

On an improved method of treatment of separation of the lower epiphysis of the femur / by J. Hutchinson, jun. and H.L. Barnard.

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ON AN IMPROVED METHOD OF TREATMENT
OF
SEPARATION OF THE LOWER EPIPHYSIS
OF THE FEMUR

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It would have been impossible to prove the contention of the following paper without the aid of skiagraphy. The accompanying illustrations, although apparently diagrammatic, strictly represent (with the exception of Fig. 1) the skiagraphs made for this purpose. The outlines of the bones, &c., were accurately traced from the latter, and reproduced on a smaller scale. We are much indebted to Mr. Waren Tay, Mr. Mansell Moullin, and Mr. Openshaw for permission to use cases under their care.

In practically all cases when the lower femoral epiphysis is torn off by over-extension of the knee-joint, it is carried forward on to the front of the diaphysis by the

pull of the crucial ligaments. It is then somewhat drawn up by the quadriceps extensor muscle. The thick periosteum is stripped up from the front of the femur for two or three inches, and remains attached to the epiphysis, giving it a forward tilt, so that its articular surface looks downwards and forwards. It will also be seen that the posterior edge of the lower end of the diaphysis is sharp and angular, and projects into the popliteal space perilously near the skin, and pressing on the vessels and nerves.

Our method of reduction was devised to make the epiphysis retrace its steps backwards, to apply the separated periosteum to the anterior surface of the femur, to withdraw the end of the diaphysis from the popliteal space, and when these objects have been attained to so fix the limb that the displacement cannot recur. The method is as follows :

Under complete anæsthesia an assistant makes steady but strong traction upon the tibia in the line of the limb. This overcomes the upward pull of the quadriceps extensor, and brings the epiphysis down to the line of separation. The operator then clasps his hands beneath the thigh and draws it steadily upwards, *gradually flexing completely the knee and hip-joint.*

It will be seen that this manœuvre causes the epiphysis to move back upon the fractured surface of the diaphysis until it has reached its normal position, and further movement is prevented by the periosteum coming into tight contact with the anterior surface of the femur (see Fig. 1).

A domette bandage is then applied around the thigh and ankle, fixing the heel upon the buttock, and the limb is laid upon its outer side on a pillow. An ice-bag can conveniently rest upon the front of the knee to limit effusion.

The advantages of maintaining this position for a fortnight are these :—The quadriceps exerts tension in the length of the bone, keeping the surfaces in close apposition and squeezing out effused blood. The tendon

of the quadriceps and the patella fit into the groove between the two condyles, and prevent lateral displace-

FIG. 1.

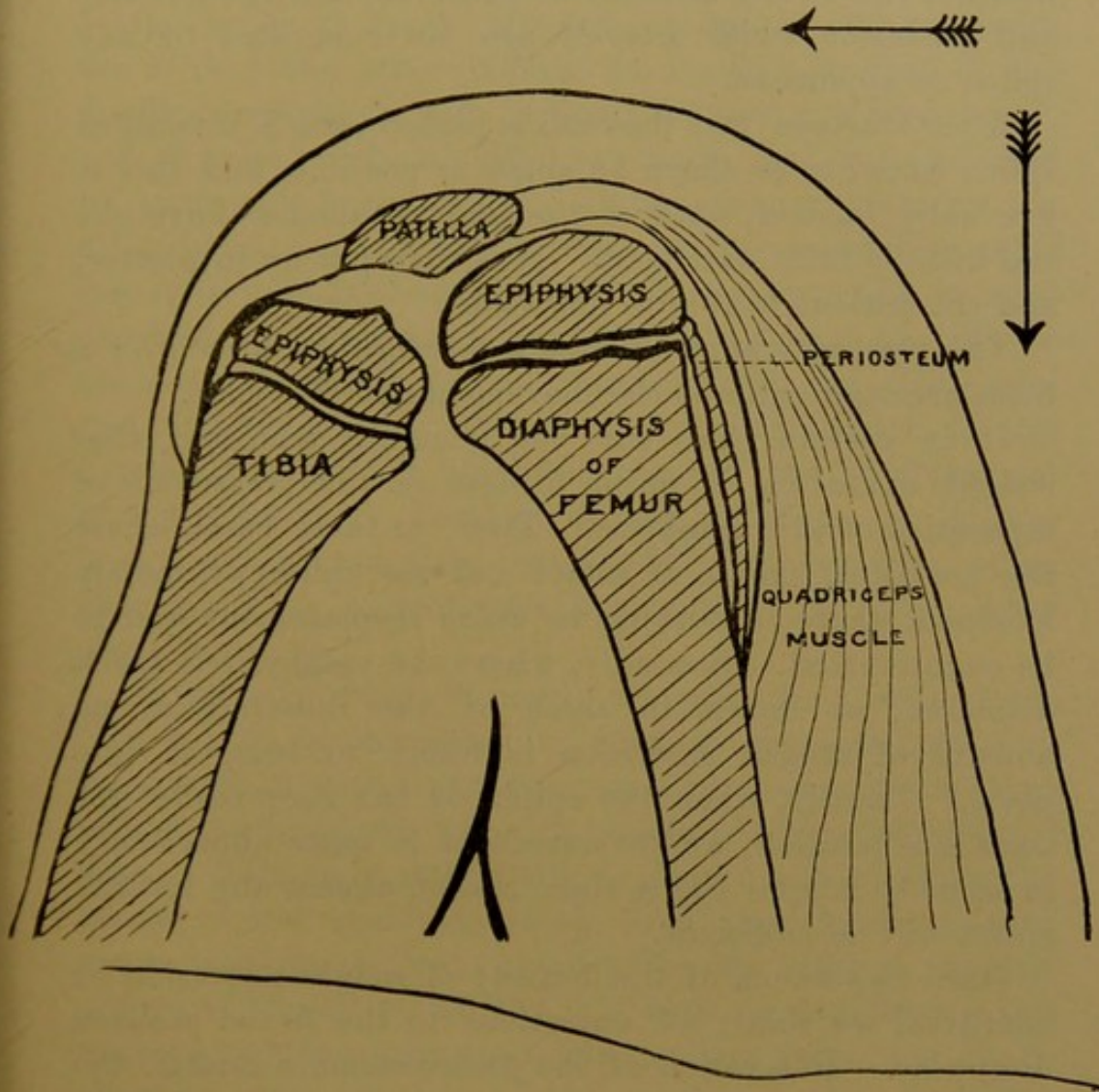


Diagram representing the method of reduction described above. Full flexion of the knee carries the detached epiphysis back into place in the direction of the horizontal arrow, whilst the tension of the quadriceps thus produced presses the epiphysis against the end of the diaphysis, as indicated by the vertical arrow.

ment; and since the tendon of this muscle changes its direction at a right angle, to be inserted into the tubercle of the tibia, it prevents recurrence of the forward displacement of the epiphysis. This position also removes the sharp end of the diaphysis as far as possible from the

popliteal space, and relaxes the skin and vessels and nerves completely. The articular surfaces of the epiphysis are subcutaneous and uncovered, so that their position can at any moment be observed, and the anterior and posterior tibial arteries are not concealed by any splint or apparatus.

After fourteen days the limb is placed upon a Macintyre splint flexed to as sharp an angle as possible, and this is gradually opened, until at the end of another fortnight the knee is fully extended. It is then put up in plaster, and the patient is able to get about.

The plaster is kept on from a fortnight to a month; a little massage restores the movements of the joint.

It is certain, but not yet generally admitted, that weight extension is quite useless in the treatment of separation of this epiphysis. First, in those cases where the periosteal sheath is intact and the epiphysis merely loosened, there is nothing to cause displacement and to be counteracted. Secondly, where the epiphysis is much displaced, as shown in some of the illustrations, no amount of weight extension is likely to bring it into place. Thirdly, when the epiphysis has been really got back into position, weight extension is quite unnecessary in order to keep it there, since rest on almost any form of splint will be sufficient.

Once this axiom of the inutility of weight extension be admitted, we think all objections to the flexed position disappear. Relaxation of the gastrocnemius muscle, the powerful effect of direct pressure upon the epiphysis through the quadriceps muscle and patella, and thirdly, the backward traction exerted through the tibia and crucial ligaments, can only be obtained during flexion of the knee.

Theoretical considerations, post-mortem experiments, and above all the experience of actual cases, are alike in favour of the treatment by flexion. We are confident that if this method of treatment comes into general use, with the aid of the accurate control of skiagraphy, com-

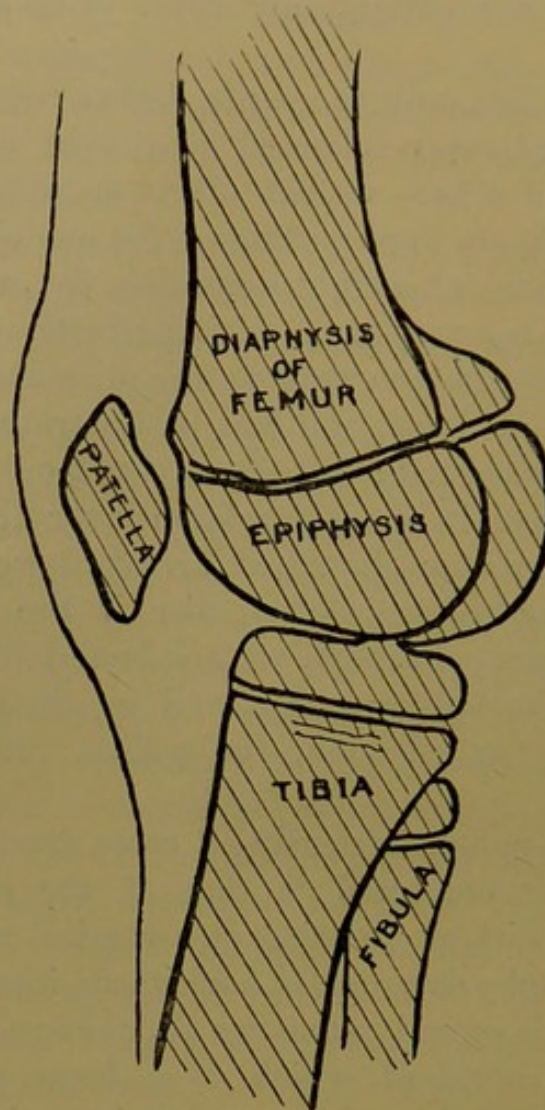
plete separation of the lower femoral epiphysis will lose its dangers to the patient, and cease to be a discredit to surgery.

This applies not only to simple, but to compound cases. In the series of cases collected by one of us¹ examples are to be found where violent efforts at reduction of the displaced epiphysis were prolonged for one or more hours, and of cases in which weight extension, &c., were followed by extremely bad results. It is perfectly true, on the other hand, that nature moulds the displaced fragments into a very useful bone, and this is illustrated by at least one case now recorded; but there is not only the risk to the popliteal vessels by compression over the diaphysial end, but the greater chance of arrest of growth in this extremely important epiphysial disc if the displacement be not overcome. Further, we are bound to aim at the best possible immediate result, and in these days, when skiagraphy is so common, the public will insist upon obtaining it.

As already noted, in nearly all cases the displacement that has to be corrected is that of the epiphysis forward with or without twisting on a vertical axis; in other words, the diaphysis projects backwards into the popliteal space. This is exactly what we should expect from the nature of the accident, which in a large proportion of cases involves violent hyper-extension with a varying degree of torsion of the leg. If this displacement is left uncorrected, the ultimate result on the joint will be to allow of extension beyond the normal, so that the tibia and femur form an angle with each other, open in front, instead of a vertical line. More than one case could be here adduced to prove this statement, but since the hyper-extension constitutes only a slight defect, it is unnecessary to give more than one example; this case is of interest, since the child was examined and the skiagraph obtained four and a half years after the accident (Fig. 2).

¹ Jacksonian Prize Essay, R.C.S.

FIG. 2.



Skiagraph from Case 1, obtained four years after the accident.

CASE 1.—Sophia S—, a rickety child aged 6, fell in the street and sustained a separation of the lower epiphysis of the left femur on April 3rd, 1893. The limb was put up extended in a box splint for a month. In November, 1897, she was seen again; there was no shortening, and she could walk and run well; nevertheless the epiphysis had united in a somewhat rotated position, so that the outer condyle faced more inwards than it should, the inner condyle more posteriorly. The left knee could be hyper-extended no less than 25° more than the right one, but, as already said, the limb was perfectly useful.

We believe that the method of treatment advocated in this paper is to some extent a new one, and we are not

aware of any records of cases so treated (that is by the full flexion of the knee). This idea is due to Mr. Barnard; at the same time it has been held by some for long that flexion to at least a right angle is essential in the treatment of cases where the displacement has been complete. Thus, for instance, Mr. Hutchinson, sen., wrote in 1888 (*re* displacement of this epiphysis), "When once it has occurred, such a displacement is probably impossible of rectification excepting by putting the limb with the knee at right angles, and in that position it is exceedingly difficult to secure the needful extension. I do not know of any case in which, after such displacement, reduction was proved to have been effected."¹

With regard to the latter point, we maintain that extension by weight is wholly unnecessary in these cases; and further, that, as the examples now brought forward show, there is no difficulty in getting perfect reposition of the displaced epiphysis.

In an abstract of three lectures on "Injury to the Epiphyses" one of us wrote,² "Before attempting to reduce the displacement it is absolutely essential that muscular spasm should be prevented by thorough anæsthesia; the knee should be flexed, and then traction and direct pressure brought to bear on the epiphysis. . . . When reduction has been effected the best splint to use is a carefully padded Macintyre's one, flexed to an angle of 135°."

In a single case with typical backward projection of the diaphysis recorded by Mr. A. F. McGill (see John Poland's work on the Epiphyses, p. 764), "under ether the deformity was easily reduced by forcible flexion of the limb till the heel touched the buttock." This is the only allusion to the method advocated by us that we have been able to find.

The epiphysis, if separated, nearly always travels forwards, whilst the diaphysis projects into the popliteal

¹ 'Clinical Illustrations of Surgery,' vol. ii, p. 3.

² 'British Medical Journal,' 1894.

space, because the injury is caused by hyper-extension of the knee (very commonly by the leg getting caught in a wheel, and the patient being swung round by it).

In experiments on the dead subject one of us¹ found extreme hyper-extension with some twisting force to be the easiest method of producing detachment of the epiphysis. In the living subject we find some lateral displacement often complicating the forward one, and there may be rotation of the epiphysis on a vertical axis, proving the occurrence of a twisting force, but the forward displacement is the chief and most usual one; indeed, it may be said the epiphysis never travels backwards. The stretching of the popliteal vessels, and even the internal popliteal nerve, over the edge of the diaphysis, which projects backwards, has been well illustrated in Mr. Hutchinson's 'Clinical Illustrations of Surgery,' the drawing being taken from a case in which gangrene was produced.

It is of interest to compare separation (with displacement) of the lower epiphysis of the humerus with that of the femur.

We find precisely the same statement applies to both,—that the diaphysis tends to project towards the flexor aspect of the joint, where run the main vessels.

Here, again, some lateral displacement or twisting of the epiphysis may be present, but the antero-posterior one is the chief. Owing, however, to the bone being separated from the artery by the brachialis anticus, the diaphysis is less likely to press on the artery. It is easy to overlook this projection of the diaphysis forwards, and sometimes difficult to overcome it, even if recognised. Some surgeons, especially Professor Christopher Heath, have advocated putting up the arm with the elbow fully flexed, and from analogy with the knee-joint it would appear to be an excellent method.

It is not contended that all cases of separation of this epiphysis are likely to give much trouble to the surgeon,

¹ J. Hutchinson, jun.

or require any special method of adjustment. Everything depends on whether the diaphysis has been forced through the periosteal sheath, which it will be remembered is continuous with the epiphysis, and in cases of separation is invariably dragged off with it. It stands to reason that if the periosteum is merely loosened from the bone, and the epiphysis not shifted from the broad end of the diaphysis, good union will result in whatever position the limb is put up, and the only result of the injury may be temporary deposit of new bone round the lower end of the femur, with the chance of arrest of growth at a later stage. There is no doubt whatever that many of these cases of detachment of the epiphysis without displacement are overlooked in children and young adults; indeed, it may be extremely difficult to detect them.

The following case is an example of the condition just described, and the skiagraph taken eight months after the accident showed that the treatment with the limb in an extended position left nothing to be desired (Fig. 3).

CASE 2.—F. O—, a boy aged $3\frac{1}{2}$, was admitted into the hospital on February 21st, 1897, having sustained a fracture in the middle third of his left femur, with a separation of the lower epiphysis of the same bone, without any displacement. The limb was put up in a box splint with weight extension. At the end of five weeks he was sent out in a poroplastic splint. On November 1st, 1897, the boy was brought up for inspection and the skiagraph obtained. He could then walk and run well. There was neither shortening of the limb nor over-extension of the knee.

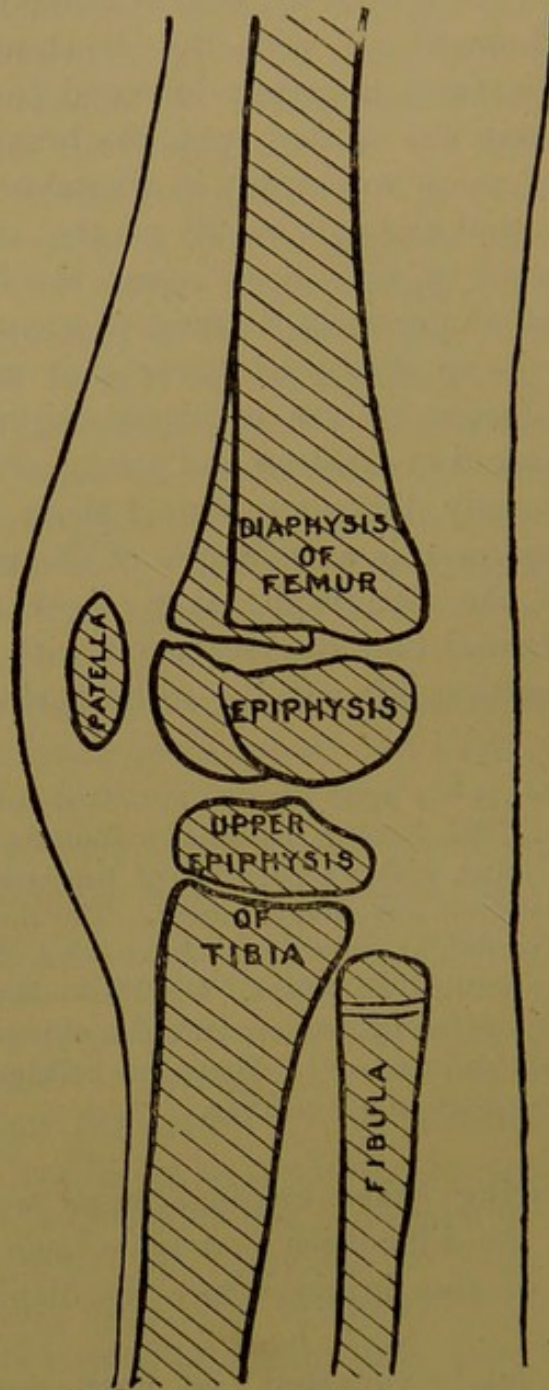
Before adducing other original cases we will quote illustrations of the difficulties that have been met with in the treatment of this injury where the displacement has been complete.

M. Ardouin lately reported¹ an unsuccessful attempt to save a limb in a case of compound separation of the lower femoral epiphysis. The patient was a lad aged sixteen, whose leg was caught in some printing machinery,

¹ 'Bull. de la Soc. Anat.,' June, 1897.

and he was carried round by it. Through a large wound at the back the lower end of the diaphysis protruded.

FIG. 3.



Skiagraph obtained nine months after separation of the epiphysis without displacement (Case 2).

After reduction (no details are given as to the method of treatment employed) things appeared to go on well for a

fortnight, when it became necessary to amputate the limb, after which operation the boy recovered. It was found that the projecting diaphysis had torn open the popliteal vein, and that much hæmorrhage had occurred. Further, there was an abscess in the wall of the popliteal artery.

Such a case, where one or both main vessels in the popliteal space are seriously damaged by the projecting diaphysis, is probably doomed to amputation from the first, and it is to be feared that this will, with rare exceptions, in spite of the advance of surgery, remain true for long. But one must discriminate, and we believe the prognosis would be less grave than has been just stated if two simple rules were observed in the treatment of these cases. Before giving them we shall be excused for dwelling on a few preliminary points.

First, as regards the gravity of compound separation of the lower femoral epiphysis the following figures¹ will convince anyone that it has not been exaggerated. Out of thirty cases collected the result was—

Death from shock	4 (13%)
Primary amputation, of which at least 3 cases died	13 (43%)
The diaphysial end was resected and reduction thus secured—all recovered with useful but somewhat shortened limbs	5 (17%)
Reduction was more or less effected without resection; of these 3 died from pyæmia, 4 required subsequent amputation, and one only recovered, retaining his limb after prolonged suppuration and necrosis	8 (27%)

Thus, out of the total of thirty cases, ten at least proved fatal (*i. e.* no less than 33 per cent.), whilst of the remainder fourteen recovered only at the cost of the limb (in one case amputated at the hip-joint), and only six (20 per cent.) recovered without this mutilation.

Is there any other compound fracture of similar frequency in which such depressing results follow the sur-

¹ J. Hutchinson, jun., 'Injuries to the Epiphyses,' Jacksonian Prize Essay, R.C.S. See also 'Brit. Med. Journ.,' 1894.

geon's best efforts at treatment? And it must be remembered that all the patients are young and probably healthy lads. It is no exaggeration to say that a compound fracture of the skull, if properly treated, is in itself of little importance compared with a compound separation of the lower epiphysis of the femur.

Of course, much better results are obtained when no wound has complicated the separation of the epiphysis. But even here there is very much to be desired. Thus, out of thirty-four cases which one of us observed or collected records of,—

Good reposition was obtained, and recovery with very useful or perfect limbs resulted in	19 (57%)
Imperfect (we may say very imperfect) reduction in	15 (43%)
Of these sloughing or suppuration followed in no less than	6
And every one of these required an operation:	
Amputation through the thigh in	4
Excision of the knee-joint	1
Resection of the end of the diaphysis	1

It should also be noted that in more than one of the cases in which suppuration did not follow, the backward displacement of the diaphysis produced such trouble from the pressure on the popliteal vessels, &c., that an operation had to be done (chiselling or sawing off the end). In one famous case (Sir C. Bell's) the projection of the diaphysis led to an aneurism of the popliteal artery by its pressure on the wall of the vessel. This occurred twenty years after the original separation of the epiphysis, and amputation then became necessary.

Those who have not encountered cases where the epiphysis has been completely displaced, and the diaphysis projected through the periosteal sheath, will hardly credit the extreme difficulty that may be met with under such circumstances in procuring reduction by traction and direct pressure in the extended position of the knee.

Many cases could be quoted in which repeated or prolonged attempts under anæsthesia have quite failed (in some of these amputation has been resorted to), and

many others in which reduction has been supposed to have been effected, but the displacement was said to have recurred subsequently. In the latter case it is safe to say that a proper reduction had never been made. We believe that such difficulty in reduction, even in compound cases, will be almost, if not quite, removed by the adoption of the full flexion treatment.

A few typical cases will here suffice.

In the well-known case recorded by M. Delens,¹ a boy aged eight had a compound separation of the epiphysis, the diaphysis projecting through the skin on the outer side of the popliteal space; prolonged efforts at reduction under chloroform proved unavailing, both on the day of accident and the following one, so that it became necessary to resect the end of the diaphysis by means of a saw.

In a case under the care of Dr. McDougall, of Carlisle, a man aged twenty had simple separation of the epiphysis; so much difficulty was experienced in effecting reduction that the attempt had to be abandoned, and as at the end of a month the skin had ulcerated over the projecting diaphysis, whilst no union had occurred, amputation was done.

In a case under the late Mr. Gay of a lad aged 13, there was protrusion of end of diaphysis through wound over popliteal space; failure of all attempts to reduce the displacement under anæsthetic; resection of diaphysial end necessary.

In a similar case under M. Reverdin,² although the projecting end was in part cut off, the reduction under full extension was evidently quite incomplete, since gangrene ultimately followed from thrombosis of the popliteal artery, due to pressure on it of the diaphysial end. M. Reverdin's account is a very full one; he candidly admits the imperfect reduction was to blame in the loss of the limb, and whilst he gives a good general review of the subject,

¹ 'Archives gén. de Médecine,' 1884, p. 272.

² 'Revue Médical de la Suisse Romande,' 1886, p. 291.

he makes no mention of any other position in the treatment than full extension.

In a case recorded by Hamilton,¹ a doctor's son sustained compound separation, and it was only after an hour's vigorous efforts on the father's part that some sort of reduction was effected. After some necrosis the boy recovered with a shortened leg and an ankylosed knee-joint.

It is unnecessary to extend the list further. Examples could be adduced where gangrene of the limb, and even death of the patient, has followed even in simple cases of this displacement, which have been either diagnosed wrongly, or forcibly and unavailingly manipulated in the extended position. Thus in the case of a boy aged thirteen, treated by M. Richet,² the diaphysis projected through a wound; reduction was effected (or supposed to be effected) by violent and prolonged traction and extension, with the aid of a spatula introduced through the wound. This instrument broke, and was replaced by forceps used as a lever. The displacement had recurred before the child's death on the eighth day from pyæmia.

A consideration of these facts must favourably incline surgeons to adopt any method which promises better results. From the cases we now bring forward we believe it will be found that all such violent manipulation is unnecessary, and that the resection of the diaphysial end will very rarely be required. Of course everything depends on correct diagnosis being made early, and unfortunately, owing partly to the belief that separation of the epiphyses is too rare an accident to be worthy of careful study, and to the wholly inadequate manner in which the subject is treated in most of the text-books, mistakes in the diagnosis are very apt to occur.

The skiagram from which the following figure was made was taken two months after complete separation of the lower epiphysis, and is of particular interest since the

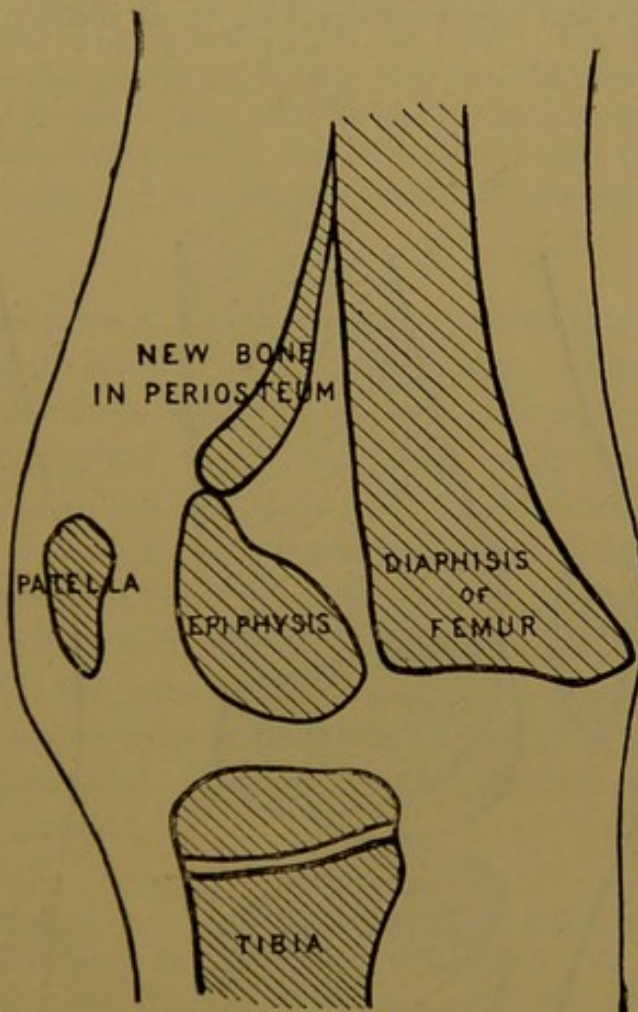
¹ 'Fractures and Dislocations,' p. 530.

² 'L'Union Médicale,' 1876, p. 426.

case had been under treatment in hospital during the whole of this time, and the extensive displacement had not been made out before the photograph was taken.

CASE 3.—William R—, a schoolboy aged 8, whilst riding on the back of a carriage got his right leg entangled in the wheel, and was carried round by it. He was brought to the hospital the same day,

FIG. 4.



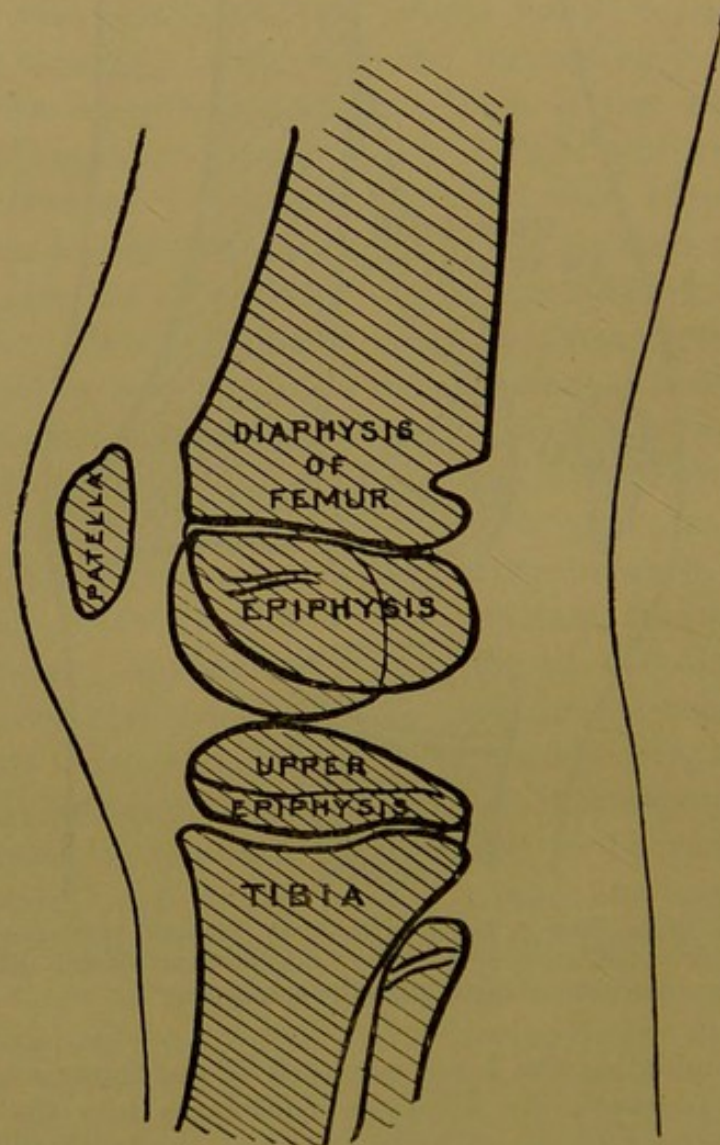
Skiagraph from Case 3, taken after two months' treatment with weight extension, showing backward displacement of the diaphysis with new bone connecting it with the epiphysis.

and on examination the lower epiphysis of the femur could be felt to project forwards, the diaphysis backwards into the popliteal space; abnormal lateral mobility and some creaking were present. The limb was put up in a box splint with weight extension; at the end of eight weeks, when the patient was up on crutches, a skia-

graph was made. This showed that the diaphysis only touched the epiphysis at the posterior edge of the latter. The epiphysis itself was tilted forwards, and running up from its upper border to the anterior surface of the femur was well seen the periosteum, which had already ossified, and was practically the only means of union between the two (see Fig. 4). It is remarkable that with so great a backward displacement the circulation in the popliteal vessels was not wholly obstructed. It was thought best to operate, especially since the power of flexion in the knee was very limited. There was then only one eighth of an inch shortening.

Accordingly Mr. Openshaw operated by an incision on the inner

FIG. 5.



Skiagraph from Case 3, taken seventeen months after the operation, showing that the new bone has formed an almost normal femur-end.

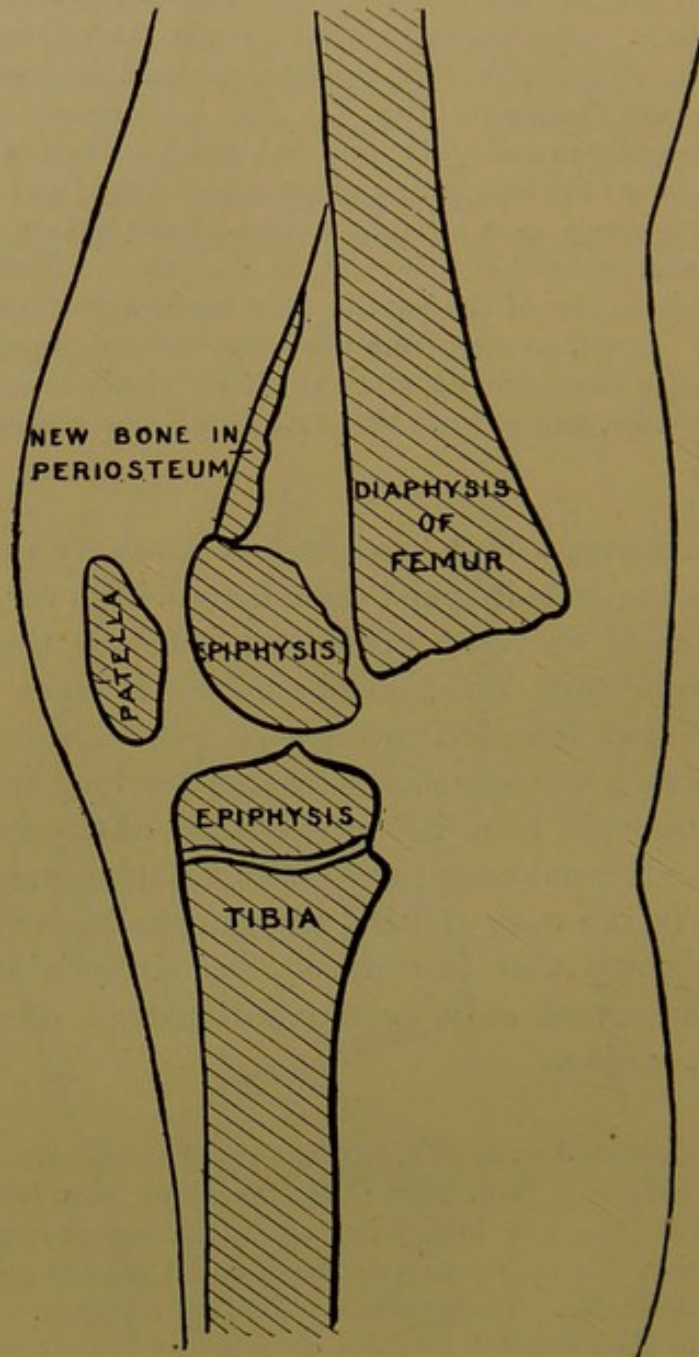
side of the outer condyle; one inch of the lower end of the diaphysis was chiselled off, so that the knee could be flexed to an angle of 140° . The wound healed perfectly, and the patient left the hospital much improved. This was in June, 1896. In November, 1897, seventeen months later, the patient was got up for inspection, and a second skiagraph made. This shows in what a really marvellous way the bone has been re-formed, so that hardly anything abnormal can now be noticed in the skiagraph (Fig. 5). The knee cannot be hyper-extended; he can run and walk well, but wears a thick sole on his boot to counteract the shortening of three quarters of an inch. The surface of the condyles is at right angles to the axis of the bone, but is displaced somewhat forwards, so that in full flexion of the knee the upper border of the patella only reaches over one third of the condyle. It will be seen from the above measurements that no arrest of growth has occurred, since the limb is only three quarters of an inch shorter, and at least this amount of bone was removed at the operation.

This illustrates a fact brought out strongly in a series of experiments on epiphysial detachment in lower animals made by one of us some years ago. It was then found that the epiphysial disc, consisting as it does only of columns of modified cartilage cells, is remarkably difficult to destroy, and will sometimes remain for long unaltered, although removed from its normal place at the end of the diaphysis. It would appear that this holds true perhaps even more in the case of man than in the lower animals. It may be noted that the life of the epiphysial disc in a rabbit is measured only by months instead of years in the human subject.

CASE 4.—Joseph J—, aged 9, had the right thigh run over by a van wheel, February 2nd, 1896. The accident was followed by much effusion into the knee-joint and swelling around it, and hyper-extension of the leg on the thigh could readily be obtained under an anæsthetic. There was no definite crepitus. The limb was treated in the extended position on a splint for six weeks, and after some time a positive diagnosis of separation of the lower epiphysis was arrived at. This was fully confirmed by the Röntgen rays. The accompanying reproduction of the skiagraph shows the epiphysis displaced forwards with the tibia, the diaphysis touching it only at one point and projecting strongly into the popliteal space (see Fig. 6). As the swelling went down the projection of

bone could be plainly felt. The boy was in hospital eighteen weeks. When he left he could walk fairly, but the power of flexion

FIG. 6.



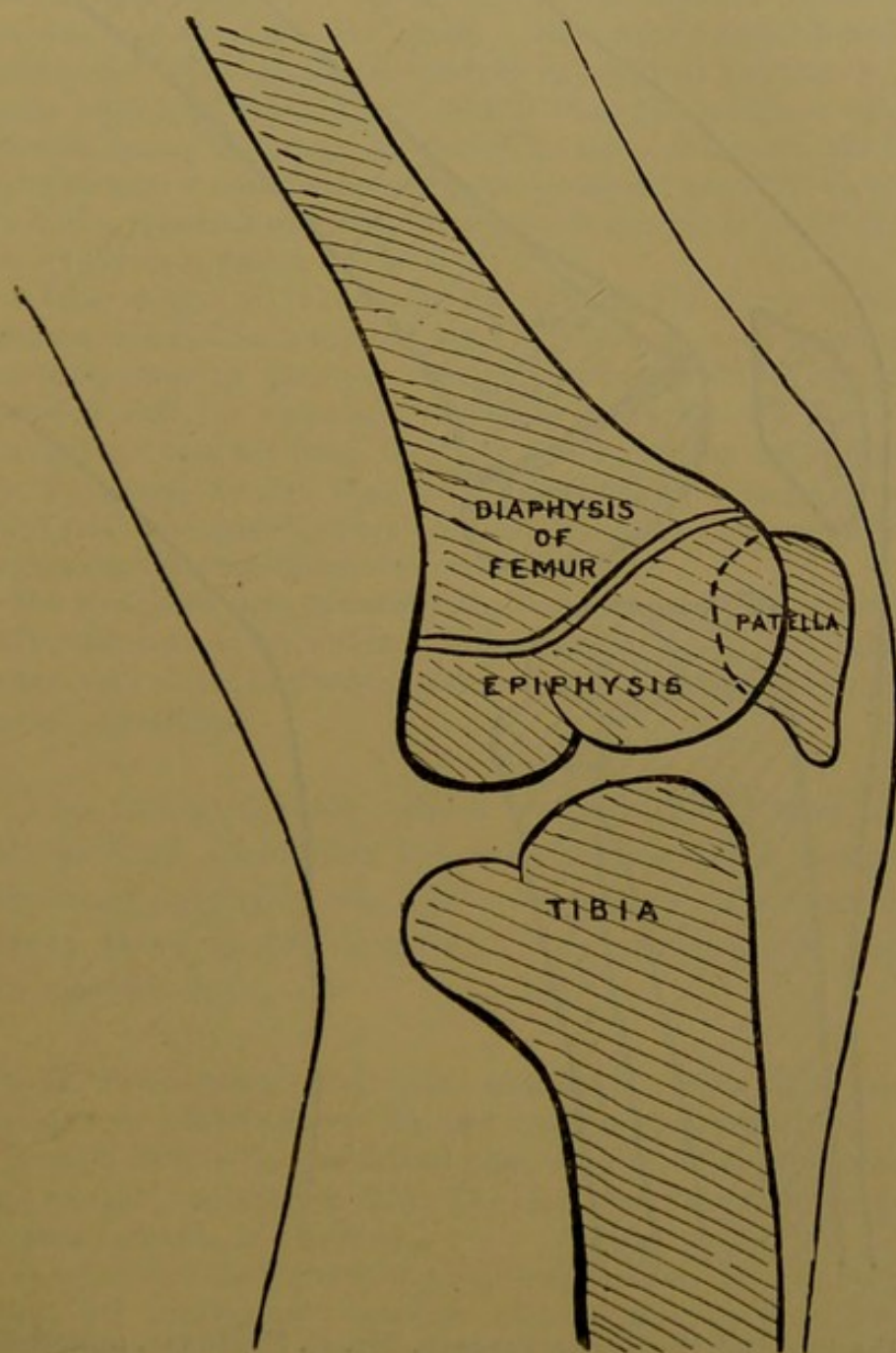
Skiagraph from Case 4, treated with weight extension, showing persistent backward displacement of the diaphysis.

was extremely limited, and some hyper-extension was present. It has been found impossible to follow up this patient.

The following case illustrated the excellent result to be obtained from the treatment by full flexion.

CASE 5.—Arthur W. M—, aged 11, was running behind a cab and attempting to jump up behind, when his right leg caught between

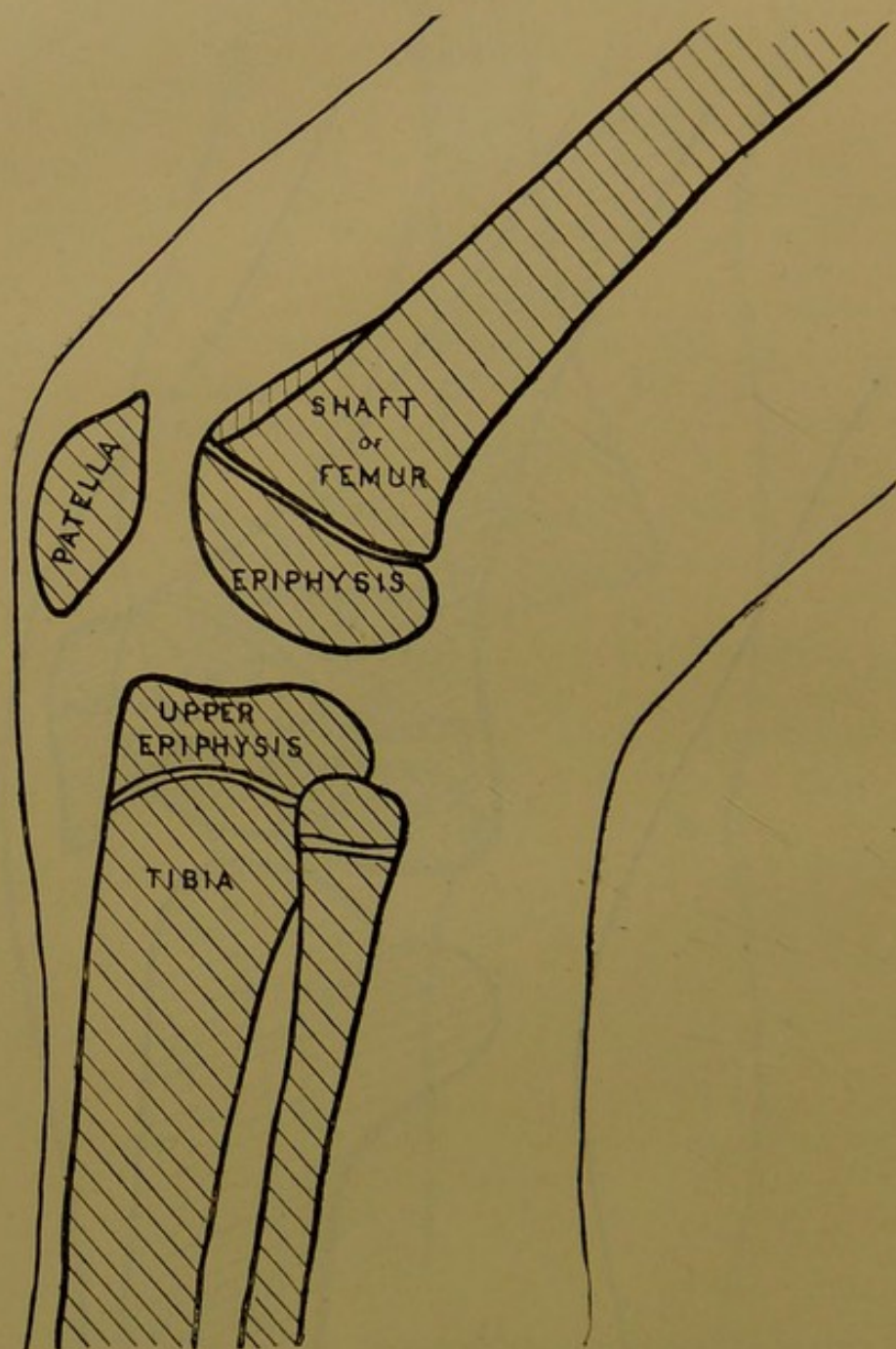
FIG. 7.



Figs. 7 and 8 show the result of treatment by full flexion in Case 5, the epiphysis being in perfect position.

the spokes of the wheel, and he was carried round by it until the vehicle was actually stopped by his limb catching against the spring. After the accident he was much collapsed. On admission

FIG. 8.



to the hospital the house surgeon, Mr. C. B. Howse, anæsthetised him and readily made out a complete separation of the lower epiphysis of the femur, the diaphysis projecting back into the

popliteal space. Traction was made on the leg in the extended position and kept up, while another person flexed the hip and knee by clasping his hands under the thigh and slowly elevating it. A soft leathery crepitus was felt. The limb was then fixed by a bandage in the fully flexed position, and an ice-bag applied over the flexed knee-joint.

A small dose of morphia was given, but there was no great discomfort after reduction. At the end of ten days the bandage was removed and the limb put up on a Macintyre's splint flexed to a right angle. The epiphysis remained in excellent position, and was firmly united at the end of a month from the accident, when he was sent out of the hospital. Before he left a skiagraph was taken, and although it was made somewhat obliquely (see Fig. 7), so that the bones appear a very peculiar shape, it can yet be made out that the epiphysis is well in position.

A later skiagraph, taken from the side (see Fig. 8), shows that the result could not be improved upon. It is necessary to emphasise the facts that in this case complete forward displacement had occurred, that the reduction was quite easily effected, that no inconvenience resulted from the fully flexed position maintained for ten days, and finally, that good union without damage to the epiphysial line speedily resulted. At the end of two months from the accident his condition was as follows:

The two limbs were of exactly the same length; he could run and walk well, and there was nothing abnormal about the right knee except very slight limitation of flexion and a little thickening above the epiphysial line.

The following case, which was under the care of Mr. Waren Tay, illustrates the ease with which a completely displaced epiphysis was got back into position and maintained there in full flexion. This position was kept up for sixteen days.

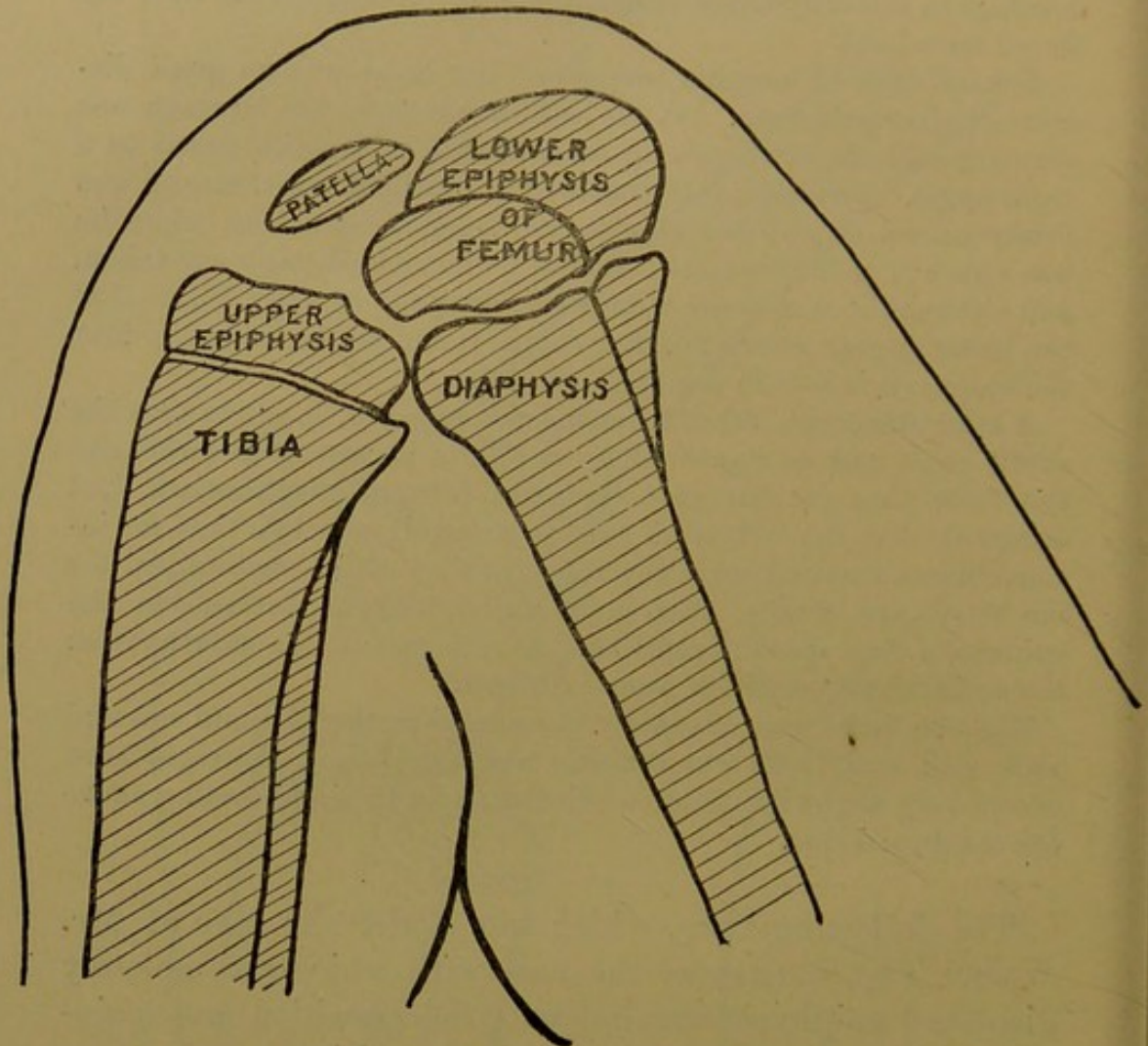
CASE 6.—History.—Fell down crossing a road, and a brougham passed over his left knee. He was brought on a stretcher.

Present state.—The femur had gone back into the popliteal space, and was just beneath the skin. The tibia with the epiphysis was dislocated forwards and rotated.

Treatment.—The patient was put under ether, and the leg pulled upon and rotated into position. The thigh was then gradually flexed upon the belly whilst extension was still kept up on the leg until the knee was fully flexed, when it was fixed in that position by a bandage applied round thigh and leg. It was then placed upon

its outer side on a pillow. Morphia one sixth grain given. The arteries of the foot were watched; Lotio Plumbi applied to the knee.

FIG. 9.



Skiagraph from Case 6, taken shortly after reduction of the displacement by full flexion of the knee.

October 1st, 1897.—Great swelling and ecchymosis, especially in popliteal space. A skiagraph was taken a day or so after the accident (see Fig. 9). The swelling gradually went down.

15th.—The leg was taken down and put up on a Macintyre at a right angle. It had been totally flexed for sixteen days.

The Macintyre was then gradually opened until it was in a week or so quite straight.

It is of especial interest to follow up cases of separation of this epiphysis years after the accident has occurred,

but few records of such observations have been published. We are fortunately able to give four such cases besides the one described already (Case 1).

CASE 7.—Charles G—, aged 14. December 18th to March 31st, 1888. In hospital 103 days, with compound fracture of skull and separated lower epiphysis of right femur.

History.—Fell down a lift hole 30 to 40 feet.

Examination.—Right leg, some effusion (probably blood) into knee-joint. Right anterior superior spine to internal malleolus = $25\frac{2}{5}$ inches; left = $27\frac{2}{5}$ inches, hence 2 inches shortening.

During the night and next morning he complained of a good deal of pain in the right leg and foot, which was very markedly colder than the left one, though pulsation could be detected in both anterior and posterior tibial arteries at the ankle.

December 19th.—Right knee 14 inches round; left knee $11\frac{3}{4}$ inches round.

Right leg.—Distinct lateral movement under anæsthetic. The lower border of projection behind is most prominent on the outer side and level with the tubercle of the tibia, and runs in a regular line for about three inches across the popliteal space.

This abrupt projection is evidently the lower end of the diaphysis, and it does not appear to move with the leg on moving that laterally, whereas the epiphysis (whose upper margin corresponds to about the upper margin of the patella) distinctly moves with the leg. No rotation or flexion of the epiphysis can be made out, though of course an exact examination is difficult owing to the swelling.

The knee being somewhat flexed, steady extension was made on the leg whilst the end of the diaphysis was pressed forwards. At first no yielding was obtained, but after a few minutes the diaphysis was felt to return into its place with a cartilaginous "rub," no bony crepitus whatever being felt. On measurement the limb was found to be 27 inches. It was then put upon a Macintyre splint flexed at an angle of 150° .

22nd.—The posterior tibial pulsation is much more vigorous in the right leg than before. There seems to be still some tendency for the diaphysis to be displaced backwards, but it is very difficult to be sure of this, owing to the effusion of blood into the knee-joint lifting up the patella. Ice-bag still applied to knee.

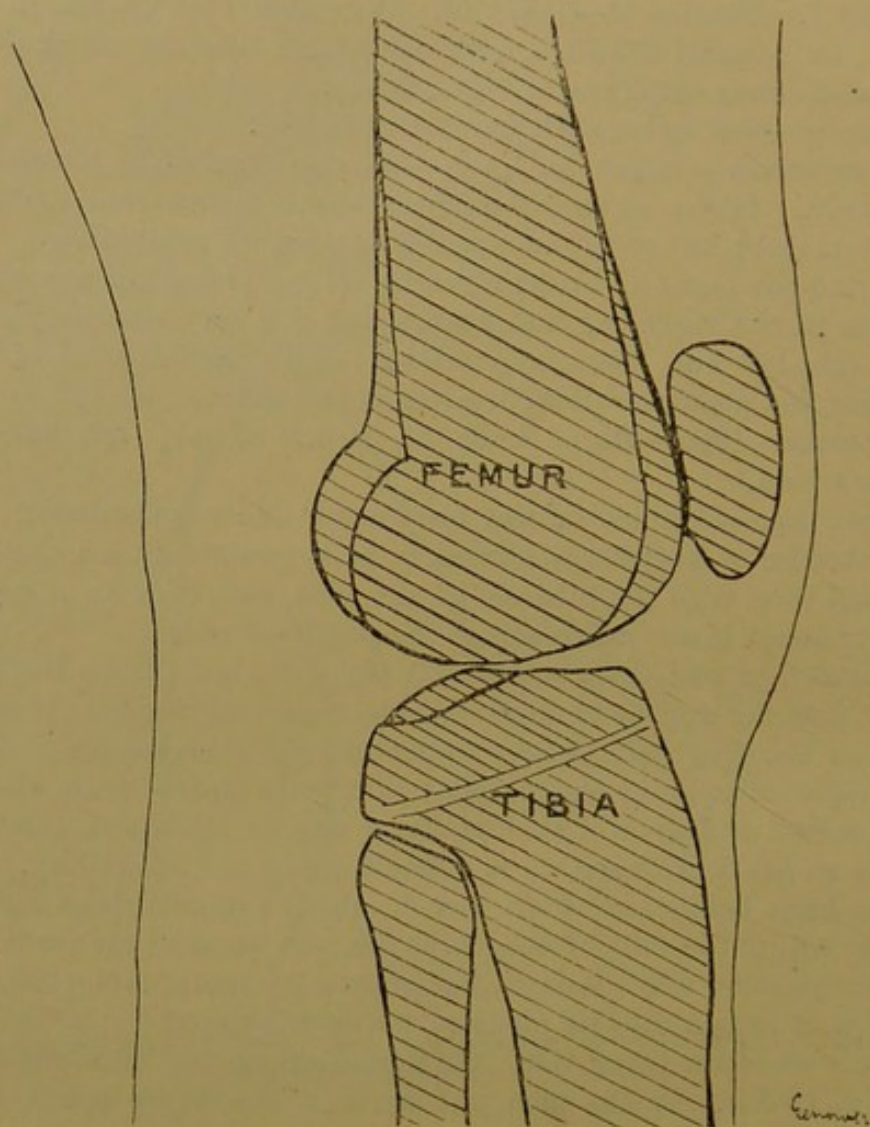
January 4th.—Leg taken down from splint, each measures $26\frac{1}{2}$ inches, no shortening, but a little increase of circumference ($\frac{1}{2}$ inch). No displacement detected; the union already seems very fair.

29th.—One third inch or a quarter inch increased circumference in right knee, due to thickening round the bone; both legs precisely

the same length; can flex knee to a right angle, beyond this some pain.

The patient was examined by Mr. Barnard in Feb., 1898, and a skiagraph (Fig. 10) taken. The epiphysis of the femur has com-

FIG. 10.



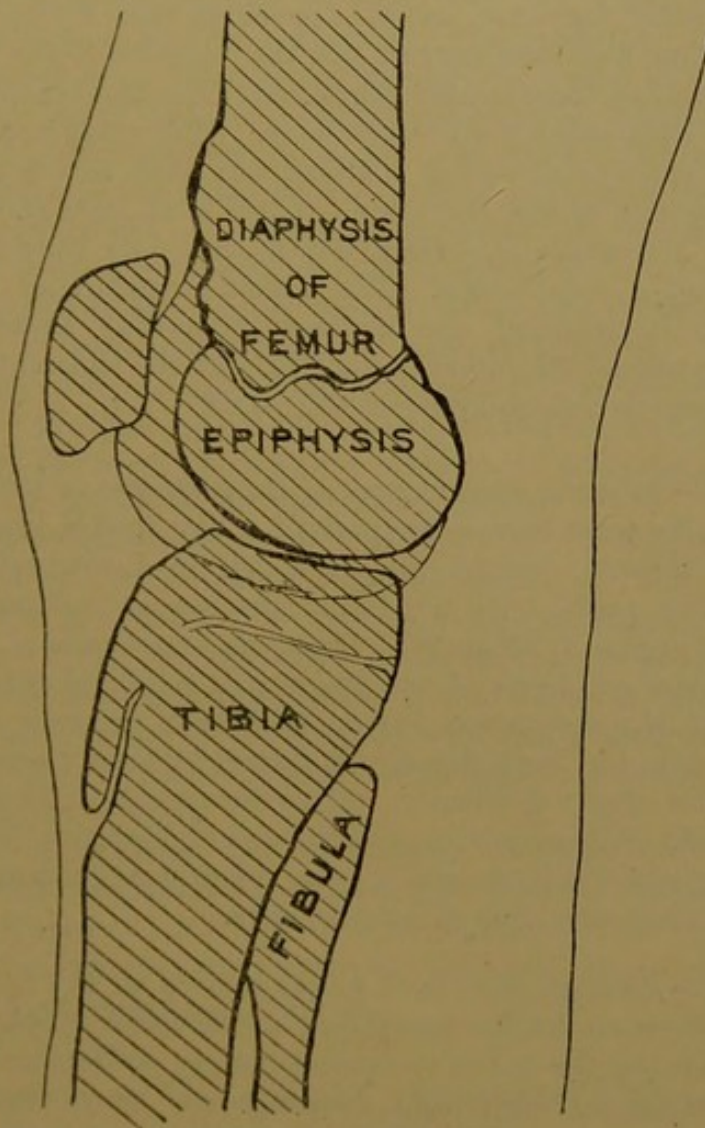
Skiagraph from Case 7, obtained ten years after the accident. The epiphysial line of the femur has become obliterated.

pletely fused with the diaphysis without the least sign of displacement. As the upper epiphysial line of the tibia has not yet disappeared it is certain that the accident has resulted in somewhat premature fusion. This is confirmed by the fact that there is one inch shortening of the right lower limb, at least three quarters of which is in the femur. This shortening has led to slight scoliosis and obliquity of the pelvis; the right thigh is half an inch smaller

in circumference than the left. Flexion and extension of the knee are perfect, and he walks and runs well. He is engaged as a painter, and does much kneeling. Since the accident, ten years ago, he has twice had synovitis in that knee-joint.

CASE 8.—Separation at age of 12; examined at age of 17. E. H— was admitted into the London Hospital for complete dis-

FIG. 11.



Skiagraph from Case 8, obtained six years after the accident. There is some irregularity of the diaphysial end.

placement of the lower epiphysis of the femur, which was reduced under an anæsthetic, and the limb put up on a Macintyre splint,

bent to a right angle. The accident had occurred when he was carrying three boys on his back, the left leg giving way at the knee. This was on the 9th of July, 1892. There was synovitis requiring the use of an ice-bag for a long time. Two months after the accident the limb was gradually extended, and passive motion employed; this caused a return of the swelling; there was then half an inch shortening of the limb. By October 6th he could walk a little, using crutches; but on the 17th the knee was still very much bent, and he limped. He was in the hospital in all seventeen weeks. It seems certain from the shortening that the displacement was not wholly corrected, and it is probable that if the treatment by full flexion had been carried out the duration of the treatment would have been considerably shortened. He was examined again February, 1898—nearly six years later. The skiagraph (Fig. 11) shows the epiphysis in good position, but some new bone in front of the lower end of the diaphysis. There is an inch shortening in the limb. Extension is perfect, but he can only bend the knee a little beyond a right angle. The articular surface of the femur appears to be widened and twisted outwards; there is some thickening behind the internal condyle, and the shortening has led to some scoliosis and obliquity of the pelvis.

CASE 9.—*Outward displacement of the epiphysis in 1889; patient examined nine years later.*—The patient, a boy aged 8, when running behind a hansom, caught his right leg in the wheel, and was dragged fifty yards. On admission the leg was abducted at the knee to an angle of 30° or 40° . Under an anæsthetic it was found that the lower epiphysis of the femur was displaced outwards, and a soft kind of crepitus was felt on reduction. A back splint was applied, with the knee flexed. A fortnight later there was still swelling and slight deformity. After four weeks a Croft's splint was applied. When examined at the age of eighteen there was no shortening, and the limb was in every respect as good as the other one. The skiagram showed no deformity.

CASE 10.—George H—, aged 6, was treated in the London Hospital for seven weeks for separation of the lower epiphysis of the right femur, but the notes are unfortunately so deficient that it is enough merely to state that twelve years later there was no shortening, and the limb was in every respect as good as the other one.

In the following two cases, which occurred in 1888 and 1890, it has been impossible to trace the patient, but they are of sufficient intrinsic interest to be included.

CASE 11.—Alfred F—, February 17th to April 18th, 1888. In hospital sixty-eight days.

Left femur fractured; right lower epiphysis of femur separated; left humerus, simple fracture at the middle; sternum fractured in lower third.

History.—Caught his coat in engine band; brought in stunned. (We omit the notes which do not relate to the epiphysial separation.)

Right femur.—Knee-joint kept somewhat flexed on a Macintyre splint; considerable effusion into the joint, but less than there was; patella floats in its normal position, but can readily be pressed backwards so as to rest on the front of the condyles. It is impossible to say whether there is any shortening, owing to the fracture of the other femur and the different positions of the thighs, but at present the measurement from the ant. sup. spine to the lower border of the patella is the same on both sides. There is considerable bruising on the back of the knee on the outer side, just over as well as below a marked projection of bone which appears to be connected with the shaft of the femur, possibly being the lower end of the diaphysis; at present it is only just beneath the skin. The axis of the limb does not seem to be much altered, but following down the shaft of the femur it appears to incline backwards, and on pressing gently on it movement is communicated to the projecting fragment. Pulsation can be felt in the post. tibial artery.

March 1st.—Splints removed from right leg. Abrasion on outer side painted with collodion and iodoform paste.

22nd.—Mr. McCarthy, now that he is able to examine both legs and compare them, thinks there is no doubt that the process of bone to be felt on the right side, which at one time was taken for the separated head of the fibula, is really a process connected with the external condyle of femur, proving the diagnosis of separation of the lower epiphysis correct.

April 18th.—Patient was discharged. He can walk about on crutches with comparative ease, and uses the left leg, the femur of which was fractured; but the right leg is more or less useless; the right knee is much larger than the left, and the piece of bone mentioned above can be plainly felt.

CASE 12.—Arnold S—, aged 10. In hospital forty-four days—September 20th to November 3rd, 1890.

History.—Accident on the morning of September 20th. He was climbing on to the back of a trolley, with his feet on the axle, when the trolley moved forward. His right foot was caught in the spokes of the wheel, and his leg was pulled very violently, so that he fell to the ground.

Present condition.—One inch shortening on the right side, measured from ant. sup. spine to the lower border of the patella. The leg is bowed outwards; the diaphysis projects outwards, and its lower end is felt as a rounded mass about one inch above the head of the fibula. The epiphysis can be distinctly felt on its inner side. There is a well-marked concavity on the inner aspect and convexity on the outer.

Treatment.—The leg was put up on a Macintyre splint, with the knee flexed and an ice-bag applied after an anæsthetic had been given, and reduction effected with the knee flexed without material difficulty.

October 27th.—Patient has been kept in bed, the leg having been on a Macintyre splint, and he has progressed favourably.

28th.—Good movement of knee. Each leg measures 26 inches, and there is perhaps slight displacement of the diaphysis backwards.

CASE 13.—An additional opportunity of testing the method advocated has been afforded by a patient aged 10, in the London Hospital, under the care of Mr. Mansell Moullin. Whilst riding behind a cab the boy caught his left foot in the wheel and was swung round, sustaining concussion and a complete separation of the lower epiphysis of the left femur. The diaphysis could be felt in the lower and outer part of the popliteal space nearly as low as the head of the fibula. There was shortening of $1\frac{1}{2}$ inches and much effusion of blood into the knee.

Treatment.—Extension was made on the leg, whilst the lower end of the diaphysis was drawn forwards so as to flex the knee-joint; when the heel touched the buttock it was fixed in that position by straps and a bandage. During the next ten days the limb was kept in this position, resting on its outer side on a pillow, and *there was no tendency to displacement, although the boy was restless and delirious for several days* as the result of the concussion.

An ice-bag was applied to the knee-joint. At the end of the ten days the limb was taken down and placed in a Macintyre splint flexed to 130° .

At the end of four weeks the limb had been gradually extended; two weeks later the knee could be fully flexed and almost completely extended. After being up in gum and chalk for some further period slight stiffness remained, but promised to wholly clear off under massage, &c.

The two limbs were exactly the same length, and the left knee was only one third of an inch greater in circumference than the right. This case was throughout under the observation of Mr. Barnard, and we are indebted to Mr. Mansell-Moullin for permission

to test the treatment and to record the result. Owing to the extreme displacement and the complication of the head injury, it furnished a specially good test of the full flexion method, and the result left nothing to be desired.

CONCLUSIONS.

1. That separation of the lower epiphysis of the femur is a very serious injury, attended when compound by a high mortality.

2. That in the extended position of the knee even with an anæsthetic reduction of the fragment is often very difficult.

3. That when treated by extension and a long Liston's splint it is almost impossible to keep the fragments in position, and with a Macintyre splint it is sometimes difficult.

4. Nevertheless the ultimate result, in most cases that recover at all, is very good. The articular surface of the femur gradually grows into a useful position.

5. That with the method advocated by us reduction is always easy, the time of treatment is short, and it is the rule to obtain perfect movement in the knee without shortening or deformity of the leg.

(For report of the discussion on this paper, see 'Proceedings of the Royal Medical and Chirurgical Society,' Third Series, vol. xi, p. 29.)

