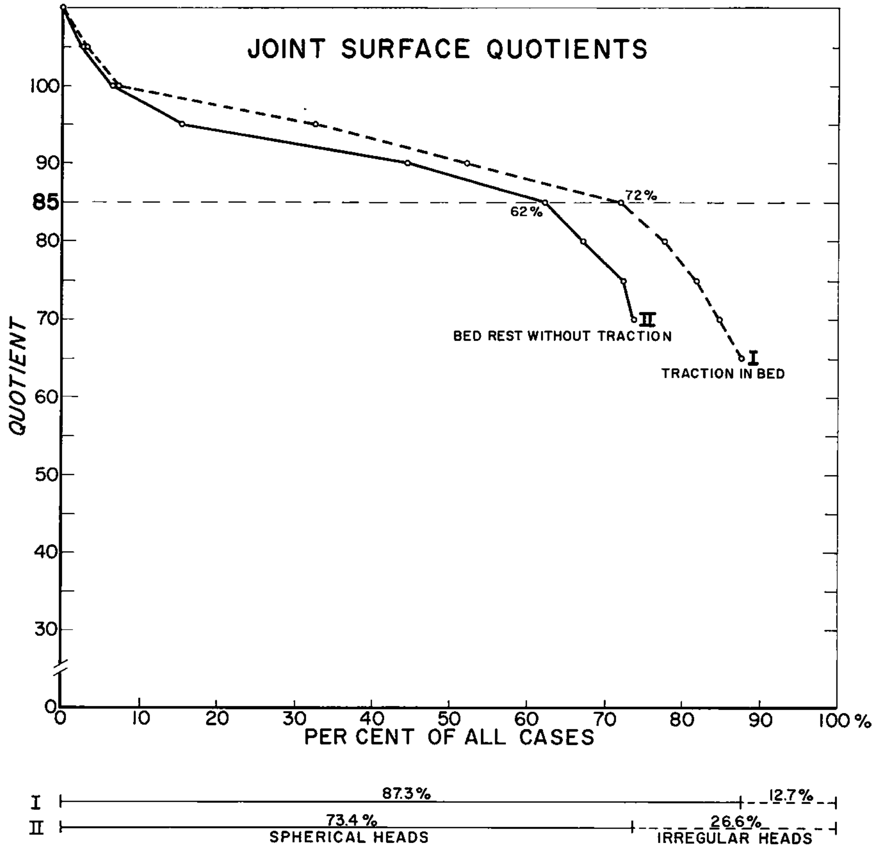


Diagram 12. Joint surface quotients *in series I and II.*
I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
Cf. also legend to Diagram 2. (Tables 5^2, 4^2*).*

number of good results in Helbo's material calculated by the method of Mose, *i.e.* 8 per cent.

A very interesting fact is evident from Diagram 11 as a whole. It shows that the *epiphyseal flattening decreases in proportion to the increasing efficacy of non-weight-bearing*—from symptomatic or no treatment, through ambulatory relief from weight-bearing, bed rest alone, to traction in bed—provided that "ambulatory treatment" affords a less effective relief than bed rest. This must be a very strong argument demonstrating that non-weight-bearing actually does prevent

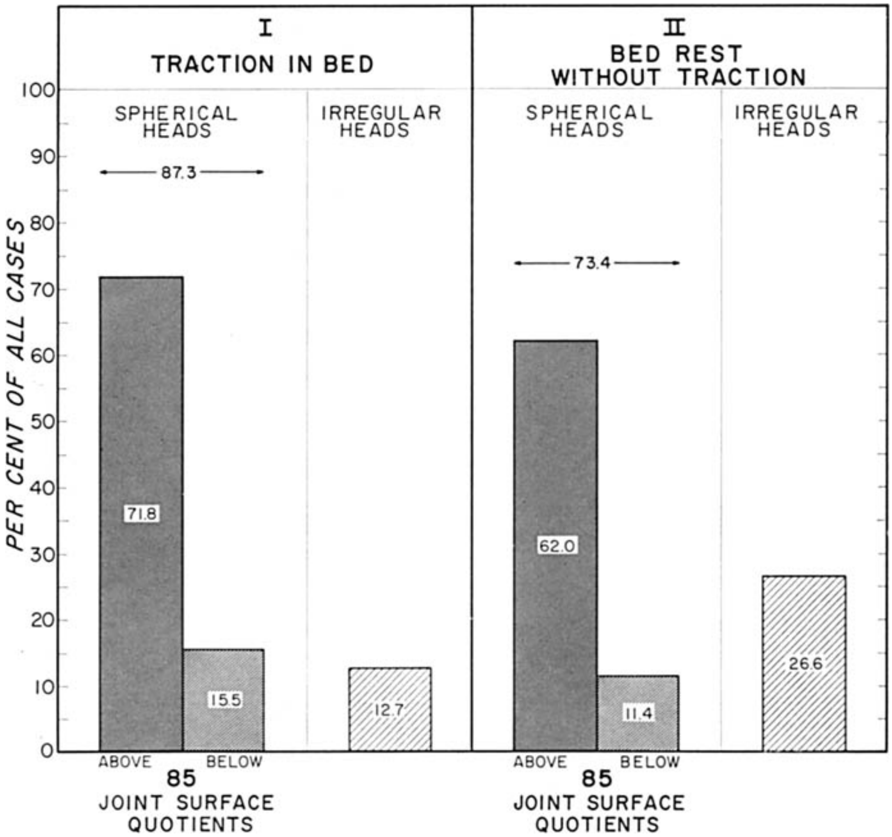


Diagram 13. Survey on patients with spherical and with non-spherical (irregular) heads in series I and II and distribution of joint surface quotients *above and below 85 in patients with spherical heads.*

I. Traction in bed. Refsnæs 1958–62, 71 patients.

II. Bed rest without traction. Refsnæs 1953–57, 79 patients.

(Tables 52, 42).

epiphyseal flattening. What previously was a hypothesis, has now been confirmed by the analysis of concrete case materials.

However, although the measurement of epiphyseal quotients may afford an excellent, relevant measure of epiphyseal flattening during various forms of treatment, it is an unreliable and unsuited basis for assesssing the prognosis.

To obtain prognostic information, we must use methods which measure the *shape of the femoral head* directly. As already mentioned,

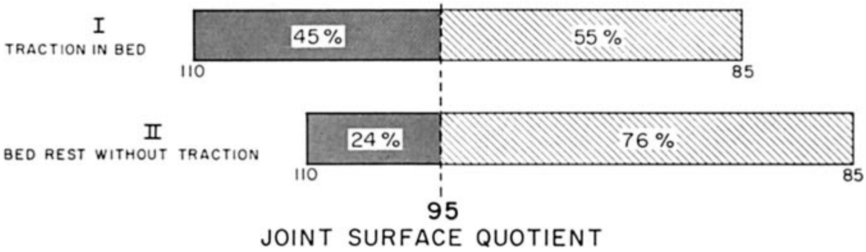


Diagram 14. Distribution of joint surface quotients *above and* below 95 *within the normal range (above 85) in series I and II.*
I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients. (Tables 5[2]*, 4*[2]*).*

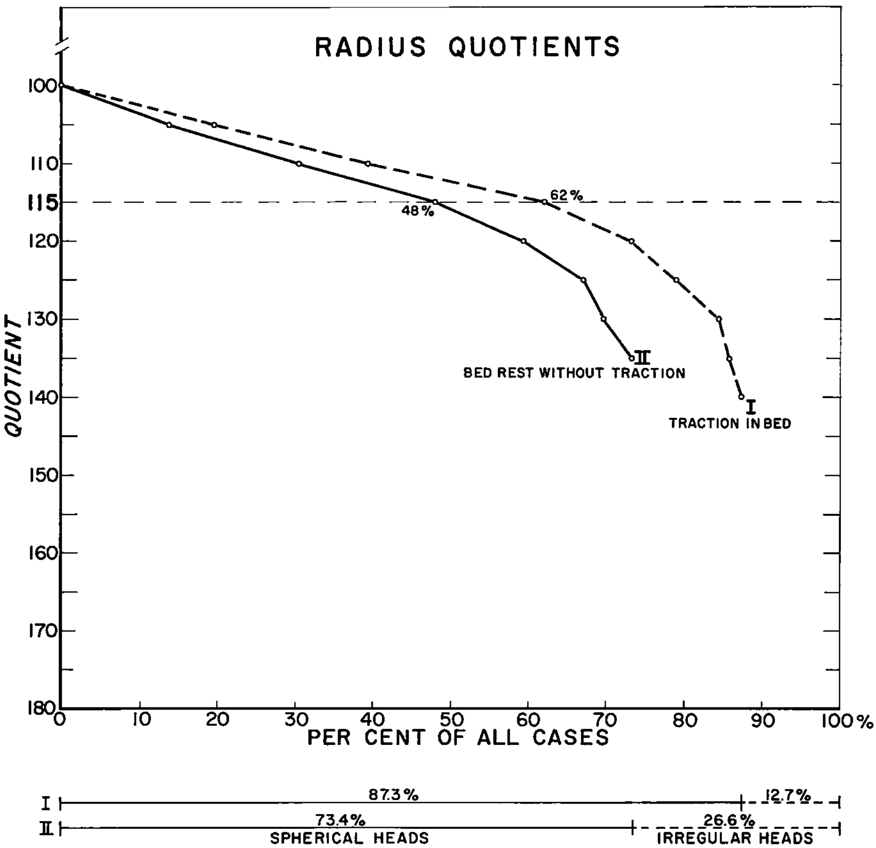


Diagram 15. Radius quotients *in series I and II.*
I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
Cf. also legends to Diagram 5. (Tables 5[3]*, 4*[3]*).*

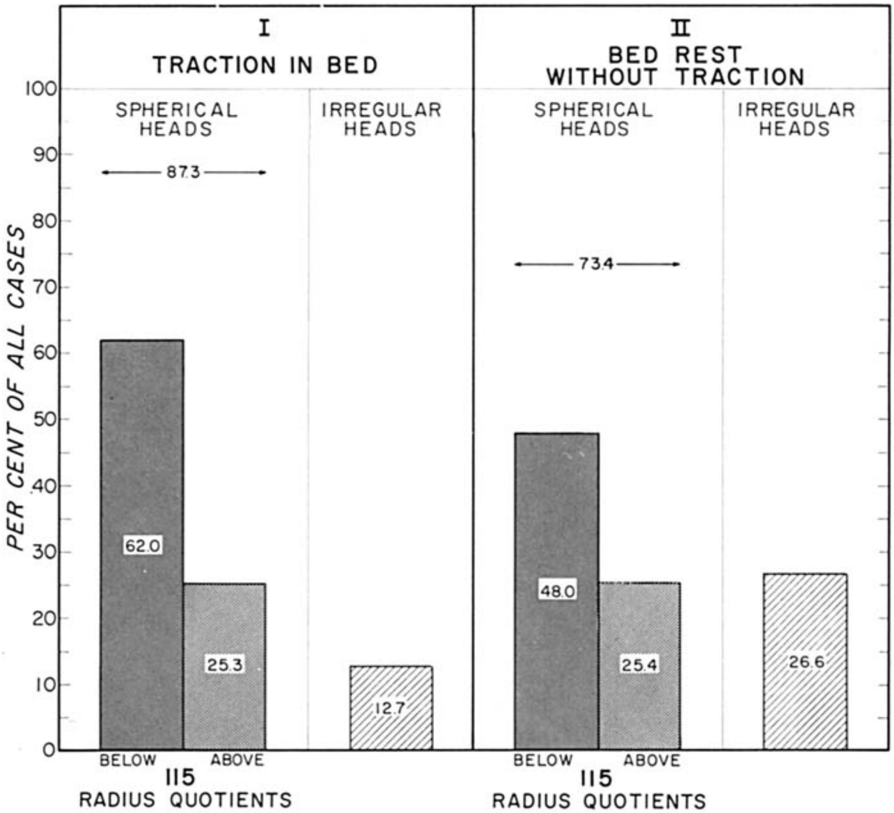


Diagram 16. Distribution of patients with spherical and with non-spherical heads in series I and II and distribution of radius quotients *above and below* 115 *among the patients with spherical heads.*
I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
(Tables 5^3, 4^3*).*

such methods are available, *i.e.* measurement of the joint surface quotient and of the radius quotient.

Diagrams 12, 13, 14, and 15, 16, 17 with appurtenant tables give the results of these measuring methods performed on the traction series and on the bed rest series.

In the traction series 72 per cent of the patients had joint surface quotients within the normal range, in the bed rest series only 62 per cent.

Measurement of the radius quotient showed the corresponding values

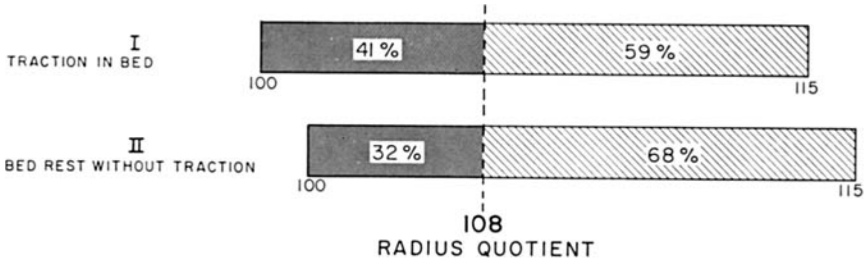


Diagram 17. Distribution of radius quotients *above and below 108 within the normal range (below 115) in series I and II.*
I. Traction in bed. Refsnæs 1958–62, 71 patients.
II. Bed rest without traction. Refsnæs 1953–57, 79 patients.
(Tables 5³, 4³).

to be 62 per cent in the traction series and 48 per cent in the bed rest series.

Thus, both measuring methods revealed the most favourable results in the traction series. This is further accentuated when the distribution of the joint surface quotients and radius quotients within the normal range in the two series is investigated: The result in terms of the joint surface quotient is not only quantitatively, but also qualitatively better after treatment with traction than without (Diagram 14). The same applies to measurement of the radius quotient (Diagram 17).

Thus, not only measurement of the epiphyseal quotient, but also the use of the two methods whose results ought to be of particular prognostic value shows better results in the traction than in the bed rest series.

A collected survey of the results of the measurements in the traction series is given in Diagram 18. The corresponding values for the bed rest series are listed in Diagram 6.

DISCUSSION OF RADIOLOGICAL ASSESSMENT

Table 15, p. 67, gives a survey of the results. It is apparent, primarily, that regardless of which method of assessment is used, the results go on improving with the efficacy of the relief from weight-bearing.

Nowhere does the table show an exception to this rule.

If this general tendency is taken into account—and of course no finding should be left out of consideration—a *statistical calculation* shows that an essential part of the improvements found are statistically

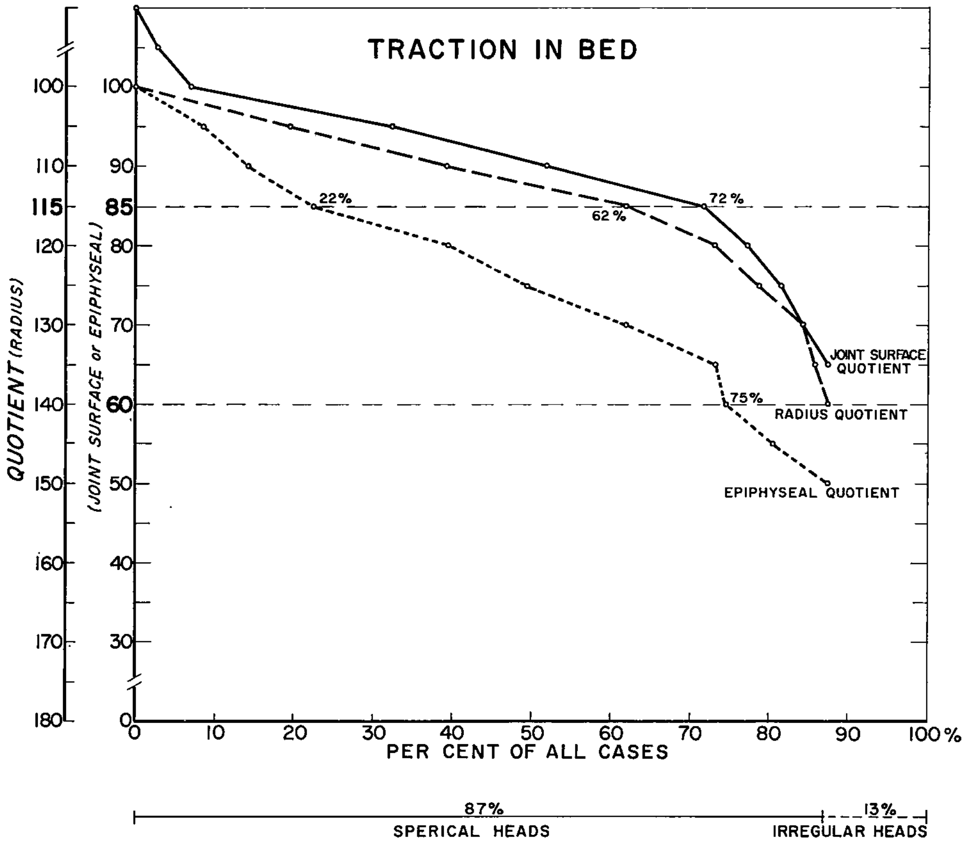


Diagram 18. Epiphyseal quotients, joint surface quotients, *and* radius quotients. *Traction in bed. Refsnæs 1958–62, 71 patients. Cf. Diagram 6. (Table* 5^{1-2-3}*).*

significant. On the other hand, if no regard is paid to the tendency apparent from the table, but it is assumed, *a priori,* that more effective relief from weight-bearing may give poorer as well as better results—which is hardly realistic or reasonable—only a few of the differences are statistically significant (Appendix III).

However, in both forms of statistical calculation—the unilateral test and the bilateral test—the results are influenced by the fact that from a statistical point of view the series are relatively small. Mose encountered the same difficulty, but met it by combining two bed rest series—although the treatment was not entirely identical—and thus obtained a bed rest series of 148 patients. Only by comparing this larger series

Table 15. Results obtained by 4 different methods of treatment. Radiological assessment.

Treatment	Spherical heads	Epiphyseal quotient above 60	Epiphyseal quotient above 85	Radius quotient below 115	Joint surface quotient above 85
	% of all pts.	Mose's rule % of all pts.	Within the normal range % of all pts.		
1. Bed rest with traction (71 pts.)	87	75	22	62	72
2. Bed rest without traction (79 pts.)	73	59	14	48	62
3. Ambulatory relief from weight-bearing (64 pts.)	61	42	11	...	...
4. Symptomatic or no treatment (70 pts.)	19	8	0	...	...

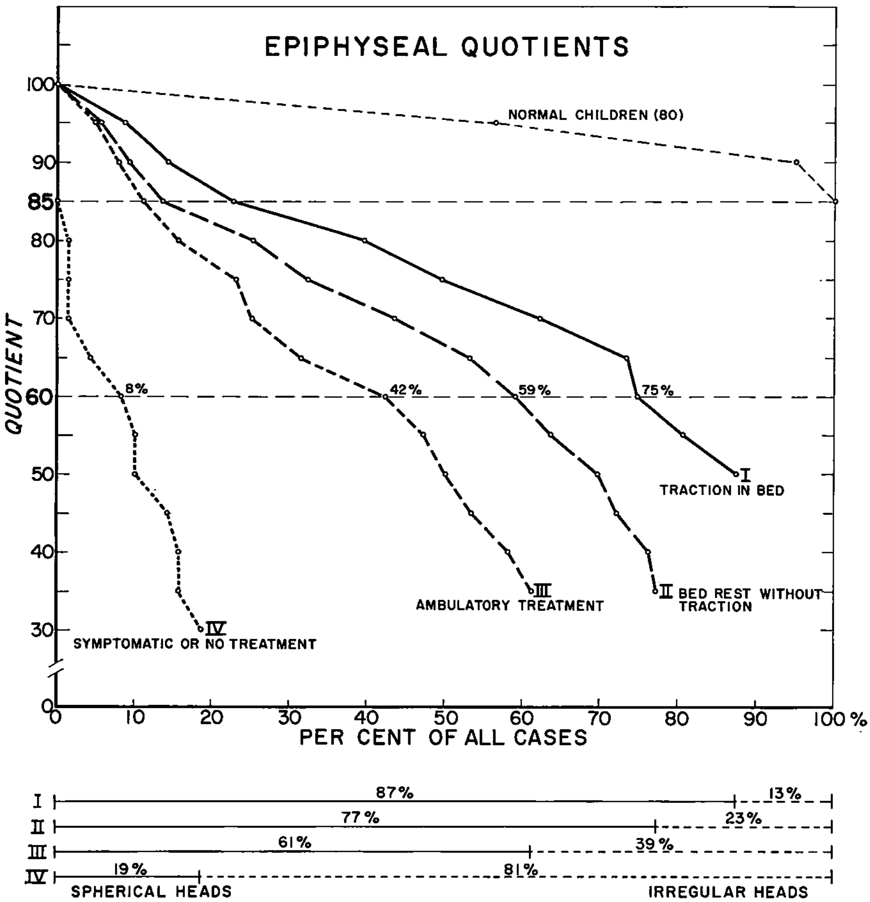


Diagram 19. Epiphyseal quotients *in 6 series treated by 4 different methods (a total of* 413 patients*).*

I. Traction in bed. Refsnæs 1958–62		*71 pts.*
II. Bed rest without traction. Collected series		*208 pts.*
Hornbæk 1953–57 (measured by Mose)	*70 pts.*	
Refsnæs 1953–57 (measured by J.M.)	*79 pts.*	
Refsnæs 1941–50 (measured by Helbo)	*59 pts.*	
III. Ambulatory treatment (measured by Mose)		*64 pts.*
IV. Symptomatic or no treatment (measured by Helbo)		*70 pts.*
Total		*413 pts.*

Cf. Diagram 7. (Table 5[1]*, 11, 6, 8).*

with the ambulatory series did he succeed in demonstrating a statistically significant difference between the results of the two forms of treatment.

I have tried to repeat Mose's procedure—with the difference that our bed rest series is supplemented not only with Mose's series from Hornbæk, but also with Helbo's from Refsnæs, treated during a period immediately preceding that under discussion. This gave a bed rest-treated series of 208 patients in which the result, in terms of the epiphyseal quotient, is practically identical with that in our smaller bed rest series of 79 patient (Diagrams 19 and 20, Table 11).

If the statistical calculations are carried out using this combined bed rest series, the most reasonable way of calculating—the unilateral test—reveals that all improvements in respect to *spherical shape* and *epiphyseal quotient exceeding 60* are statistically significant. Traction is definitely better than bed rest, bed rest better than ambulatory treatment, and ambulatory treatment better than no treatment (Tables 19, 20, 21).

If the "stricter"—but more theoretical, less realistic calculation—the bilateral test is used, the improvements are also statistically significant, only less so and not including the number of patients with spherical heads in the traction series compared with corresponding patients in the bed rest series. If comparison is made with the ambulatory series the improvement is highly significant—also by this way of calculation.

The number of patients with epiphyseal quotients exceeding 85 shows exactly the same tendency as in the other methods of assessment —increasing relief from weight-bearing, better results—but the improvements are not statistically significant by either manner of calculation. The number of patients having epiphyseal quotients in excess of 85 is too small in all the series. A reliable statistical assessment would require a much larger material.

Measurements of the radius quotient and joint surface quotient also records better results with more effective relief from weight-bearing—*i.e.* better *with* than *without* traction—but these differences too are not statistically significant by any form of calculation. In part, the series are too small—and cannot yet be supplemented—and in part the improvements obtained by traction, measured by the radius quotient and joint surface quotient, are in fact on the average less marked than when measured by the epiphyseal quotient (Table 22).

Only a considerable increase in the number of patients treated by

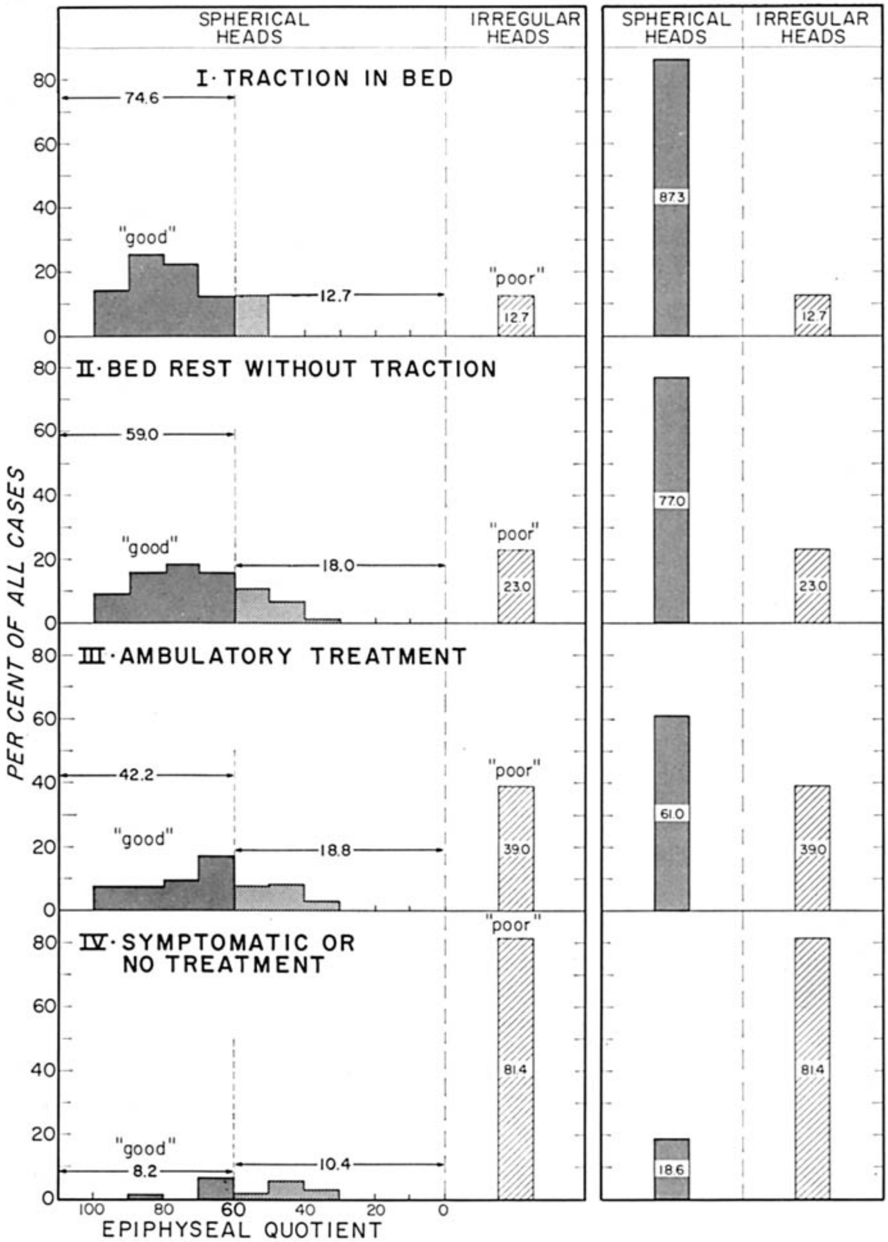


Diagram 20. Distribution of patients with spherical and patients with non-spherical (irregular) heads and distribution of epiphyseal quotients above and below 60 in patients with spherical heads in 6 series (a total of 413 patients) treated by 4 different methods. Cf. legend to Diagram 19. (Tables 51, 11, 6, 8).

traction and measurement of the joint surface quotient and/or radius quotient in a larger number of patients treated with bed rest alone can be hoped to afford a decision as to whether the improvement obtained by traction and measured by the radius quotient and joint surface quotient is statistically significant.

But on the whole, the statistical analysis has demonstrated that the constant improvement in the results after a more effective relief from weight-bearing is in fact statistically significant in such important respects and by so many different methods of assessment, that it cannot be due to chance.

It must be justified to conclude that the favourable effect of a more effective relief from weight-bearing is an established fact.

However, a look at the figures obtained by measuring the epiphyseal quotient and those obtained by measuring the joint surface quotient and the radius quotient discloses two striking differences:

(1) After a given therapeutic method the number of good results—cases within the normal range—is far smaller measured by the epiphyseal quotient than when measured by the radius quotient and in particular by the joint surface quotient (with traction *e.g.* 22 per cent, 62 per cent, 72 per cent). (Table 15, p. 67).

(2) The *improvement* of the therapeutic results with more effective relief from weight-bearing is considerably less pronounced when measured by the radius quotient and joint surface quotient than when measured by the epiphyseal quotient (Table 16).

Table 16. Improvement in per cent obtained by treatment with traction in bed *compared with* bed rest without traction, *calculated at various levels of epiphyseal quotient, radius quotient, and joint surface quoeient.*

Epiphyseal quotient Joint surface quotient	>60	>65	>70	>75	>80	>85	>90
Radius quotient	<140	<135	<130	<125	<120	<115	<110
	%	%	%	%	%	%	%
Improvement measured by:							
Epiphyseal quotient	27	38	44	53	56	57	55
Radius quotient	19	17	21	18	22	29	39
Joint surface quotient	19	19	15	14	15	16	18

The explanation of the former difference has been mentioned several times above in discussing the advantages and disadvantages of measuring the epiphyseal quotient and the joint surface quotient (radius quotient)—but perhaps it should be briefly summed up:

The epiphyseal quotient is a measure of epiphyseal flattening. Epiphyseal flattening is considerable in all forms of treatment, and it is only in a few cases that the measurements can be kept within the normal range.

Epiphyseal flattening is counteracted by the compensatory growth processes in the femoral head which often succeed, despite considerable epiphyseal flattening, in keeping the shape of the head within the range of normal.

As the joint surface quotient and the radius quotient measure the shape of the head, the great majority of cases measured by these methods will be within the normal range.

The *latter phenomenon* has not been discussed before.

That improvements obtained by a more effective relief from weight-bearing are more marked measured by the epiphyseal quotient than by the joint surface and radius quotient is apparent from Table 16, (p. 71) and Diagram 21 which show that the curves representing the joint surface quotients in the two series in which these quotients were measured are far closer than the corresponding curves representing epiphyseal quotients. The same applies to the curves representing the radius quotients.

The explanation is to be found in the same factors which made the epiphyseal quotients after the same treatment record far more pronounced deviations from normal than the joint surface quotients and radius quotients:

If a less effective treatment is instituted, this is immediately reflected in the epiphyseal quotients, epiphyseal flattening being increased, while the joint surface quotient and the radius quotient show little reaction, as the compensatory processes included in these two measurements set in and counteract the flattening.

Reversely: When changing to better treatment the epiphyseal flattening will immediately be diminished and the epiphyseal quotient consequently improved—in some cases considerably. If the compensatory processes during the inferior form of treatment have been very effective, there will be only little improvement in the shape of the head —and thereby in the joint surface and radius quotients—possibly none, only diminished flattening of the epiphysis.

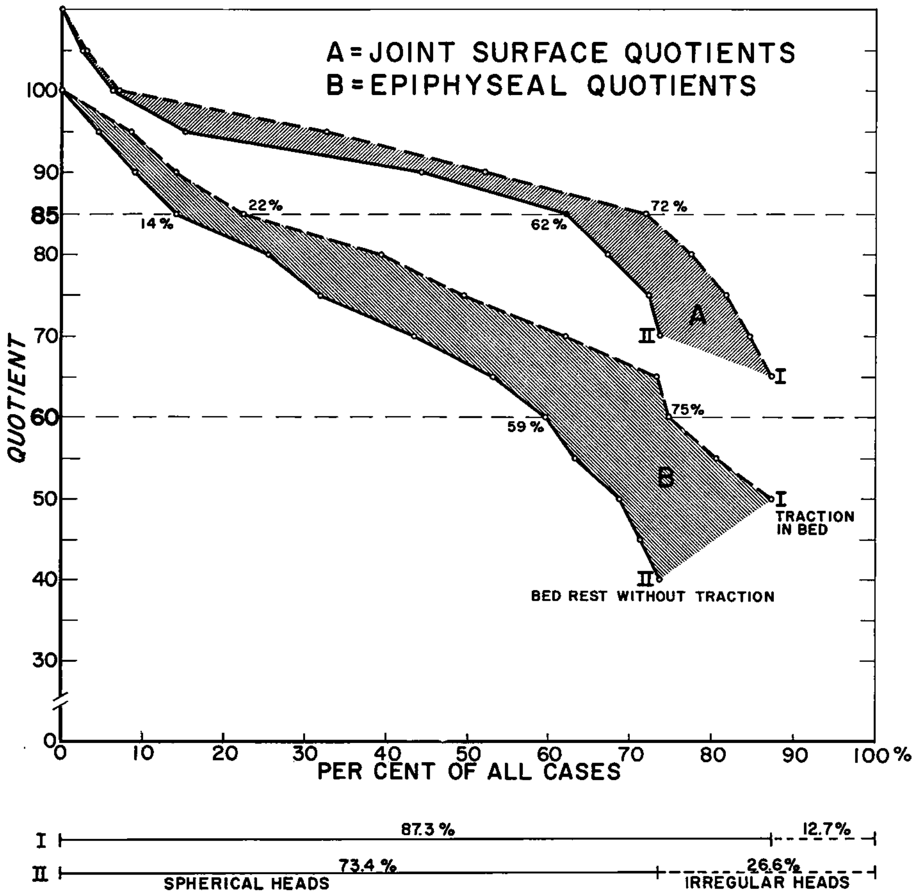


Diagram 21. The improvement in the therapeutic result obtained by traction in bed compared with bed rest without traction is greater measured by the epiphyseal quotient *(lower shaded area) than measured by the* joint surface quotient *(upper shaded area). (Cf. Table 16).*

I. Traction in bed. Refsnæs 1958–62, 71 patients.

II. Bed rest without traction. Refsnæs 1953–57, 79 patients.

(Tables 5^2, 4^2, 5^1, 4^1).

In brief: The compensatory processes act as a regulator on the reaction of the joint surface quotient and radius quotient, while the epiphyseal quotient fluctuates unimpeded, in step with the epiphyseal flattening.

Therefore, it is easy to understand that we found less marked differences in joint surface and radius quotients than in the epiphyseal quotients when the treatment improved.

These calculations—and the curves on Diagram 21—are to some extent influenced by the fact that the number of cases with spherical heads increases with the use of traction. This influence may be eliminated by fixing the number of spherical heads as 100 per cent in both series.

It turned out that this did not alter the conclusion.

We have now analysed what can be elucidated by a radiological assessment of the results obtained by various therapeutic methods.

The most important finding is that the *radiological results improve with increasing efficacy of the relief from weight-bearing.* This rule applies without exception to all methods of assessment and all methods of treatment (Table 15, p. 67). The best results are obtained by treatment with traction in bed.

When the evaluation is based upon the number of spherical heads and epiphyseal quotients exceeding 60, the improvements are statistically significant throughout.

When the assessment is based upon the figures representing epiphyseal quotients, joint surface quotients, and radius quotients exceeding 85 the improvements are not statistically significant. In the first place, the number of patients having epiphyseal quotients in excess of 85 and the series measured by the radius quotient and joint surface quotient are too small. In the second place, the differences measured by the joint surface quotient and radius quotient are in actual fact smaller than those measured by the epiphyseal quotient.

The latter is not merely of theoretical interest, but of great importance in any prognostic discussion. The fact is that judging by all findings the prognosis depends upon the shape of the femoral head—and this is what is measured by the joint surface quotient and the radius quotient. Therefore, the finding that improvements in the therapeutic results are less marked when measured by the joint surface quotient and radius quotient than by the epiphyseal quotient means that *from a prognostic point of view the improvement is less marked than indicated by the measurement of the epiphyseal quotient.* The epiphyseal quotient is an expression of the efficacy of the treatment in preventing epiphyseal flattening, not of the prognosis.

The ultimate question is then which of the two methods of assessment—the radius quotient, which measures the shape and size of the head, or the joint surface quotient, which only measures the shape—is more relevant in assessing the prognosis. According to my estimate it is the joint surface quotient, as the size of the head is presumably of less prognostic importance.

On the basis of the joint surface quotients, 72 per cent of the cases treated with traction have a favourable prognosis—as compared with 62 per cent after treatment by bed rest alone.

Thus, the measurement of the joint surface quotient sorts off the cases which have a *good* prognosis. By dividing the material into cases with spherical and with non-spherical heads, it is possible to sort off cases with a *poor* prognosis—*i.e.* cases with irregular heads. Of course, this can also form the basis of a prognostic assessment. After treatment with traction 13 per cent of the patients will have irregular heads—and therefore a poor prognosis—as compared with 27 per cent after treatment with bed rest alone, 39 per cent after ambulatory treatment, and 81 per cent when no treatment is instituted. The two forms of radiological assessment supplement each other. Both afford information of interest—but in general most interest is taken in the number of successful results.

However, all these prognostic predictions are mere hypotheses based on a radiological assessment.

In the last chapter it will be endeavoured to establish the actual relation between the radiological assessment and the clinical course of the disease—*i.e.* the symptoms and signs at the time of primary healing and the prognosis at longer sight.

Clinical Assessment of the Various Forms of Treatment

In this section the word *symptoms,* which will be encountered over and over again, is used as a designation of *all* forms of clinical manifestations—subjective as well as objective.

Subjective, clinical manifestations will be called *subjective symptoms,* meaning all complaints, regardless of whether or not an objective basis is demonstrable.

Objective clinical manifestations will be called *objective signs,* meaning all divergences from normal which are—or can be—demonstrated by physical examination.

The result of an investigation of the frequency of symptoms in a group of patients depends of course entirely upon the examiner's energy and interest in the matter.

At the time of primary healing of LCPD the patients are usually children in the age range 6–10 years. In such patients the subjective symptoms are very few and as a rule they can only be disclosed by interviews with the parents—who are not always good observers (or listeners!). On the other hand, an efficient and experienced examiner can nearly always find objective signs of past disease. As a rule, such signs are not outstanding, but they are present in almost 100 per cent of the cases.

It is evident, therefore, that analyses of the frequency of symptoms after the course of a LCPD will give extremely different results when done by different persons. Accordingly, statements in the literature should be regarded with criticism.

Helbo states that 26 per cent of his patients who were treated with bed rest had "symptoms" at the time of primary healing. An attempt was also made to assess our bed rest series for "symptoms" at this juncture. We found the rate to be 57 per cent. The majority of these symptoms were very modest—an explanation of the general opinion that LCPD heals *without* symptoms. Since presumably there is not a real difference between Helbo's series and ours, the discrepancy between the two rates merely means a difference of opionion as to what is interpretable as symptoms. Presumably, it is merely that our "symptoms" comprise a larger number of mild objective signs than Helbo's "symptoms", *e.g.* limited motion, which can be demonstrated only by a detailed examination, and slight shortening.

But although a discrepancy between the statements of different authors concerning the frequency of symptoms is rather illusory, comparison between the number of symptoms found by *one* examiner after various forms of treatment and in various radiological types may perhaps be of value.

For instance, *Helbo* found that among the patients who had received no or only symptomatic treatment about 75 per cent had "symptoms" at the time of primary healing, while this applied to only 26 per cent of the patients who had been treated with bed rest without traction.

We found "symptoms" in 57 per cent of the patients treated with bed rest and in 52 per cent of the patients treated with bed rest and traction. Subjective symptoms were found in 22 per cent after bed rest without traction and in 13 per cent after bed rest with traction.

In other words, after bed rest without traction our incidence of *subjective* symptoms corresponds on the whole to Helbo's "symptoms" (22 per cent and 26 per cent), but too much emphasis should not be laid on this accordance. The most important thing is that Helbo found a considerable difference between no or symptomatic treatment on the one hand and bed rest without traction on the other and that between bed rest without and with traction we found a less marked difference —but yet quite pronounced as far as subjective symptoms are concerned.

Now, if our series (bed rest with and without traction) are investigated for the relation of symptoms to the radiological appearance of the femoral head, we find that—as might perhaps be expected—the symptoms are not present exclusively in the cases with the most deformed heads, but are distributed over *all groups*.

The incidence of symptoms in the presence of irregular heads is 77 per cent, in the presence of spherical heads 50 per cent. The percentages are identical in both series, indicating that both the irregular and the spherical heads exhibited about the same deformity in both series. The difference: 77 per cent and 50 per cent (subjective 37 per cent and 11 per cent) is, if anything, less marked than expected, and it should be noticed that more than 20 per cent of the irregular heads did not give rise to any symptoms at all.

When dividing the spherical heads into two groups (good and not so good) some of the groups will be so small as to give room for chance variations:

Out of the patients with *joint surface quotients* exceeding 85, 47 per cent of both series had symptoms, but out of the patients whose joint surface quotients were below 85, 66 per cent of the bed rest series (6/9) and 54 per cent of the traction series had symptoms. Of course, this last-mentioned variation may be due to pure chance.

On the whole, the figures show simply that patients with more deformed heads have symptoms oftener than patients with more well-shaped heads. This is no cause for wonder, but perhaps it is useful to submit a numerical support.

If the patients with spherical heads are divided by *epiphyseal quotient,* as done by Mose, it is difficult to find any regularity. After treatment with traction there is an equal number of patients with symptoms in the groups having epiphyseal quotients above and below 60, and the "better" group includes a larger number of patients with subjective symptoms. This lack of regularity upon measuring the epiphyseal quotient may be due, among other things, to the epiphyseal quotient being an unreliable criterion of capital shape.

Thus, our investigations concerning "symptoms" *at the time of primary healing* have shown, in the first place, that symptoms are less common after traction in bed than after bed rest alone. This applies particularly to the subjective symptoms: 13 per cent and 22 per cent—but the difference is not pronounced.

In the second place, the symptoms are found to be present in *all* radiological groups, but are most common in the most deformed femoral heads (77 per cent), least common in the best radiological groups (45–47 per cent).

However, practically all the named symptoms are very slight.

A more serious matter is the prospect of developing *secondary osteoarthritis* at a relatively early age.

How common is such osteoarthritis and at what age does it set in?

It was mentioned above that Helbo performed a follow-up examination on 47 untreated or symptomatically treated patients 25 or more years after the onset of the disease. His object was to establish the incidence of osteoarthritis, or of hip symptoms due to other reasons, among the patients.

Helbo considered the following to be manifestations of osteoarthritis: (1) *radiological signs:* narrowing of the joint space, sclerosis of the bony tissue on the edges of the joint surface—in some cases with osteophytes —and subchondral cysts; (2) *clinical symptoms:* joint pain—often intermittent depending upon changes in the weather and upon starting to move—a sensation of stiffness and limited mobility in the hip joint.

Signs of osteoarthritis were found in 68 per cent (32/47) of the patients.

Two-thirds of these patients presented radiological as well as clinical evidence of osteoarthritis.

One-third had only clinical symptoms, while no radiological evidence could be found. Such a "clinical osteoarthritis" was diagnosed by Helbo when hip symptoms appeared after a symptom free period of several years or in the event of *exacerbation* of symptoms which had been constantly present since the time of primary healing, as an evidence of the deformity left by the disease. It is a matter of discussion whether such clinical phenomena actually do represent incipient osteoarthritis—but this is Helbo's opinion and the basis of his figures.

In a similar series (63 patients) examined after the same follow-up period, *Sundt* found evidence of osteoarthritis in *63* per cent. Considering that this series can hardly have been of exactly the same nature as Helbo's and considering the uncertain definition of the syndrome osteoarthritis, the conformity with Helbo's figures (69 per cent) appears surprising.

In addition to the named patients with osteoarthritis Helbo found a smaller number (6) who had had constant, mild symptoms right from the time of primary healing, but in whom evidence of osteoarthritis had not developed.

A total of 81 per cent (38/47) of the followed patients had hip symptoms—with or without osteoarthritis. In this connection—and in all prognostications deduced from this study—the word symptoms should be interpreted in the sense that Helbo used it, *i.e.* pain, restricted mobility—mainly when noticed by the patient himself—and a limp.

All Helbo's 47 patients had been X-rayed at the time of primary healing, and he therefore could relate the symptoms found at follow-up to the radiological appearances at the time of primary healing. He discovered that all the patients who had hip symptoms at follow-up belonged to the groups which primarily had healed with what Helbo calls "greatly flattened" and "irregular" femoral heads corresponding to our "irregular heads". Out of the total patients of these two groups 76 per cent showed evidence of secondary osteoarthritis and a total of 90 per cent symptoms—with and without osteoarthritis. All the patients whose disease had healed with a "spherical head" had remained symptom free.

Now, an attempt will be made to utilize this result of Helbo's follow-up study for assessing the prognosis in the 4 treatment series which in the present study were analysed at the time of primary healing.

First, it must be realized that the follow-up series is of a *special nature:*

In the first place, it contains only a very few cases which primarily healed with "spherical heads"—not more than 5! The study therefore goes to show mainly the fate of cases healing with "greatly flattened and irregular" heads. Helbo's conclusion that cases healing with "spherical heads" will remain symptom free can only be taken with reserve. We have seen that several of our cases with spherical heads corresponding to Helbo's had symptoms already at the time of primary healing. It is not likely that all these patients will prove to be symptom free at the end of 25 or more years. And the longer the follow-up period the larger the number of cases that develop osteoarthritis in the presence of such slightly deformed femoral heads.

Second, the patients of the follow-up series had not received sufficient treatment. If the incidence of osteoarthritis and of symptoms from the radiological groups of this series is to be transferred to the corresponding groups of more effectively treated series, it is important to be sure that the radiological groups of the various series are in fact of the same nature—*i.e.* of the same "severity". Helbo's cases with "greatly flattened" and "irregular" heads proved to correspond—as already mentioned—to our cases with irregular heads. But in the more effectively treated series—the bed rest series and the traction series—the cases which healed with irregular heads are not only fewer, but the heads are presumably also *less irregular* than in an untreated series.

Thus, the use of the figures from Helbo's follow-up study on a series with *many* spherical and *few* moderately irregular heads, involves the *risk of 2 forms of erroneous assessment.* On the one hand, the large group which has healed with spherical heads will be assessed too favourably; no doubt, there will be some cases of late symptoms and osteoarthritis in this group too. On the other hand, the assessment of the prognosis of cases with irregular heads will be too pessimistic. Late symptoms and osteoarthritis will presumably be more rare in this group than in an untreated series.

It is difficult to say which of the two erroneous assessments is of more significance. I incline to the belief that the prognosis is assessed *too favourably*—at least after a long follow-up period—when Helbo's figures are used in series consisting mainly of cases which have healed with spherical heads. But this is of course doubtful. Perhaps, the two erroneous assessments eliminate each other when the follow-up period is relatively short as in Helbo's series (*vide infra*).

At any rate we do not at present possess a better guide than Helbo's figures.

When applied to our 4 treatment series they give the following results:

Table 17. Long-term prognosis after 4 methods of treatment.

Treatment	No. of pts.	Expected osteoarthritis	Expected late symptoms (with and without osteoarthritis)
		according to Helbo's follow-up study	
		%	%
Bed rest with traction	71	10	12
Bed rest without traction	79	20	24
Ambulatory relief from weight-bearing	64	30	35
No or only symptomatic treatment	70	62	73

Thus, the risk of osteoarthritis is reduced to two-thirds on transition from ambulatory relief from weight-bearing to bed rest without traction. From the latter to bed rest with traction the risk is reduced to one-half.

These cases of osteoarthritis must be expected to occur at an early age. At follow-up Helbo's patients were in the age range of approx.

30–50 years, and the osteoarthritis had appeared at approx. 20–40 years of age.

It must be added, however, that 30–50 years is a very early age for analysing the *final* number of cases of osteoarthritis. If Helbo's patients are after-examined 50 years or longer after the onset of the disease, *i.e.* at an age of 60 or over, a considerably larger proportion will show signs of osteoarthritis. However, it must then be realized that at this age osteoarthritis may also be present in persons whose history is negative for hip disease.

The figures representing the clinical prognosis in Table 17, p. 81, then, carry some uncertainty, partly owing to the special nature of Helbo's follow-up series and partly because they apply only to the prognosis up to the age of 30–50.

A more reliable assessment of the prognosis, in more effectively treated series, presupposes a follow-up on a treated series in which a large proportion of the cases have healed primarily with spherical heads—and preferably the follow-up period should be longer than Helbo's.

However, this cannot be done in this country until a late follow-up on Helbo's patients, treated with bed rest in 1940–50, is possible—*i.e.* some time towards the end of the century.

Concluding Discussion on the Radiological and Clinical Assessment

Now, a "radiological assessment" of 4 methods of treatment has been rendered. This is taken to mean a description of the radiological appearances at the time of primary healing and, on this basis, a long-term prognosis which is of course hypothetical.

Thereafter, it was attempted to perform a "clinical assessment", comprising a description of the symptoms at primary healing. Moreover, it has been attempted to ascertain—by means of a reported late clinical follow-up—whether the tentative prognosis set up merely on the basis of the radiological appearances is in fact in keeping with reality.

It may be said that the "radiological assessment" is not merely radiological and that the "clinical assessment" presupposes a radiological evaluation—but the two designations sum up the essentials of the two modes of assessment and are, thus, expedient for descriptive purposes.

Now, the results of the radiological and clinical assessment will be recapitulated and discussed.

A collected survey is given in Table 18, p. 84.

A number of radiological measurements were carried out at the time of primary healing. These measurements were supplemented by measurements performed by Mose and Helbo—checked by J. M.—so that a good survey of the radiological results of the 4 methods of treatment is obtained.

Any radiological assessment must start with dividing the series into cases with *spherical* and cases with *non-spherical* (irregular) heads—the first rough sorting by capital shape. The application of "Mose's plate" makes this sorting very reliable.

As the shape of the head decides the prognosis, the results of this

Table 18. Total result—4 methods of treatment.

Method of treatment	No. of treated pts.	Radiological assessment at time of primary healing				Clinical assessment. Expected clinical condition after a follow-up period of at least 25 years		
		Practically normal heads		Spherical heads	Non-spherical heads	expected osteo-arthritis	expected symptoms (osteo-arthr. and not osteo-arthr.)	expected number of symptom free pts.
		Mose epiph. quot.* >60	J.M. joint surf. quot. >85			according to Helbo's follow-up study		
		%	%	%	%	%	%	%
I. Traction in bed	71	75	72	87	13	10	12	88
II. Bed rest without traction	79	59	62	73	27	20	24	76
III. Ambulatory relief from weight-bearing	64	42		61	39	30	35	65
IV. No or symptomatic treatment	70	8		19	81	62	73	27

% signifies % of treated patients in the series concerned.

* criticism of the epiphyseal quotient as an expression of capital shape, cf. p. 40 ff.

division is of significance in assessing the prognosis: Cases healing with irregular heads are sure to have a *poor* prognosis, cases with spherical heads a better prognosis, but prognostically they make up a far more mixed group. As they occur in large numbers after one of the more effective methods of treatment, this group requires a closer analysis.

This can be done, firstly by measuring the *joint surface quotient* which is a direct expression of capital shape. This measuring method too is, then, of importance in assessing the prognosis, mainly as it makes it possible to pick out a group of cases having a *definitely favourable* prognosis, viz. cases which have healed with a femoral head whose shape is within the range of normal.

The group of cases with spherical heads may also be assessed by measurement of the *radius quotient*. This quotient is directly proportional to the size as well as the shape of the head. Therefore, it presumably gives too pessimistic a basis for assessing the prognosis: The size of the head is not of as much prognostic importance as its shape.

Measurement of the *epiphyseal quotient* does not afford an expression of the shape of the femoral head, but of the shape of the epiphysis. Accordingly, the results of this measurement are not suited for prognostic assessment. On the other hand, they afford an excellent, sensitive indicator of the ability of treatment to prevent epiphyseal flattening.

Application of these radiological measuring methods to the result of 4 different therapeutic methods gives a number of figures representing the number of cases having a *favourable and a poor prognosis* and the number of cases with *flattened and less flattened epiphyses*. The significance of these figures is radiologically well-defined, and they represent the results of measurements which can be performed with considerable accuracy. But whether the percentages for a good and for a poor prognosis found by these measurements actually do indicate the long-term clinical prognosis after the various therapeutic methods is a question which cannot be answered just so. But anyway, together with the results of measuring the epiphyseal quotient, they no doubt form a reliable basis for assessing the *relative* efficacy of the various methods of treatment.

The four methods of treatment are:

I. Relief from weight-bearing by bed rest with traction.
II. Relief from weight-bearing by bed rest without traction.

III. Ambulatory relief from weight-bearing.
IV. No or only symptomatic treatment.

The efficacy of the relief from weight-bearing increases from treatment IV to treatment I.

The radiological measurements revealed that the values which were to indicate the prognosis improved considerably the more effective the relief from weight-bearing had been:

The number of *spherical heads* is about *4* times larger after traction than after treatment without relief from weight-bearing (all differences in the number of spherical heads are statistically significant).

The number of cases with practically normal heads, found by measuring the *joint surface quotient,* could regrettably not be established for all 4 therapeutic methods, but only following treatments I and II. This is the more unfortunate as measurement of the joint surface quotient is the only method which affords information concerning the number of cases having a definitely good prognosis. Grouping into cases with spherical and with non-spherical heads affords information, primarily, about the number of cases having a *poor* prognosis. The two measuring methods whose results influence the prognostic assessment give information concerning different aspects of the prognosis and must be said to supplement each other.

The number of cases with practically normal heads, determined by measuring the joint surface quotient, is 16 per cent larger after treatment with traction than after treatment with bed rest without traction. The number of spherical heads is 19 per cent larger. (The latter difference is statistically significant).

When looking at the result of measuring the *epiphyseal quotient,* which expresses the ability of the treatment to prevent epiphyseal flattening, we find the improvement with increasing relief from weight-bearing to be greater still than indicated by the values supposed to represent the prognosis. The group of least flattened epiphyses (epiphyseal quotient > 60) is about 10 times larger after treatment with traction (I) than after treatment without relief from weight-bearing (IV). This indicates that—as expected—the epiphyseal quotient is not a measure of the prognosis, but merely of the therapeutic effect upon the epiphysis.

Thus, the radiological assessment has shown, without leaving any room for doubt, that the efficacy of the treatment increases with increasing relief from weight-bearing: Treatment by relief from weight-bearing is better than treatment without relief from weight-bearing. Relief from weight-bearing by bed rest without traction is better than ambulatory relief from weight-bearing, and relief from weight-bearing by bed rest with traction is the best method.

As already mentioned, this simple conclusion concerning the relative efficacy of the therapeutic methods may, in my opinion, be drawn with great certainty. It is based on objective, simple radiological measurements, and is independent of inaccurate, disputable clinical definitions of "good" and "poor" results.

However, it concerns only the *relative* value of the methods. It does not say anything about the validity of the actual prognosis set up for each treatment series on the basis of the radiological assessment at the time of primary healing.

The problem was then: Are these absolute percentages, found for the number of cases having a favourable prognosis, in accordance with the actual clinical course after the various methods of treatment?

In an endeavour to answer this question, it was tried, by means of a late clinical follow-up conducted by Helbo, to establish the clinical prognosis for the radiological types described in the present paper. This was hoped to confirm the prognoses set up exclusively on a radiological basis.

In other words, it was attempted to check the radiological assessment clinically.

The report on this analysis may be restricted to the prognosis following treatment with traction in bed. The relation to the other forms of treatment is apparent from what has been stated above.

The following findings were made:

In the radiological assessment it was estimated that after treatment with traction *72 per cent* of the patients had a good prognosis.

The radiological criterion of a good prognosis was that measurement of the *joint surface quotient* showed the shape of the femoral head to be within the range of normal. If this criterion is observed, one need not, at least, fear that the prognostic assessment will be too favourable. On the contrary, it is probable that a number of patients with capital shapes which differ definitely—but only to a slight extent—from normal will also prove to be symptom free, even at a late follow-up examination.

Thus, the 72 per cent represent a minimum value.

At the clinical assessment, it was found that *88 per cent* of the patients treated with traction would presumably remain symptom free.

But the basis of the clinical assessment was Helbo's follow-up on a series of a nature entirely different from that which would be available after treatment with traction. It has been stated that if conclusions drawn on the basis of this follow-up study are used for assessing the prognosis following treatment with traction, there will be *two sources of error.* In part, the large number of cases healing with spherical heads after traction will be assessed too favourably, and in part the prognosis for cases with irregular heads will be assessed too pessimistically.

These sources of error involve an uncertainty in assessing the prognosis following treatment with traction, but possibly the two sources of error will eliminate each other.

But one thing is beyond doubt: Helbo's follow-up study was conducted when the patients were 30–50 years of age. This mere fact makes his conclusions concerning osteoarthritis *too optimistic,* not only in respect to the final result in his own series, but especially when his figures are transferred to a series of patients treated with traction. Osteoarthritis does not develop until a late date in the large number of patients with slightly deformed heads found after this form of treatment.

Thus, the clinical assessment of the prognosis following traction is presumably too optimistic. To remain on the safe side, we must stick to the 72 per cent good results found by the radiological assessment.

Presumably, the truth lies somewhere between 72 per cent and 88 per cent.

The object of a future study, then, must be to *approach these two figures to each other, i.e.* to obtain greater accuracy in assessing the clinical long-term prognosis on the basis of the primary radiological result.

However, this can only be done if we have access to a treated series healed with a high percentage of spherical heads and thereafter followed closely, radiologically as well as clinically, for at least 25 years, preferably longer.

In this country, the result of such a follow-up study will not be available until it is possible to carry out such a late follow-up on the patients treated in 1940–50 with bed rest at the Seaside Hospital, Refsnæs (Helbo). This will not be until some time towards the close of the century.

Until then, most importance must be attached to a careful radiological description at the time of primary healing, dividing the cases into spherical and non-spherical heads, measuring the epiphyseal quotients and in particular the joint surface quotients, etc.

The result of such measurements is at any rate very well suited for *comparative* assessment of various therapeutic methods and as a basis for a preliminary prognostic estimate at the time of primary healing.

When more relevant follow-up studies become available, the prognosis may perhaps be estimated with greater accuracy.

For bilateral cases cf. Appendix I.

Appendix I.

The Bilateral Cases

The studies reported in this paper concern exclusively *unilateral* cases of LCPD which usually make up 90–95 per cent of the patients referred for treatment.

The bilateral cases were not included in the analysis, as the radiological measuring methods used in evaluating the unilateral cases are not applicable in bilateral cases: There is no normal side for comparison. True, bilateral cases *may* be assessed by altering the methods, but this makes the results less accurate.

But as a matter of fact there is nothing to indicate that the joints in bilateral cases might be influenced by relief from weight-bearing in any way different from the joints in the unilateral cases. Therefore, if a radiological assessment could be applied to a material in its entirety—*i.e.* a collected assessment of bilateral and unilateral cases —the result is not likely to be much different from that of a radiological assessment of the unilateral cases only. This, of course, presupposes that bilateral involvement is not connected with any special —favourable or unfavourable—radiological types. This is difficult to estimate before a larger number of bilateral cases is available. All considered, however, I do not believe that our radiological assessment of the efficacy of the various therapeutic methods on the basis of the unilateral cases would alter materially had a detailed radiological assessment of the bilateral cases been possible.

From a clinical point of view, however, this is different.

Given two series which after treatment are radiologically identical, we would find that the one which contained the larger number of bilateral cases would be clinically more unfavourable.

After treatment with bed rest the number of bilateral cases will be approx. 8 per cent, corresponding to the number on referral, while after ambulatory relief from weight-bearing and presumably also after symptomatic (or no) treatment it will be considerably larger. The fact is that *during* treatment of unilateral cases with bed rest no new bilateral cases will arise, while this occurs in another 8 per cent or so among the unilateral cases treated with unilateral ambulatory relief from weight-bearing (Mose). In other words, after this ambulatory treatment the number of bilateral cases will be twice that after treatment with bed rest.

Thus, even if the radiological result after ambulatory relief from weight-bearing and after bed rest were the same, the clinical result after ambulatory treatment would be poorer. But the radiological result after the two methods of treatment is not the same—it is poorer after ambulatory treatment. This is enough to make the clinical result after ambulatory relief from weight-bearing poorer—but then the effect of the larger number of bilateral cases is superadded.

Thus, there is every reason to think twice, if one feels tempted—out of economical, social, or humane regards—to try ambulatory relief from weight-bearing by a Thomas brace or the like.

APPENDIX II.

Joint Surface Quotient — Radius Quotient

As regards the relationship between the joint surface quotient and the radius quotient after treatment for LCPD it may be said in more detail:

The *flattening* makes the *radius* of the femoral head longer, its *height* lower.

The *increase in growth* makes the *radius* as well as the *height* of the head greater.

Joint surface quotient $= K_1 \times \frac{H}{R}$, where H and R are the height and radius of the diseased head, K_1 a constant based upon the measurements on the sound side.

Radius quotient $= K_2 \times R$, where R is the radius on the diseased side, K_2 a constant based on the measurement on the sound side.

From this it is apparent that:

the *flattening* affects the joint surface quotient *more* than the radius quotient: R becomes larger, H smaller,

the *increase in growth* affects the radius quotient *more* than the joint surface quotient: H is not included in the radius quotient.

In all cases treated with any success the increase in growth will completely predominate over the flattening, so that the height H will be *increased* despite the flattening. Only in the case of great flattening will the height be the same on both sides—in rare cases possibly smaller on the diseased side.

As the increase in the growth of the head (and adjacent bony areas) plays an important role in all cases of LCPD, the consequence is that in mild and moderate flattening the radius quotient shows a much greater response than the joint surface quotient—viz. it gives a stricter assessment of the result. Not until very marked flattening do the heights (H) become equal and both measurements therefore dependent only upon the radius (R)—their difference from normal will be the same.

This is the explanation why the number of cases below the normal maximum or above the normal minimum is smaller when the radius quotient than when the joint surface quotient is measured.

Calculation and Plotting of the Radius Quotient

With increasing deformation of the head the radius quotient increases, while the joint surface quotient decreases. On the diagrams, however, the curve representing the radius quotients is "turned" so that it is on the same side of the normal value (100) as the curve representing the joint surface quotient (*i.e.* below the normal value). This facilitates the incidentally very problematic comparison of the radius quotient with the joint surface quotient.

If such a plotting of the radius quotient is to be maintained, it is more correct to calculate the radius quotient as $\frac{r}{R}$ falling with increasing R deformity—rather than as $\frac{R}{r}$. True, this makes the deflections on the diagrams (and tables) rather less marked than the use of $\frac{R}{r}$, but as the variation in normal children also becomes less marked, there will be no change in the number of cases within the normal range in the two series.

Since it is more practical, for several reasons, to calculate the radius quotient as $\frac{R}{r}$—int. al in order to avoid different values for the normal variation of the radius quotient and joint surface quotient—this manner of calculation and plotting of the radius quotient was maintained.

Logarithmic plotting of the radius quotient $\left(\frac{R}{r}\right)$ and joint surface quotient also makes the two sets of values more comparable—but it also makes it difficult to give a clear graphic representation.

Appendix III.

Comments on Statistical Calculation

BY SVEND SØRENSEN, M.Sc. (econ.)

The tests were carried out as a comparison of the frequency of a given therapeutic result following two methods of treatment according to the formula:

$$u = \frac{(h_1 - \frac{1}{2\,n_1}) - (h_2 + \frac{1}{2\,n_2})}{\sqrt{h\,(1-h)\,(\frac{1}{n_1} + \frac{1}{n_2})}}$$

$$h_1 = \frac{x_1}{n_1} \quad h = \frac{x_2}{n_2} \quad h = \frac{x_1 + x_2}{n_1 + n_2} = \frac{x}{n}$$

in which x_1 is the number of patients obtaining a given therapeutic result by treatment 1 and x_2 the number of patients obtaining the same therapeutic result by treatment 2. n_1 and n_2 are the total number of patients subjected to treatment 1 and treatment 2 respecively.

The comparison between bed rest *with* traction and bed rest *without* traction was performed as a unilateral as well as a bilateral test. In the unilateral test, taking support in the available numerical material, the possibility that bed rest with traction could be inferior to bed rest without traction was ruled out. In the unilateral test the alternative to bed rest with traction being a better form of treatment than bed rest without traction is that the two methods are equally good. As it was not possible, *a priori,* to rule out the possibility that bed rest with traction is inferior to bed rest without traction, the presupposition of using this procedure was, strictly speaking, not fulfilled. Therefore, the test was also performed as a bilateral test. For the same reasons, the comparison between bed rest with traction and ambulatory treatment and between bed rest without traction and ambulatory treatment was also carried out by unilateral as well as bilateral tests.

Summary

After criticising the radiological methods used so far for assessing the results of treating Legg-Calvé-Perthes disease (LCPD), the author tries to arrive at a suited method, based upon the principle that the shape of the femoral head is of decisive prognostic importance.

The normal and the pathological radiological appearances are described and discussed. It is established that the first step in the radiological assessment of the therapeutic result at the time of primary healing, about a year or two after the discontinuation of treatment, should always be a classification of the series into cases having *spherical femoral heads* and others having *irregular, non-spherical heads.* This can now be done with greater objective accuracy than before by means of the plastic plate with concentric circles used by Mose. According to the named principle, cases with spherical heads have a better prognosis than cases with irregular heads, whose prognosis is definitely poor.

This should be followed by a closer assessment of the very large group of cases which after effective treatment have healed with spherical heads. Attempts to do so revealed that measurement of the *epiphyseal quotient,* which reflects the flattening of the epiphysis, was an excellent indicator of the effect of treatment upon the shape of the epiphysis. On the other hand, measurement of the *joint surface quotient,* which reflects the shape of the head, proved best suited for a prognostic assessment. Cases whose joint surface quotients were within the normal range must have a good prognosis.

The *radius quotient* reflects the *shape* as well as the *size* of the head and accordingly gives a stricter—and presumably too pessimistic—evaluation of the prognosis.

Thus, the radiological measurements each describe given—but mutually different—qualities of the radiological appearance: The shape of the femoral head, the shape of the epiphysis, etc. Together, they afford an all-round picture of the primary results, but measurement of the joint surface quotient gives the best guidance in assessing the number of cases having a good prognosis.

After these introductory—and of necessity rather detailed chapters—the radiological methods of assessment were applied to the results of 4 therapeutic methods:

I. Bed rest with traction.
II. Bed rest without traction.
III. Ambulatory relief from weight-bearing.
IV. No or only symptomatic treatment.

The efficacy of the relief from weight-bearing increases from treatment IV to treatment I.

Measurement of the joint surface quotient could only be carried through in series I and II. The measurements of the epiphyseal quotients in series IV and III had been performed by Helbo and Mose, but were indirectly checked by the present author.

From the various measurements it was apparent that the radiological results improved as the efficacy of relief from weight-bearing increased.

The number of spherical heads increased from series IV to series I as follows (per cent of all patients in the series concerned):

19 per cent   61 per cent   73 per cent   87 per cent.

The number of cases having epiphyseal quotients above 60 increased as follows:

8 per cent   42 per cent   59 per cent   75 per cent,

and the number of cases having joint surface quotients within the normal range (above 85) increased from series II to series I as follows:

62 per cent   72 per cent.

It is apparent from these last two figures that the shape of the head—which decides the prognosis—improved less (62–72 per cent) than the epiphyseal shape (59–75 per cent) on transition from bed rest without traction to bed rest with traction. And this is just what was to be expected, when bearing in mind the activity of the compensatory processes in the presence of greatly flattened epiphyses.

All the figures show that treatment with traction—compared with the other 3 methods of treatment—gives the best radiological results:

After traction at least *72 per cent* of the treated cases must be presumed to have a favourable prognosis.

Finally, an attempt was made to ascertain whether these radiological assessments and predictions were in conformity with the clinical findings—in brief an attempt at a clinical check on the radiological assessments.

This is difficult—and the result is uncertain.

At *the time of primary healing of LCPD*, the patients are not, as generally assumed, symptom free, but the detection of the symptoms and their frequency depends entirely upon the intensity of the examination and the definition of the concept symptoms.

Examining patients after treatment with bed rest, Helbo found primarily symptoms in 26 per cent, while the present author found symptoms in 57 per cent. This difference is due essentially to a difference in the definition of "symptoms"—mine being more spacious than Helbo's and comprising also milder symptoms.

Subjective symptoms were found after treatment with traction in 13 per cent and after bed rest alone in 22 per cent. The percentage of objective signs—some of which were very mild—was approximately the same after these two methods of treatment.

These symptoms were not, as might perhaps be expected, restricted to the poorest radiological group, but in the present study distributed over *all* groups, although they were most common in patients with irregular femoral heads and uncommon in the group of practically normal heads.

A clinical check on the *prognoses* set up on the basis of the radiological appearances presupposes a late clinical follow-up study.

I am aware of only one clinical examination of patients treated for LCPD 25 years or longer after the onset of the disease in which the late symptoms can be related to the primary radiological types described in the present paper.

This is a series of 47 patients who had received no or only symptomatic treatment and who were after-examined by Helbo.

In this small series he found *secondary osteoarthritis* in *68 per cent* and symptoms (with or without osteoarthritis) in *81 per cent*. According to Helbo, all these cases belonged to the group with irregular heads

(Helbo's groups with "flattened" and "irregular" heads)—of which they made up 76 per cent and 90 per cent.

If the result from the small follow-up series is transferred to the 4 series described in the present paper, the following incidences of osteoarthritis and of symptoms are to be expected at the end of 25 years:

Osteoarthritis:	62%	30%	20%	10%
Symptoms:	73%	35%	24%	12%

decreasing from no or symptomatic treatment to treatment with traction in bed.

For various reasons it is doubtful whether it is justified to apply Helbo's figures to our series, but according to close consideration, the resulting errors cannot be of decisive importance, and at any rate there are no other applicable follow-up studies.

Thus, according to the best clinical assessment which can be done at present, only 10 per cent of the patients treated with traction need fear the development of secondary osteoarthritis, while *88 per cent* will remain symptom free.

According to the radiological assessment, we dared not estimate more than *72 per cent* "good results".

The cause of this divergence is naturally that the radiological assessment was performed with great—perhaps too great—caution and that the clinical assessment was done on the basis of Helbo's follow-up study on a series which in essential respects differs from our traction series and, therefore, is presumably a little too optimistic.

Presumably, the truth lies somewhere between 72 per cent and 88 per cent.

It must be our future endeavour to approach these two figures to each other—*i.e.* to obtain greater certainty in estimating the clinical long-term prognosis on the basis of the primary radiological result.

In an effectively treated series, however, this can be done only if we have access to a treated series healed with a larger number of spherical heads and thereafter closely followed, radiologically as well as clinically, for at least 25 years, preferably longer.

Such a series will not be available in this country until the end of this century.

Tables

Table 1. Patients treated with prolonged bed rest without traction *at Refsnæs 1953–57 (79 patients).*
Age distribution and stage at institution of treatment (per cent of all cases).

1–4 years	5–8 years	9–12 years
26 %	61 %	13 %
Early condensation without flattening	Late condensation with flattening	Fragmentation
45.6 %	26.6 %	27.8 %

Table 2. 3 series—3 therapeutic methods.
Patients' ages at institution of treatment (per cent of all cases).

	1–4 years %	5–8 years %	9–12 years %
Prolonged bed rest with traction (71 pts.)	34	50	16
Prolonged bed rest without traction (79 pts.)	26	61	13
Ambulatory relief from weight-bearing (71 pts.)	39	54	7

Table 3. 3 series—3 therapeutic methods.
Stage of disease at institution of treatment (per cent of all cases).

	Early stage (condensation) %	Late stage (fragmentation) %
Prolonged bed rest with traction (71 pts.)	62	38
Prolonged bed rest without traction (79 pts.)	72	28
Ambulatory relief from weight-bearing (71 pts.)	78	22

Table 4. Epiphyseal quotient—joint surface quotient—radius quotient.
Patients treated with bed rest without traction. *Refsnæs 1953–57. (79 pts.).*

	Number	%
Total patients	79	100
with spherical heads	58	73.4
with non-spherical heads	21	26.6

In the group of patients with spherical heads:

1

Epiphyseal quotient	No. of pts.	% of all pts.
100–96 incl.	4	4.5
100–91 incl.	7	8.9
100–86 incl.	11	13.9
100–81 incl.	20	25.4
100–76 incl.	25	31.6
100–71 incl.	34	43.2
100–66 incl.	42	53.0
100–61 incl.	47	59.5
100–56 incl.	50	63.0
100–51 incl.	54	68.4
100–46 incl.	56	71.2
100–41 incl.	58	73.4

2

Joint surface quotient	No. of pts.	% of all pts.
110–106 incl.	2	2.5
110–101 incl.	5	6.3
110– 96 incl.	12	15.2
110– 91 incl.	35	44.3
110– 86 incl.	49	62.0
110– 81 incl.	53	67.1
110– 76 incl.	57	72.1
110– 71 incl.	58	73.4

3

Radius quotient	No. of pts.	% of all pts.
100–104 incl.	11	13.9
100–109 incl.	24	30.4
100–114 incl.	38	48.0
100–119 incl.	47	59.4
100–124 incl.	53	67.0
100–129 incl.	55	69.8
100–134 incl.	58	73.4

Table 5. Epiphyseal quotient—joint surface quotient—radius quotient. Patients treated with traction in bed. *Refsnæs 1958–62. (71 pts.).*

	Number	%
Total patients	71	100
with spherical heads	62	87.3
with non-spherical heads	9	12.7

In the group of patients with spherical heads:

1			2			3		
Epiphyseal quotient	No. of pts.	% of all pts.	*Joint surface quotient*	No. of pts.	% of all pts.	*Radius quotient*	No. of pts.	% of all pts.
100–96 incl.	6	8.5	110–106 incl.	2	2.8	100–104 incl.	14	19.7
100–91 incl.	10	14.1	110–101 incl.	5	7.0	100–109 incl.	28	39.4
100–86 incl.	16	22.5	110– 96 incl.	23	32.4	100–114 incl.	44	62.0
100–81 incl.	28	39.4	110– 91 incl.	37	52.0	100–119 incl.	52	73.3
100–76 incl.	35	49.4	110– 86 incl.	51	71.8	100–124 incl.	56	78.9
100–71 incl.	44	62.0	110– 81 incl.	55	77.4	100–129 incl.	60	84.5
100–66 incl.	52	73.2	110– 76 incl.	58	81.6	100–134 incl.	61	85.9
100–61 incl.	53	74.6	110– 71 incl.	60	84.5	100–139 incl.	62	87.3
100–56 incl.	57	80.5	110– 66 incl.	62	87.3			
100–51 incl.	62	87.3						

Table 6. Epiphyseal quotients in patients treated with ambulatory relief from weight-bearing *(Mose).*

	Number	%
Total patients	64	100
with spherical heads	39	61
with non-spherical heads	25	39

In the group of patients with spherical heads:

Epiphyseal quotient	No, of pts.	% of all pts.
100–96 incl.	3	4.7
100–91 incl.	5	7.8
100–86 incl.	7	10.9
100–81 incl.	10	15.6
100–76 incl.	13	23.0
100–71 incl.	16	25.0
100–66 incl.	20	31.2
100–61 incl.	27	42.2
100–56 incl.	30	47.0
100–51 incl.	32	50.0
100–46 incl.	34	53.2
100–41 incl.	37	58.0
100–36 incl.	39	61.0

Table 7. Epiphyseal quotients in patients treated with bed rest without traction. *Refsnæs 1941–50 (Helbo).*

	No. of pts.	%
Total patients	59	100
with spherical heads	45	76.4
with non-spherical heads	14	23.6

In the group of patients with spherical heads:

Epiphyseal quotient	No. of pts.	% of all pts.
100–96 incl.	1	1.7
100–91 incl.	5	8.5
100–86 incl.	7	11.8
100–81 incl.	15	25.4
100–76 incl.	16	27.0
100–71 incl.	21	35.6
100–66 incl.	26	44.0
100–61 incl.	32	54.3
100–56 incl.	35	59.0
100–51 incl.	41	70.0
100–46 incl.	42	71.0
100–41 incl.	45	76.4

Table 8. Epiphyseal quotients in patients who received symptomatic or no treatment *(Helbo).*

	Number	%
Total patients	70	100
with spherical heads	13	18.6
with non-spherical heads	57	81.4

In the group of patients with spherical heads:

Epiphyseal quotient	No. of pts.	% of all pts.
100–96 incl.	0	0
100–91 incl.	0	0
100–86 incl.	0	0
100–81 incl.	1	1.4
100–76 incl.	1	1.4
100–71 incl.	1	1.4
100–66 incl.	3	4.3
100–61 incl.	5	8.2
100–56 incl.	7	10.0
100–51 incl.	7	10.0
100–46 incl.	10	14.3
100–41 incl.	11	15.7
100–36 incl.	11	15.7
100–31 incl.	13	18.6

Table 9. 6 patient series—4 methods of treatment.
Patients' age at institution of treatment *(or at time of diagnosis).*

Series	Age		
	>4 years	5–8 years	<9 years
	%	%	%
Traction in bed, (Refsnæs, J. M.)	34	50	16
Bed rest without traction, (Refsnæs, Mose, J. M.)	26	61	13
Bed rest without traction, (Refsnæs, Helbo)	14	67	19
Bed rest without traction, (Hornbæk, Mose)	37	52	11
Ambulatory treatment, (Mose)	39	54	7
No or symptomatic treatment, (Helbo)	12	60	28

Table 10. 6 patient series—4 methods of treatment.
Stage of disease *at institution of treatment (or at time of diagnosis).*

Series	Stage of condensation	Stage of fragmentation
	%	%
Traction in bed, (Refsnæs, J. M.)	62	38
Bed rest without traction, (Refsnæs, Mose, J. M.)	68	32
Bed rest without traction, (Refsnæs, Helbo)	67	33
Bed rest without traction, (Hornbæk, Mose)	74	26
Ambulatory treatment, (Mose)	78	22
No or symptomatic treatment, (Helbo)	46	54

Table 11. Patients treated with bed rest without traction.

Collected series:

Hornbæk 1953–57 (Mose)	70 pts.
Refsnæs 1953–57 (Mose, J.M.)	79 pts.
Refsnæs 1941–50 (Helbo)	59 pts.
Total	208 pts.

	Number	%
Total patients	208	100
with spherical heads	160	77
with non-spherical heads	48	23

In the group of patients with spherical heads:

Epiphyseal quotients	No. of pts.	% of all pts.
100–96 incl.	11	5.3
100–91 incl.	19	9.1
100–86 incl.	28	13.5
100–81 incl.	52	25.0
100–76 incl.	67	32.2
100–71 incl.	90	43.3
100–66 incl.	110	53.0
100–61 incl.	123	59.0
100–56 incl.	132	63.5
100–51 incl.	145	69.5
100–46 incl.	150	72.0
100 41 incl.	158	76.0
100 36 incl.	160	77.0

Table 12. Epiphyseal quotients in patients treated with bed rest without traction.
Hornbæk 1953–57, Mose.

	Number	%
Total patients	70	100
with spherical heads	57	81.4
with non-spherical heads	13	18.6

In the group of patients with spherical heads:

Epiphyseal quotients	No. of pts.	% of all pts.
100–96 incl.	6	8.6
100–91 incl.	7	10.0
100–86 incl.	10	14.3
100–81 incl.	17	24.6
100–76 incl.	26	37.0
100–71 incl.	35	50.0
100–66 incl.	42	60.0
100–61 incl.	44	63.0
100–56 incl.	47	67.0
100–51 incl.	50	71.5
100–46 incl.	53	76.0
100–41 incl.	55	78.5
100–36 incl.	57	81.4

Table 13. Epiphyseal quotients in patients treated with bed rest without traction.

Collected series:	Refsnæs 1953–57, Mose, J.M.	79 pts.
	Refsnæs before 1950, Helbo	59 pts.

	Number	%
Total patients	138	100
with spherical heads	103	74.6
with non-spherical heads	35	25.4

In the group of patients with spherical heads:

Epiphyseal quotients	No. of pts.	% of all pts.
100–96 incl.	5	3.6
100–91 incl.	12	8.7
100–86 incl.	18	13.0
100–81 incl.	35	25.4
100–76 incl.	41	29.7
100–71 incl.	55	39.9
100–66 incl.	68	49.3
100–61 incl.	79	57.3
100–56 incl.	85	61.6
100–51 incl.	95	69.0
100–46 incl.	98	71.0
100–41 incl.	103	74.6

Table 14. Epiphyseal quotients in patients treated with bed rest without traction.

Collected statistics:	
Refsnæs 1953–57 (Mose, J.M.)	79 pts.
Hornbæk 1953–57 (Mose)	70 pts.

	Number	%
Total patients	149	100
with spherical heads	115	77.2
with non-spherical heads	34	22.8

In the group of patients with spherical heads:

Epiphyseal quotients	No. of pts.	% of all pts.
100–96 incl.	10	6.7
100–91 incl.	14	9.4
100–86 incl.	21	14.0
100–81 incl.	37	24.8
100–76 incl.	51	34.2
100–71 incl.	69	46.3
100–66 incl.	84	56.4
100–61 incl.	91	61.0
100–56 incl.	97	65.0
100–51 incl.	104	70.0
100–46 incl.	109	73.2
100–41 incl.	113	76.0
100–36 incl.	115	77.1

Table 19. Statistical calculation of significance of differences between the results obtained by 4 different methods of treating LCPD, assessed by the number of patients with irregular heads.
The difference is considered statistically significant when $p < 0.050$.

Treatment	Series	Irregular heads %	Statistical calculation: Bilateral test	Statistical calculation: Unilateral test
Traction in bed	71 pts. J.M.	12.7	u = 1.71	u = 1.71
Bed rest without traction	208 pts. coll. ser.	23	p = 0.087	*p = 0.044*
Traction in bed	71 pts. J.M.	12.7	u = 1.92	u = 1.92
Bed rest without traction	79 pts. Mose, J.M.	27	p = 0.055	*p = 0.027*
Bed rest without traction	208 pts. coll. ser.	23	u = 2.36	u = 2.36
Ambulatory relief from weight-bearing	64 pts. Mose	39	*p = 0.018*	*p = 0.0091*
Ambulatory relief from weight-bearing	64 pts. Mose	39	u = 4.85	u = 4.85
Symptomatic or no treatment	70 pts. Helbo	81.4	*p = 0.000012*	*p = 0.000006*
Traction in bed	71 pts. J.M.	12.7	u = 3.33	u = 3.33
Ambulatory relief from weight-bearing	64 pts. Mose	39	*p = 0.00087*	*p = 0.00043*

Table 20. Statistical calculation of significance of difference between the results obtained by 4 different methods of treating LCPD, assessed by the number of patients having epiphyseal quotients above 60.
The difference is considered statistically significant when $p < 0.050$.

Treatment	Series	Epiphyseal quotient above 60 %	Statistical calculation	
			Bilateral test	Unilateral test
Traction in bed	71 pts. J.M.	75	u = 2.20	u = 2.20
Bed rest without traction	208 pts. coll. ser.	59	$p = 0.026$	$p = 0.014$
Bed rest without traction	208 pts. coll. ser.	59	u = 2.24	u = 2.24
Ambulatory relief from weight-bearing	64 pts. Mose	42	$p = 0.025$	$p = 0.013$
Ambulatory relief from weight-bearing	64 pts. Mose	42	u = 4.55	u = 4.55
Symptomatic or no treatment	70 pts. Helbo	8	$p = 0.000005$	$p = 0.000003$
Traction in bed	71 pts. J.M.	75	u = 3.66	u = 3.66
Ambulatory relief from weight-bearing	64 pts. Mose	42	$p = 0.00025$	$p = 0.00013$

Table 21. Statistical calculation of significance of difference between the results obtained by 4 different methods of treating LCPD, assessed by the number of patients having epiphyseal quotients above 85.
The difference is considered statistically significant when $p < 0.050$.

Treatment	Series	Epiphyseal quotient above 85 %	Statistical calculation	
			Bilateral test	Unilateral test
Traction in bed	71 pts. J.M.	22.5	$u = 1.63$	$u = 1.63$
Bed rest without traction	208 pts. coll. ser.	13.5	$p = 0.10$	$p = 0.052$
Bed rest without traction	208 pts. coll. ser.	13.5	$u = 0.313$	$u = 0.313$
Ambulatory relief from weight-bearing	64 pts. Mose	10.9	$p = 0.75$	$p = 0.38$
Ambulatory relief from weight-bearing	64 pts. Mose	10.9	$u = 2.45$	$u = 2.45$
Symptomatic or no treatment	70 pts. Helbo	0	*$p = 0.014$*	*$p = 0.0074$*
Traction in bed	71 pts. J.M.	22.5	$u = 1.56$	$u = 1.56$
Ambulatory relief from weight-bearing	64 pts. Mose	10.9	$p = 0.12$	$p = 0.059$

Table 22. Statistical calculation. Significance of the difference between the results obtained by 2 different methods of treating LCPD, assessed by the number of patients having joint surface quotients above 85 *and* radius quotients below 115. *The difference is considered statistically significant when* $p < 0.050$.

Treatment	Series	Joint surface quotient above 85 %	Statistical calculation: Bilateral test	Statistical calculation: Unilateral test
Traction in bed	71 pts. J.M.	72	$u = 1.10$	$u = 1.10$
Bed rest without traction	79 pts. Mose, J.M.	62	$p = 0.270$	$p = 0.140$
		Radius quotient below 115 %		
Traction in bed	71 pts. J.M.	62	$u = 1.54$	$u = 1.54$
Bed rest without traction	79 pts. Mose, J.M.	48	$p = 0.120$	$p = 0.062$

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