PNEUMOARTHROGRAPHY OF THE KNEE JOINT WITH PARTICULAR REFERENCE TO THE SEMILUNAR CARTILAGES

BY

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PREFACE

The investigations recorded in this volume were carried out during my term of service as Assistant Radiologist at the Copenhagen County Hospital in Gentofte.

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Aalborg, February 1948.

Kjeld Andersen.

CONTENTS

HISTORICAL INTRODUCTION

In spite of considerable progress during the last decades, clinical diagnosis of traumatic lesions affecting the inside of the knee joint is still in a stage which justifies a search for new methods of examination to improve the diagnostic security in these cases.

The development of clinical diagnosis goes from *Hey*'s formulation of the term "internal derangement" at the end of the 18th century, proceeding to the German "Binnenverletzungen" about 1900, to the present time's fairly precise diagnoses of the various injuries to the soft parts of the knee: lesions of the semilunar cartilages, ruptures of the cruciate ligaments, loose bodies and traumatic changes in the fat pad.

Of greatest importance are the tears of the semilunar cartilages, because they are so common. There is some difference of opinion as to the inaccuracy of their diagnosis, *Schaer* (1938) stating the percentage of error upon clinical diagnosis alone to be 20 per cent, whereas *Stark* (1941) considers it to be higher.

It is, therefore, natural that efforts have been made to arrive at more precise methods of examination.

Among these experiments auscultation is worth mentioning. It has been advocated by *Bircher* (1913) and also used by *Schaer* (1938). The latter maintains, however, that the method demands immense personal experience, if it is to be used with fair accuracy, and that it is, therefore, hardly the method of the future.

Arthro-endoscopy was thoroughly tested by *Bircher* (1923) but he was disappointed in it, because the visual field was too small.

Little is to be gained by plain roentgenography in the diagnosis of changes in the soft parts of the knee. They become visible in rare cases only, when it is a question of calcification, for instance of the semilunar cartilages. Such cases have been published by *Werwart*

(1928), *Bruchholtz* (1929), *Rubaschow* (1929), *Henrichsen* (1932), and *Hilgenreiner* (1932).

According to *Schaer* (1938) rupture of a semilunar cartilage may in rare instances, if the cartilage has become wedged between the articular surfaces, press the latter so far apart that X-ray reveals a gaping joint space. This arouses a suspicion of rupture of the semilunar cartilages, but there cannot be any question of exact diagnosis. The significance of plain roentgenograms in affections of the semilunar cartilages is, therefore, exclusively of an indirect nature. It is capable of revealing certain conditions with a symptomatology exactly resembling that of a tear in the semilunar cartilages (osteochondritis dissecans and fracture of the spine of the tibia).

Finally there is the method of arthrography endeavouring to visualize the soft parts of the knee joint on the roentgen film by injection of contrast media into the joint cavity. This is a rather old method of examination. Not more than about 10 years after the invention of the roentgen rays *Werndorf* & *Robinsohn* (1905), *Wollenberg* (1906), *Hoffa* (1906), and *Rauenbusch* (1907) published the first attempts at using inflation with oxygen. Since then the method has been constantly developing, particularly during the last 15 years. At the outset interest was centred on finding suitable contrast media, but later, when it was realized that this was not the only factor decisive to the development of arthrography, on the technique.

As regards the choice of contrast media, various courses have been followed, four principles being employed:

I. Filling of the joint cavity with gaseous substances (oxygen, nitrogen or atmospheric air), i.e., negative contrast media.

II. Massive filling of the joint cavity with positive contrast media.

III. Injection of small amounts of contrast medium (2-10 ml.).

IV. Simultaneous application of positive and negative contrast media, i.e., a combination of Methods I and III.

As already mentioned pneumoarthrography is the oldest method which, however, fell into discredit almost immediately, in part because of its inaccuracy and presumably in part because of a death (air embolism) among *Hoffa*'s patients. The case was not, however, published by *Hoffa* or his collaborators, but it is mentioned by *Bircher*

(1929) and *Ulrichs* (1930) both of whom resumed the method without succeeding in obtaining satisfactory roentgenograms of the semilunar cartilages.

Schum (1933) has done much in the field of pneumoarthrography. The reason why *Schum* adopts this method of examination is probably sooner the large number of patients referred to his department with injuries to the semilunar cartilages, compelling him to do something, than the anticipation of any diagnostic aid from the well-known and often rejected method. *Schum* has his own way of performing it. Instead of complicated instruments for the injection (*Wollenberg* & *Bircher*) he employs an ordinary record syringe and his contrast medium is ordinary atmospheric air injected in rather large quantities (100-120 ml.). Using this procedure *Schum* has not seen complications, either in the form of infection or even a hint of symptoms of air embolism. His results are encouraging, particularly with regard to the diagnosis of injuries to the semilunar cartilages. *Schum* would not do without this method, but he also states that it demands great experience, there are numerous sources of error, and he who adopts this method of examination will not be spared erroneous diagnoses, particularly in the beginning.

Stark (1941) has performed 157 pneumoarthrographies without complications of any kind. He maintains that his results could not possibly have been obtained by clinical methods. Lastly, *Kromer* (1942) emphasizes pneumoarthrography as the best of the methods available.

Colp & *Klingenstein* (1925) and *Borak* & *Goldhammer* (1927) were the first to report arthrography with liquid contrast media. For this purpose they employed solutions of potassium iodide (10 and 20 per cent.). In 1927 *Sievers* recommends iodipin (40 per cent.) as a contrast medium. *Sievers* particularly studied the hip joint and employing the contrast oil mentioned he obtained satisfactory details about the anatomical construction of this joint in various conditions, e.g., congenital dislocation of the hip. *Kreutscher* & *Kilikian* (1930) also report the use of contrast oil. For diagnostic purposes they injected iodized oil into the knee joint in 7 cases and into the hip joint in 3. They mention a favourable therapeutic effect of the injection. The mobility improves and the pain subsides. The subsequent year *Knoll* & *Mathies* (1931) report some experiments of intra-articular injection of large quantities (about 70 ml.) of iodipin (20 per cent.) on cadavers.

Burmann, Tunich & *Pomeranz* in 1932, sounded a warning against employing injection of lipiodol and other iodized oils into the joints, partly because the diagnostic result was slight and partly because it caused violent pain in the joints. The pain persisted for 12 hours and then subsided gradually in the course of 2 to 10 days. A total of 13 patients were thus examined. Permanent injury was not observed.

Kobes & *Militzer* (1928) state that years after the injection the contrast could be demonstrated in the knee joint. After that arthrography with contrast oils must be considered of no value, and later individual reports of intra-articular injections have been made exclusively for therapeutic purposes (*Forestier* (1933) and others).

During the progress made in chemical research for the benefit of urology in the late twenties and early thirties several water soluble contrast media (uroselectan, abrodil and perabrodil) were added to those already known. They were harmless to the organism and were discharged in an unsplit state in the urine. It was not long before these substances were used also for the contrast filling of joint cavities.

In 1931 *Michaelis* recommends uroselectan (strength not stated) as a particularly suitable medium for arthrography on account of its comparatively mild irritating effect and its quick absorption (3-5 hours). This procedure cannot, however, have been quite painless for the patients. In one of his 12 experiments *Michaelis* had to remove the contrast medium quickly because of intolerable pain and in other instances there was intense burning and exudation. *Nagy* & *Polgár* (1932) also used uroselectan at first, but abandoned it quickly for abrodil. Uroselectan caused pain, elevation of temperature and swelling, whereas injection of abrodil (20 per cent.) in quantities of 15-20 ml. on the whole failed to cause any reaction. *Epstein* (1931) using abrodil 40 per cent. agrees with *Nagy* & *Polgár*: he has not observed complications the 7 times he has used abrodil. *Schüller*'s (1932) experience with abrodil (20 per cent.) is based on 50 cases. He states that the injection is always followed by exudation and pain, subsiding in the course of 5-6 days. A temporary elevation of temperature is not either rare, in one case it reached 39° centigrade. *Boyd* (1934) uses an aqueous jopax solution (30 per cent.) in rather large quantities from 20 to 40 ml. and has not observed complications with this method. He warns, however, against the use of much larger quantities, not more than 60 ml. should be used because of the risk of rupture of the articular capsule. In this connexion he refers to the report of *Colp* & *Klingenstein* (1925) stating that injection of 100 ml. fluid does not seldom result in suprapatellar or postcondylar rupture of the capsule. *Lagergren* (1934) has made special studies of the effect of perabrodil upon the knee joint. Injection of 30 ml. of perabrodil (17.5 per cent.) resulted in quite some exudation and correspondingly rather severe pain. A quantity of 20 ml. of the same dilution resulted in much less marked symptoms in the form of mild pain setting in 3-5 hours following the injection and subsiding in the course of 6-8 hours. He also observed a small exudate, disappearing in the course of 4-5 days.

Furthermore, *Lagergren* made cytologic studies of joint exudates before and after injection of perabrodil. He found that the mononucleosis usually present in effusions of traumatic origin was transformed by the contrast medium to an equally marked polynucleosis, disappearing and replaced by the original mononucleosis in the course of 10-14 days. In other words perabrodil, in the concentration (17.5) and quantity (20 ml.) used by *Lagergren,* causes a mild, transitory and harmless irritation of the synovial membrane and formation of an exudate attended with mild subjective discomfort. *Lagergren* prefers liquid contrast media to gaseous, because they give good radiograms, are easy to handle, only requiring a syringe and a needle which may be removed immediately after the injection because of the quick absorption of perabrodil. Lastly, liquid contrast media rule out the risk of air embolism.

In practice *Lagergren*'s investigations applied particularly to the semilunar cartilages and his experience is based on 30 arthrographies of the knee joint. Great experience is required to interpret the roentgenograms. This applies particularly to the lateral cartilage the situation of which is extremely varied in relation to the popliteus tendon. The method has proved valuable in several cases where clinical examination has left a doubt, but the material is too small to form a basis for any decisive judgment.

Bircher & Oberholzer (1938) report experiments with lipiodol, iodipin, uroselectan, abrodil, perabrodil, and thorotrast. They arrive at the result that 2 considerable faults attach to massive filling of joint cavities. The rather large amounts of contrast medium irritate the synovial membrane, causing the patient pain, and the massive contrast shadows make the interpretation of the roentgenograms difficult. Therefore, *Bircher & Oberholzer* reject this procedure which on the whole appears to have been completely abandoned.

When the method of filling the joint cavity with massive contrast medium, oils or aqueous solutions, failed to give satisfactory results, attempts were made at progressing further by means of modifications.

Böhm (1933) was the first to propose injection of contrast media in quite small amounts.

Böhm employs the water-soluble uroselectan B (35 per cent.) which has been specially made for arthrography at *Böhm*'s initiative. In the small quantities used by him (2.5 ml. for an adult knee joint) it causes no reaction. In order that the contrast medium may become distributed all over the inner surface of the knee joint *Böhm* recommends a series—30 to 40—of movements of flexion and extension. The method marks a progress. Now it is actually possible, *Böhm* maintains, to visualize important details, particularly of the cartilage lining of the articular surfaces, partly the semilunar cartilages and also foreign bodies, if any.

Rejecting pneumoarthrography and massive filling of the joint *Buckart* (1933) advocates *Böhm*'s method which has given him good pictures and caused no discomfort to the patients. It is still difficult to see the semilunar cartilages, but the use of uroselectan B in small amounts is an indubitable step forward.

In 1933 *Stör* reports his results from *Böhm*'s method. He feels convinced that *Böhm*'s method is better than those of *Bircher* or *Schum* and, in addition, it is much simpler.

Stör has examined 33 knees and one elbow joint, but he only states details in 12 cases of knees operated upon for injuries to the semilunar cartilages. In 9 of these 12 cases it was possible to make an exact diagnosis, with regard to the nature as well as the site of the rupture, in 2 cases it was realized that the cartilage was torn, but it was impossible to afford details about its kind and site. In 1 case the examination was a complete failure, the tear could not be seen.

Stocker (1935) has used the method of *Böhm* in 50 cases and has never observed discomfort or mishaps which only occur if large amounts, 20 ml. or more, are injected and the medium is not uroselectan B. There are other advantages of uroselectan B. It spreads quickly and easily all over the inner articular surface and is absorbed quickly—in the course of ½ to 1 hour the contrast has completely disappeared.

The method has proved of special value in cases of injuries to the semilunar cartilages, particularly in those remaining doubtful after the clinical examination. In a few cases it has also been possible to demonstrate injuries to the cruciate ligaments.

In his department in Zürich *Schaer* (1938) employs the method of *Böhm* in a slightly modified form. He injects 3 ml. of panthesine solution, ½ per cent., into the knee joint followed by 4-5 ml. of uroselectan B. This dilutes the contrast medium which thereby amounts to 7-8 ml. This procedure is usually completely painless and the quantity used is sufficient to line the internal relief of the knee with a fine layer of contrast medium after 30-40 movements of the joint. *Schaer* is not at all satisfied with the results obtained and is therefore unable to share the view advanced by several authors that arthrography should be an accurate method for diagnosing injuries to the semilunar cartilages. Still, he adds that for the time being *Böhm*'s method must be considered the best one, and he feels convinced that it can be developed further.

Lindblom (1940) uses perabrodil (35 per cent.) in quantities of about 10 ml. which he tries to distribute in the knee joint, partly by movements, partly by compressing the suprapatellar bursa with a tight bandage. The roentgenograms are taken as soon as possible after the injection because of the rapid absorption. Sometimes the patient will complain of mild pain a quarter of an hour or half an hour after the injection, but no other complications have been observed.

In this manner he has performed 74 arthrographies, and 43 times a diagnosis of injuries to the semilunar cartilages was made. Of the patients 27 were operated upon and the X-ray findings were verified in the 25. The diagnosis was wrong in only 2 cases.

In 1944 *Lindblom*'s material comprises 2000 cases among whom 481 were operated upon. The percentage of error is only 2, whereas it was 9 in the cases diagnosed by clinical examination and not submitted to arthrography prior to the operation.

Attempts at improving the method of arthrography by the simultaneous use of positive and negative contrast media appear to have been made for the first time in America by *Colp* & *Klingenstein* (1925). Their method was irrigation of the knee joint with a 10 per cent. solution of potassium iodide followed by inflation with air. They expected some of the contrast fluid to line the tissue surfaces with a fine layer which then would present itself on the films more distinctly when the joint had been inflated by the air. This method did not, however, become practicable until it had been improved by *Bircher*. It was briefly reported in 1931 and later in more detail at the Congress of German Surgeons in Berlin 1933.

Employing strict aseptic precautions 2-7 ml. of abrodil or perabrodil were first injected and distributed in the knee joint by means of passive movements. This was followed by injection of oxygen, slowly and at low pressure, until the patient experienced a slight feeling of tension. After the examination the air was removed.

At that time (1933) *Bircher* had performed the examination in 700 instances. The complications were few and unimportant. A few times the contrast medium had been injected into the soft parts, but this did not give rise to further complications, and in a few other cases there was a transitory mild hydrops. As to the results *Bircher* states that it has been possible to discern loose bodies, incrustations of synovial folds and pathological changes in the popliteus bursa. The interpretation of changes in the semilunar cartilages was more difficult because of the numerous outlines intersecting at various angles, but in cases where the clinical diagnosis has left a doubt, it has often been possible to arrive at a precise diagnosis. Total tear of a cartilage with dislocation, bucket handle fracture, was easiest to recognize. Tongue-shaped fringes were also demonstrable in the form of abnormal soft-tissue shadows. Localized longitudinal tears, on the other hand, were usually impossible to discern. The lateral cartilage was more difficult to interpret than the medial one, but several times *Bircher* succeeded in diagnosing tears in that site all the same. He is of opinion that lateral tears are more common than assumed earlier. Although the method has failed in a certain number of cases, it still constitutes no small progress which can be developed further.

On the basis of *Bircher*'s paper *Mandl* (1933) did not find the method so promising and in order to elucidate the problem further he made experiments on the cadaver. These experiments confirmed his scepticism. It should be mentioned in this connexion that *Bircher* himself had made experiments on the cadaver during the years 1930 and 1931. His results were the same as *Mandl*'s, but he maintains that this is due to the fact that the joint capsule of the cadaver exhibits a very different condition from that of the living subject. It is less yielding and cannot be filled to the extent necessary to obtain satisfactory roentgenograms. *Hetzar* (1935) and *Laarmann* (1937) recommend the method of *Bircher*. In Denmark a report was given in 1937 by *Scheibel* who has chiefly studied the technique. Instead of oxygen *Scheibel* employs nitrogen monoxide, introduced by *Teschendorf* (1936), a gas which diffuses more rapidly. The information gained by the examination applies mainly to the semilunar cartilages, *Hoffa's* fat pad, the thickness of the articular cartilage and the synovial folds. *Scheibel* is in no doubt that continued use of the method will mark a step forward.

In 1938 *Oberholzer* reported his experience with *Bircher*'s method in a monograph called "Röntgendiagnostik der Gelenke Mittels Doppelkontrastmethode" containing a number of illustrations of torn semilunar cartilages and other pathological conditions of the knee joint. These roentgenograms are so clear and beautiful, that an admiring reader will invariably get the feeling that the problem of arthrography has been solved. *Oberholzer*'s material comprises more than 2.000 arthrographies. He gives no numerical statement of the results obtained, but, as *Bircher* writes in the foreword, one must be convinced by the illustrations.

Karcher (1940) uses 3-4 ml. of uroselectan and about 2 ml. of air. In his 40 operated cases he has compared the accuracy of the clinical and the arthrographic diagnosis and found 31 correct clinical against

22 correct arthrographic diagnoses. He, therefore, considers the method to be of small value.

In spite of the numerous experiments with various contrast media, it is still an open question which is the most suitable medium for arthrography. Among the chief reasons for this one might vènture the following: An investigator adopting the method with some contrast medium or other, perhaps chosen by mere chance, will become so used to this particular medium in the course of a short time that any attempt at trying other contrast media will disturb and reduce the diagnostic accuracy. Therefore, such attempts will quickly be abandoned for the original contrast medium. It follows as a natural consequence that the investigator in question will recommend the contrast material used by him as the best one. Another and equally important reason is the fact that the quality of arthrography depends less on the kind of contrast medium than on the radiographic technique. If the technique is good, it is not of decisive importance whether you employ a positive or negative contrast medium or a combination of the two. Still, it is no doubt wise to proceed with a medium once it has been chosen and one has become used to it. Faced with the problem of having to choose a contrast medium for arthrography, one has still a choice between positive and negative contrast media, although recent publications on the subject indicate increasing use of negative media (*Oberholzer* (1938), *Stark* (1941), *Krömer* (1942),*Möhlmann* & *Madlener* (1942)).

Of the former there is only a question of water-soluble contrast media. Among them uroselectan B (*Stör* (1933)) and perabrodil (*Bircher* (1933), *Oberholzer* (1938), *Lagergren* (1934) and *Lindblom* (1940)) are preferable because of the comparatively slight irritating effect they exert on the tissues, if they are used in small amounts, up to 10 ml. Injection of much larger amounts will result in irritation of the synovial membrane involving pain and exudation.

The most common negative contrast media are ordinary atmospheric air (*Schum* (1933)), carbon dioxide (*Bernstein* & *Arens* (1926)), oxygen (*Hoffa* (1906)), and nitrogen monoxide (*Teschendorf* (1936)).

Laarmann's (1937) assertion that "Gase drängen nicht wie wässerige Lösungen in engste Spalten" (gaseous substances do not reach the narrowest recesses as well as do water soluble ones) has been rejected by *Stark* (1941) whose experience indicates the reverse to be the case. Moreover, *Stark* emphasizes that small amounts of positive contrast media are much more difficult to distribute. They collect in depots which chiefly settle in front of the cruciate ligaments. *Meyer-Wildisen* (1938) and *Krömer* (1942) also feel the inconvenience of the disturbing depots of perabrodil and are, therefore, now almost exclusively using negative contrast media. The fact that there actually is a weak point here is furthermore indicated by the numerous instructions in methods aiming at spreading the contrast: massage, passive and active movements of the knee, so warmly advocated by nearly every one using positive contrast media (*Oberholzer* (1938), *Lindblom* (1940)).

As far as the quality of the roentgenogram is concerned the kind of gas used is indifferent, but it is practical to employ a gas which diffuses rather quickly in order to avoid the discomfort of leaving a needle in the knee joint during the examination or of having to puncture it again afterwards to tap off the air.

All gases are capable of diffusing through animal membranes. Whether this diffusion proceeds in the one direction or the other depends upon the relative partial pressures of the gases on the two sides of the membrane, the diffusion proceeding from the place of higher to that of lower pressure.

Provided that the contact surfaces and pressure differences in a cavity and the adjacent tissues is the same, the rate of diffusion of gases accumulated within the tissues—in this case the knee joint—is directly proportional to the absorption coefficient of the gases concerned in the blood and inversely proportional to the square root of the molecular weight of the gases.

In practice this means that the velocity of diffusion in the circumstances mentioned is practically proportional to the absorption co-efficients of the gases. Having a very low (0.012) absorption co-efficient in the blood at 38° centigrade and a very high tension (563 mm. Hg.) in the blood and tissues, nitrogen diffuses very slowly and is, therefore, like atmospheric air, not so suitable for arthrography. Carbon dioxide, on the other hand, has an absorption co-efficient of 0.51 and a tension in the tissues of only 46 mm. Hg.

It, therefore, diffuses much more rapidly and is preferable for the purpose. The absorption co-efficient of nitrogen monoxide is 0.43 and its tension in the blood 0, so it diffuses rapidly and is very suitable.

With animal experiments *Teschendorf* (1936) has demonstrated that 100 ml. of carbon dioxide, introduced into the peritoneal cavity

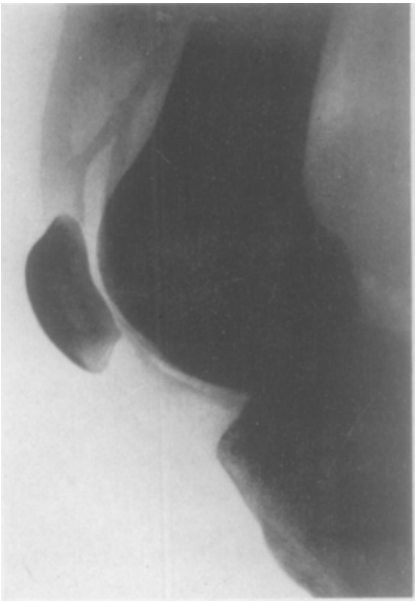


Fig. 1.

A remnant of nitrogen monoxide 18 hours after the injection of 60 ml.

of rabbits, will diffuse in the course of 45 to 90 minutes, whereas nitrogen monoxide takes 60 to 150 minutes. According to *Scheibel* (1937) N_2O will diffuse from the human knee joint in the course of 24 to 48 hours, and the writer is in a position to confirm his statement. Fig. 1 shows the amount remaining 18 hours after the injection of about 60 ml.

In the following 5 items *Michaelis* (1931) set out the properties required of an ideal contrast medium: (1) it must have no detrimental effect, generally or locally, (2) it must be light and (3) give a good contrast, (4) its injection must be possible with a simple technique, and (5) it must be rapidly absorbed. These demands are fulfilled by the rapidly diffusing gases mentioned above.

As mentioned already it is of minor importance whether arthrography is performed with a negative or positive contrast medium, but the technique is all-important.

This was only realized at a fairly recent date. *Schum* (1933) was the first author to consider the problem. He makes stereoscopic roentgenograms from the antero-posterior and lateral views and maintains that this method gives a far better insight into the numerous recesses of the knee joint. It is easier to recognize tears and dislocations on serial than single roentgenograms, and if it is a question of localizing loose bodies, stereoscopy is indispensable. Sometimes *Schum* has also made stereoscopic roentgenograms from the oblique view. This may be connected with certain advantages, but it is difficult to decide beforehand, where the central ray should preferably be centred and the interpretation becomes more complicated because of the unusual projection. *Bircher* (1933) supplements the 2 classical pictures with roentgenograms made from the oblique or diagonal view with the knee in internal as well as external rotation. In his opinion these oblique views mark a progress, particularly with regard to the semilunar cartilages.

Lagergren (1934) also employs the oblique view in the examination of the semilunar cartilages. On a post mortem specimen he shows how the anterior and posterior horns of the semilunar cartilages are superimposed in the ventro-dorsal view and how they entirely cover each other in the lateral view. By using the oblique view one may, however, succeed in revealing certain parts of the cartilages. Oblique views are best obtained by rotating the limb concerned. Internal rotation of the right lower limb of about 30° reveals the anterior part of the medial meniscus and the posterior part of the lateral one—and reversely. Moreover, *Lagergren* recommends several oblique views with different angles. A comparison of all the films will then give a serviceable view of the condition of the semilunar cartilages. *Lagergren* gives this procedure a large part of the credit for the satisfactory results obtained by him.

Laarmann (1937) only uses antero-posterior and lateral views, but his technique differs from the ordinary one in that all the antero-posterior views are made with the knee slightly flexed. This brings the slightly backward slanting articular surfaces of the tibia at right angles to the couch. At the same time *Laarmann* inclines the tube a few degrees to the cranial side. In this way he thinks it possible to eliminate the inconvenience of superimposition of adjacent bony structures.

During a certain period *Laarmann* also used the oblique view, but that he has abandoned, as it never showed anything that was not visible in the antero-posterior view too.

Schaer (1938) only takes antero-posterior views. He has stopped taking oblique views, as they do not yield more than the others and have even caused diagnostic errors.

Oberholzer (1938) takes an antero-posterior view, a lateral view and several oblique views and sometimes stereoscopic roentgenograms. He attaches particular importance to the oblique view which, he states, often reveals torn semilunar cartilages, not apparent from the antero-posterior view. The oblique views have been difficult to interpret, mainly at the outset, but if one is interested in increasing the diagnostic skill, these difficulties must be surmounted. *Oberholzer* also stresses the importance of centring the central ray parallel with the articular surfaces of the tibial condyles and thereby also with that of the semilunar cartilages. Fig. 14 in *Oberholzer*'s monograph, showing the position of the patient in the oblique views, reveals the left knee, which is placed in slight flexion and external rotation over a foot-stool, to be also considerably adducted. Without a doubt, this lateral movement, to be discussed later, has contributed its share to the satisfactory results obtained by *Oberholzer*.

Lindblom (1940) makes stereoscopic films in flexion as well as extension and takes oblique views, but otherwise no mention is made of the technique.

Stark (1941) employs the technique of *Oberholzer*. He has tried stereoscopic roentgenograms from the antero-posterior as well as lateral view, but without success.

Krömer (1942) is very painstaking with his technique, trying to make the roentgenograms of both knees identical for the sake of comparison. The antero-posterior view is taken with the knee slightly flexed and the tube inclined slightly to the cranial side. Apart from this frontal view *Krömer* takes antero-posterior views with abducted and adducted knee. This causes the joint spaces to yawn, medially and laterally respectively. Oblique views were taken in exceptional cases only and stereoscopic roentgenograms he has abandoned, because they failed to show him anything.

An essential step forward is due to *Möhlmann* & *Madlener* (1942). They employ atmospheric air as a contrast medium, injecting only about 60 ml. into the knee joint. The X-ray examination is made in the prone position and the projection is controlled by fluoroscopy. Several oblique views are taken and each cartilage is examined separately.

With trifling modifications this technique has been employed for the examinations reported in the paper now submitted. The material is derived from the Copenhagen County Hospital and from the Orthopædic Hospital in Copenhagen and comprises 150 cases.

According to the writer's experience an accurate X-ray diagnosis of injuries to the semilunar cartilages depends more on a careful technique than on the choice of contrast material.

In order to be able to interpret the films correctly, one must, however, be in possession of intimate knowledge of the anatomical features of the knee joint, particularly those of the semilunar cartilages, as well as of the normal variations. Therefore, it is necessary to describe these features in detail.

ANATOMICAL STRUCTURE

It is taken for granted that the reader is familiar with the anatomical structure of the knee joint as it is described in the large textbooks of anatomy.

The more special description given below is based on the textbooks of *Lanz* & *Wachsmuth* (1938), *Strasser* (1917), and *Fick* (1904).

Distal End of the Femur. The distal end of the shaft of the femur expands to both sides, forming the femoral condyles, the medial and lateral condyles which together assume the shape of half a cylinder and the bulk of which is situated behind the longitudinal axis of the femoral shaft. In continuation of the posterior surface of the shaft the two condyles are posteriorly divided by the intercondyloid fossa, and on the lateral surface each of them has a small prominence: the medial and lateral epicondyle. Anteriorly, inferiorly, and posteriorly the condyles are furnished with articular surfaces, all of which together take on the shape of a horse-shoe. The anterior and superior part, the patellar surface articulates with the patella, the other joint surfaces with the tibia. In the sagittal plane these articular surfaces are shaped like a spiral, the radii of which decrease backwards. Consequently, these articular surfaces have no fixed axis of curvature, but a number of axes which, with decreasing radii of curvature move backwards, approaching the articular surfaces, see Fig. 2.

The cartilage lining of the articular surfaces is thickest in the centre along the sagittal axis, where it measures 2.5-3 mm., and then decreases evenly mediad and laterad.

The medial condyle is larger than the lateral one, it projects further distad, and in the sagittal direction it is 1-2 cm. longer than the lateral one which projects most ventrad. The articular surfaces of both condyles are in a normal anatomical position on account of the oblique position of the femur in the same horizontal plane.

Proximal End of the Tibia. Proximally the tibia spreads extensively to both sides, and anteriorly as well as posteriorly, forming the tuberosity of the tibia and the condyles, medial and lateral.

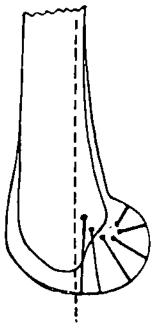


Fig. 2.
Radii of curvature of the femoral condyles.

A large portion of the condyles is situated dorsal to the longitudinal axis of the tibia; they are retroposed. Superiorly they have each an articular surface, the medial and lateral superior articular area, separated in front by the anterior intercondyloid fossa and behind by the posterior intercondyloid fossa and in the middle by the spine of the tibia.

Both articular areas are oval with their longitudinal axes in the sagittal plane, the medial one being largest from side to side. The articular surfaces are concave, particularly where they face the spine of the tibia which rises rather abruptly medially, whereas it slopes smoothly down to the articular area on the lateral aspect. From before backwards the medial area is slightly concave and the lateral one almost level, not infrequently slightly convex. In the periphery both articular areas have an almost level border.

The articular surfaces of the condyles are not at right angles to the longitudinal axis of the tibia, but slope slightly backwards; they are retroverted. This retroversion varies somewhat, according to *Lanz*

& *Wachsmuth* it amounts to 3-7° and according to *Fick* to 8-10°. In children it is more marked.

The articular surfaces are seldom parallel mutually, the medial one as a rule being more retroverted than the lateral. The cartilaginous covering is thickest in the centre, 4-5 mm., and thinner in the peripheral area, 1-2 mm.

The Semilunar Cartilages.

The convex articular surfaces of the femoral condyles and the almost plane articular surfaces of the tibial condyles do not fit each other well, and the contact surfaces between the femur and tibia are, therefore, small. In order to reduce this incongruence, increase the contact surfaces and thereby add to the stability between the bones mentioned, the semilunar cartilages, medial and lateral, are interposed medially and laterally, along the margins of the tibial articular surfaces. As indicated by their name, they are of semilunar shape. They are made of fibro-cartilage and wedge-shaped in cross section. The tips of the wedges face the spine of the tibia; they are quite thin, of an almost knife-like sharpness and projecting into the joint cavity. Their base faces the joint capsule to which it is firmly attached. The upper surface is slightly concave and moulded after the articular surfaces of the femoral condyles; less frequently it is flattened, almost plane. The latter applies particularly to the medial cartilage. The under surface is usually plane, resting on the plane border zone of the tibia and forming an almost right angle with the joint capsule.

The upper and under surfaces are quite smooth like articular surfaces, and in front and behind they are prolonged into fibrous horns by which the cartilages are attached to the tibia.

The breadth of the semilunar cartilages varies from individual to individual. On an average the medial one measures 10 mm. in the centre, 5 mm. anteriorly, and 17 mm. posteriorly and the lateral one 12-13 mm .in its entire length.

Lindblom (1940) who has measured a certain number of cartilages during operations on the knee joint, arrives at somewhat lower figures. According to him the medial cartilage measures 4 mm.

anteriorly, 7 mm. in the middle, and 10 mm. posteriorly; the lateral one 9 mm. anteriorly, 8 mm. in the middle, and 9 mm. posteriorly.

The height, measured at the base, averages 4-7 mm., each individual cartilage is usually somewhat higher in front than behind.

The medial semilunar cartilage has a larger radius of curvature than the lateral one. It is more open, being of a shape almost like a

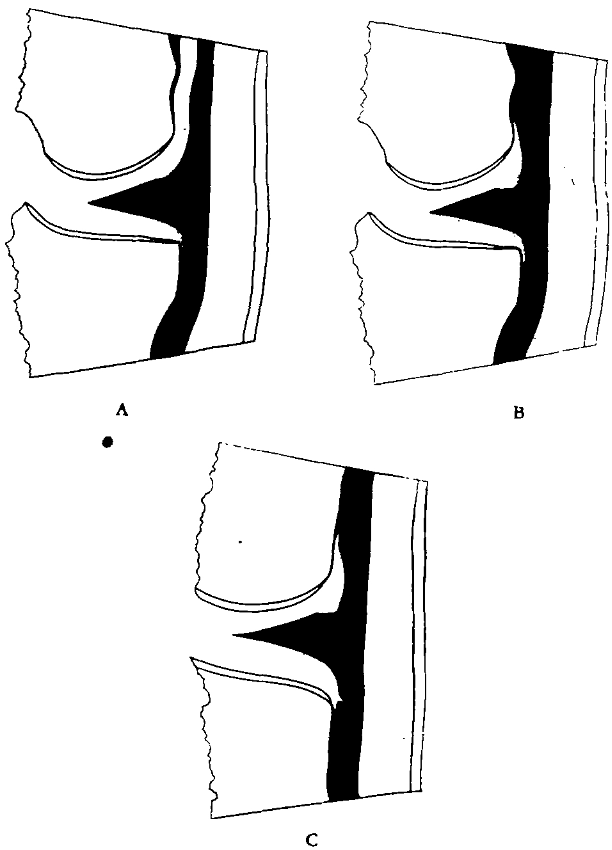


Fig. 3.
Vertical, radial sections through the medial cartilage of a left knee.
A. Anterior aspect. B. Centre. C. Posterior aspect.

C. In front, its place of insertion is the anterior intercondyloid fossa ventral to the anterior cruciate ligament, thence it proceeds along the somewhat variably developed transverse ligament which extends from one semilunar cartilage to the other across the intercondyloid fossa, moreover sending strands backwards and upwards into the anterior cruciate ligament. In its entire length the base of the medial cartilage is firmly attached to the fibrous capsule which at this site is solid and fairly unyielding. Behind it is inserted into the posterior intercondyloid fossa immediately ventral to the posterior cruciate ligament.

Fig. 3 is a schematic representation of a vertical section through the medial part of a left knee. The sections are cut radially from before backwards with the spine of the tibia as a centre. (The cartilage and the joint capsule are stained black). A. represents the anterior aspect of the section, B corresponds to the central part of the cartilage and C the posterior part. Everywhere one will notice the firm, solid attachment of the base of the cartilage to the joint capsule and the fairly small synovial folds between the cartilage and the bone except in front and upwards where the joint cavity proceeds to join the suprapatellar bursa.

The shape of the lateral cartilage is more closed, almost completing a circle, inserted anteriorly in the intercondyloid fossa immediately in front of the spine of the tibia and posteriorly in the posterior intercondyloid fossa immediately behind the spine of the tibia sending fibrous strands to the cruciate ligaments from the anterior as well as posterior horn. Anteriorly and right behind, the base of the cartilage adheres to the thinner and more loose lateral part of the joint capsule, but laterally and posteriorly the connexion between the cartilage and capsule is interrupted by a pocket-shaped space, serving as a passage for the popliteus tendon originating from the lateral condyle of the femur and heading for the posterior aspect of the tibia. Looking from above at a knee joint from which the femoral condyles have been removed, one cannot see this space, it is at any rate difficult to find. If, however, the lateral cartilage is drawn towards the spine of the tibia, the space opens up and it is now evident that it runs from above downwards and backwards, limited medially by the free base of the cartilage and laterally by the popliteus tendon which at this site is imbedded in and adhering to the joint capsule. The space proper is lined with synovial membrane and represents a depression of the joint cavity, called the vagina tendinis musculi poplitei. Distal to the cartilage this tendon sheath spreads over the small rounded surface which is seen on the upper part of the posterior aspect of the lateral tibial condyle in continuation of the articular surface, forming the bursa musculi poplitei. The bursa is rather deep, sometimes communicating with

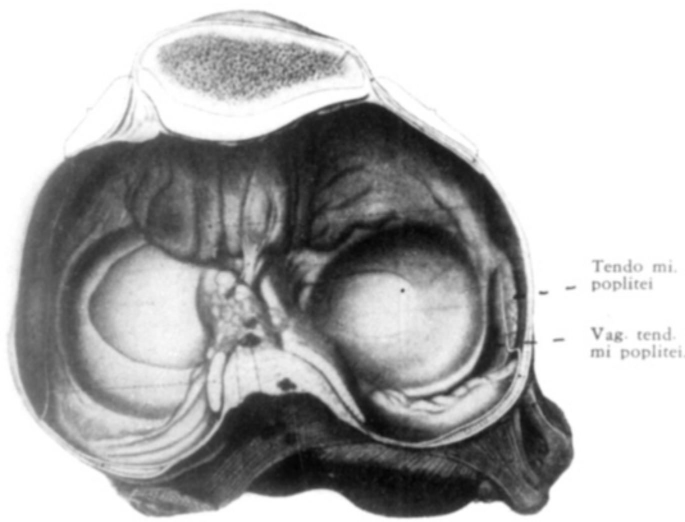


Fig. 4.
Articular surfaces of the tibia and adjacent soft tissues from above (*Lanz* & *Wachsmuth*).

the knee joint distal to the cartilage and now and then in open connexion with the tibio-fibular articulation which thus again communicates with the knee joint proper. Thereupon the popliteus tendon takes an intra-articular but extra-synovial course through the knee joint. These anatomical features, so important for the X-ray diagnosis of injured lateral semilunar cartilages, are insufficiently described in the textbooks of anatomy in ordinary use. Similarly, most papers on arthrography fail to give clear descriptions thereof.

Fig. 4, showing the origin of the tendon sheath from the knee joint, has been borrowed from *Lanz* & *Wachmuth:* Praktische Anatomie. In order to emphasize further the spatial features of the popliteus bursa, a number of schematic representations are added, showing radial sections cut vertically from before backwards through the lateral cartilage of the left knee (Fig. 5).

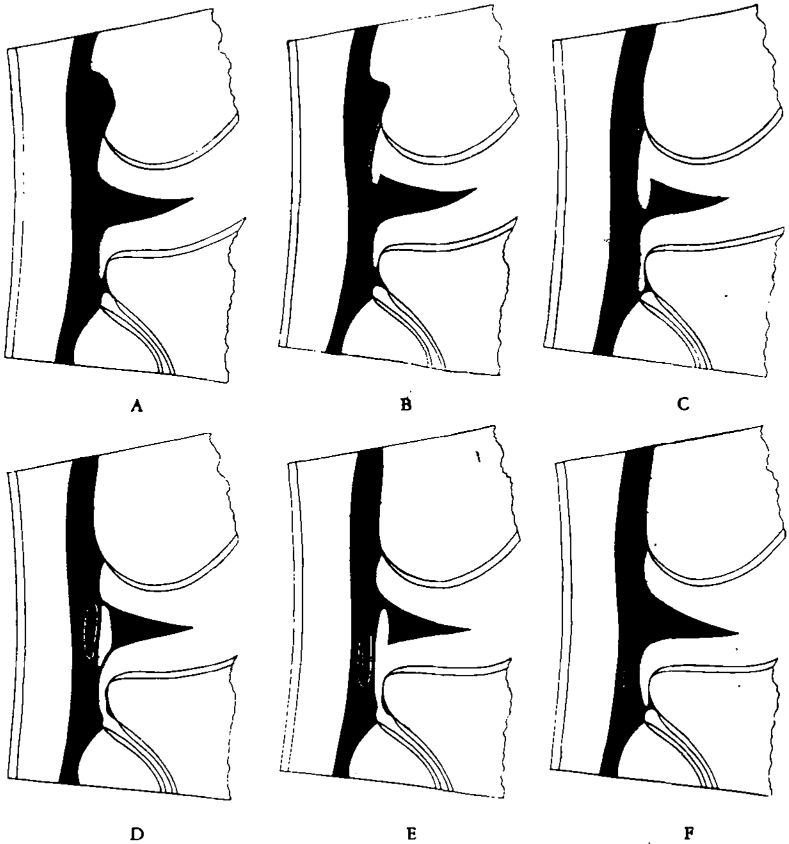


Fig. 5.

Vertical, radial sections through the posterior half of the lateral cartilage of a left knee. Antero-posterior direction.

A. Section through the origin of the popliteus tendon. B. Section a few millimetres behind A. The small notch in the upper part at the base of the cartilage is the beginning of the tendon sheath. C, D and E represent the various stages of the tendon sheath on its route through the base of the lateral cartilage. F. Section right behind. The attachment of the cartilage to the joint capsule is again broad.

A. represents a section through the knee joint on a level with the origin of the popliteus tendon (P). At this site the semilunar cartilage still adheres to the joint capsule on a broad base. B is a few mm. to the dorsal side. Here the popliteus tendon reaches further distal, and on the upper surface at the base of the cartilage there is a small notch, the first beginning of the tendon sheath. The following section (C) still further dorsal shows the cartilage only adhering inferiorly by a narrow bridge forming the bottom of the tendon sheath which now has become deep and serves to divide the cartilage from the popliteus tendon which is imbedded in the joint capsule and often somewhat projecting. Even further dorsal (D) the tendon sheath has almost worked itself through the base of the cartilage, but at the same time the latter has again obtained a narrow connexion with the capsule superiorly, forming a ceiling for the tendon sheath—and even further back (E) the cartilage only adheres superiorly by a bridge, increasing in thickness the further back one gets, until the tendon sheath has got through the base of the cartilage which again is attached to the capsule (F) on a broad space. D and E represent a wide, open communication between the popliteal bursa, the knee joint, and the tibio-fibular articulation.

The fissure between the semilunar cartilage and the capsule (vagina tendinis musculi poplitei) may exhibit considerable morphological variations, particularly with regard to size. Other variations do, however, also occur.

In several instances during operations on knee joints *Schum* (1933) has ascertained that this slit may be absent. He is not, however, in a position to decide how often this is so. *Fick* also mentions this variation. Moreover, *Schum* states that fairly often there is no communication between the popliteal bursa and the knee joint distal to the semilunar cartilage. Among 86 cases examined by him this communication was absent in 23.

An open communication between the popliteal bursa and the tibio-fibular articulation, in other words an indirect communication between the knee joint and tibio-fibular articulation through the popliteal bursa, was found in 14.3 per cent. of the cases reported by *Fick*. *Gruber* on the other hand, found this variation in merely 6.6 per cent. of a large, somewhat older material comprising 160 knees.

In *Schum*'s material this indirect communication was demonstrable in about 20 per cent. of the cases. The reason for this marked difference between the findings of *Gruber* and *Schum* is probably to be sought in the difference between the methods of examination. *Gruber* dissected his knees after they had been injected with a stiffening substance, whereas *Schum* X-rayed his material following intra-articular inflation with air. *Schum*'s procedure must be considered much more accurate, and his results are therefore without a doubt nearer to the truth.

In the same material *Schum* found 6 cases of direct communication between the tibio-fibular articulation and the knee joint distal to the semilunar cartilage without a simultaneous anastomosis with the vagina musculi poplitei which in these cases ends in a cul-de-sac. Finally, in 17 instances, he found no air in the popliteal bursa or the tibio-fibular articulation.

The medial cartilage will hardly ever differ from the classical form described above, but the lateral one in rare instances exhibits anomalies which will be discussed briefly.

Duncan, in 1932, reported a case in which the semilunar cartilage was represented by a cartilaginous disc extending like a diaphragm between the femoral and tibial condyles, completely shutting the joint cavity between the cartilaginous disc and the tibial condyle off from the remainder of the knee joint. Similar observations have been mentioned by *Bristow* (1928), *Ellis* (1932), and *Chandler* (1937).

Dubinkin & *Motnenko* (1931) studying the development of the semilunar cartilages in the foetus, have never encountered this form. It is, therefore, presumably a question of a congenital malformation and hardly of arrested development at a certain stage in foetal life.

Furthermore, the lateral cartilage may be transformed into a closed circle or else be represented by 2 spindle-shaped rudiments, originating in the usual sites of insertion and separated mutually.

In addition to the popliteal bursa mentioned above the following 4 bursae communicate with the knee joint: bursa suprapatellaris, bursa musculi semimembranacei, bursa capitis tibialis musculi gastrocnemii, and bursa capitis fibularis musculi gastrocnemii.

The bursa suprapatellaris is imbedded between the quadriceps tendon and the padding of fat covering the anterior aspect of the femur. Its anterior wall adheres firmly to the posterior aspect of the tendon and less firmly to the fat tissue. It is by far the largest of all the bursae, reaching about 8 cm. proximal to the base of the patella and is practically always in broad, open connexion with the knee joint.

Still, there may be variations. In rare cases there is no communication at all between the bursa and the knee joint and somewhat more often the opening between the two cavities is narrowed to a varying extent. This reminds one of the fact that the foetal anlage of the suprapatellar bursa is demonstrable at an early juncture, and it is not until the 5th foetal month that it acquires its communication with the knee joint.

The bursa capitis tibialis musculi gastrocnemii is situated deep to the medial head of the gastrocnemius muscle, communicating ventrally with the knee joint (in about 50 per cent. of all cases) through an opening proximal to the medial cartilage, and dorsally with the bursa of the semimembranosus muscle, situated between the medial head of the gastrocnemius muscle and the tendon of the semimembranosus, and thus acquiring a communication medially with the knee joint.

The reports are somewhat varied regarding the frequency of this communication between the bursa semimembranacea and the bursa musculi gastrocnemii. *Krause* reports 67 per cent., *Henle* 50 per cent., *Poirier* 10 per cent., whereas *Gruber* as well as *Fick* state that they are unable to set a universal rule, but report that the communication in most cases will be found in elderly, muscular individuals and most frequently on the right side.

The bursa of the fibular head of the gastrocnemius muscle is situated between the fibular condyle of the femur and the lateral head of the gastrocnemius and seldom communicates with the knee joint, and, if so, proximal to the lateral semilunar cartilage.

In extremely rare instances (according to *Gruber* 1-2 per cent.) there is a communication between the bursa infrapatellaris profunda and the knee joint through a canal deep to the inferior patellar ligament and traversing the pre-articular layer of fat.

The Fat Pad.

On both sides of the inferior patellar ligament, distal to the patella, two large pads of fat (plicae alares), lined with synovial membrane, extremely folded and irregular, roll into the joint cavity. (Fig. 6). The fat pads, of which the medial one, is the largest, touch each other in the midline. At this site there will often be a small

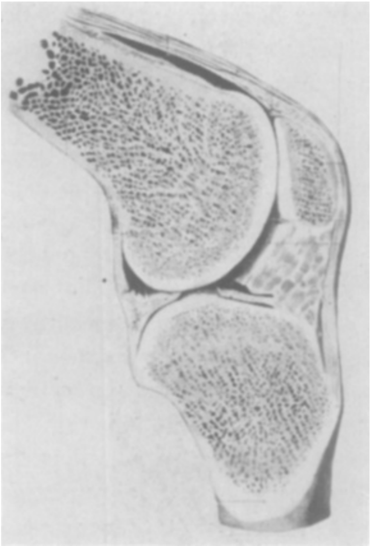


Fig. 6.
Sagittal section through the lateral femoral condyle. (*Spalteholz*).

notch of a sagittal course. In the lateral view these fat pads are triangular or wedge shaped, the tip of the wedge pointing backward and the base forward, occupying the space between the patella, the inferior patellar ligament, the femoral condyles and the tibial condyles, extending laterally and medially more than 1 cm. past the lateral edges of the patella, evenly decreasing in size. The upper surface of the wedge is concave, turning backwards and slightly upwards and evenly joining the concave surface of the semilunar cartilages. The under surface is almost plane, resting on the surface of the tibia and partly covering the anterior part of the cartilages against which the fat pads are movable.

The plica synovialis patellaris has its origin in the fat pad, in the midline, takes a sagittal course through the joint cavity and inserts itself on the lower border of the intercondyloid notch of the femur. Its development differs from individual to individual.

With the knee extended the fat pad is palpable on both sides of the inferior patellar ligament. During flexion the soft and yielding pad is shifted backwards, and at the same time it is pressed sidewards and slightly upwards, adapting itself and occupying the narrowed pre-articular space produced during flexion.

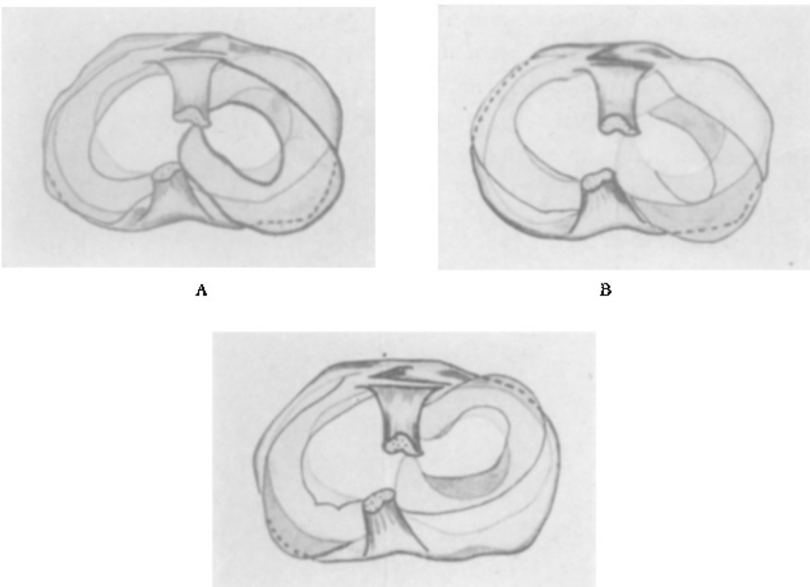
Movements at the Knee Joint and Semilunar Cartilages.

The knee joint is not a mere hinge joint, but is capable of 2 kinds of movement: flexion and extension as well as rotation with the axes at right angles with each other.

The movements of flexion and extension are not pure gliding movements but a mixture of gliding and rolling, executed on an almost transverse axis through the femoral condyles. With regard to function the knee joint is divided by the semilunar cartilages, medially as well as laterally, into an upper rolling compartment, articulatio menisco femoralis and a lower gliding compartment, articulatio menisco tibialis. Anatomically, the two communicate with each other central to the semilunar cartilages.

When the knee joint passes from extension to flexion the femoral condyles first roll upon the tibial condyles causing a slight dorsal shift of their mutual points of contact together with the semilunar cartilages. After a flexion of about 20° the points of contact remain fairly unchanged during the remainder of the flexion as far as the tibial articular surfaces are concerned, whereas the points of contact of the femoral condyles are shifted further and further backwards while the latter glide with a rotatory movement along the tibial articular surfaces and the semilunar cartilages. During extension the movements are executed in the same manner, only reversed.

Rotation or flexion rotation as it is called because the movement is only possible when the knee is flexed, is a rotation around the longitudinal axis of the crus. The movement proper takes place between the tibia and the semilunar cartilages in the articulatio menisco tibialis. It is a pure gliding movement comprising internal rotation as well as external rotation. The excursions of the movement increase with the flexion and are largest in external rotation. Together



A B

C

Fig. 7.

Position of the semilunar cartilages in movements of the knee joint (*Schaer*).

A. Position of the cartilages in extension and flexion.

B. Position of the cartilages in extension and in flexion + internal rotation of the crus.

C. Position of the cartilages in extension and in flexion + external rotation of the crus.

they amount to a maximum of about 50°, about 40° in external rotation and about 10° in internal rotation.

In other words, the semilunar cartilages move during flexion, extension, and rotation. They move passively with the femoral condyles, gliding on the tibial articular surfaces. At the same time their elasticity enables them to change their shape corresponding to the varying position of the femoral articular surfaces. Thus they fulfil their task of occupying the space between the joint surfaces in any position. The lateral cartilage is more mobile than the medial one, partly because the lateral joint capsule is looser and thinner than the medial one, partly because the two sites of insertion of the lateral cartilage are closer together than those of the medial cartilage, the distance being only about 1 cm. and lastly because the lateral cartilage is particularly movable in relation to the capsule laterally and posteriorly, where the popliteus tendon divides the two.

In flexion the semilunar cartilages glide backwards—especially during the first stage of the movement—and in extreme flexion they may be shifted so far backwards that they project over the posterior edge of the tibia. This applies primarily to the lateral cartilage. Correspondingly the semilunar cartilages glide forward in extension, assuming their resting and starting position (Fig. 7 A) in full extension which also is the resting position of the knee joint. The shift during flexion amounts to a minimum of 1 cm. While gliding backwards, the semilunar cartilages also change their shape considerably (Fig. 7 A).

A combination of flexion with a movement of rotation complicates matters. If it is, however, kept in mind that the semilunar cartilages accompany the femoral condyles, it is easy to understand that the position in marked flexion and internal rotation will be the one shown on Fig. 7 B. In this position the lateral cartilage is shifted to the dorsal and slightly to the tibial aspect and the medial one to the anterior and medial aspect, assuming almost the position seen when the knee is extended. The position is reversed, when the flexion is combined with external rotation. In that case the medial cartilage will be drawn backward and the lateral one be shifted distinctly forward (Fig. 7 C).

It will be seen from the figures that the lateral cartilage moves considerably less than the medial one, and the former changes its shape more than the latter.

In addition to the two kinds of movement described above, there is a third kind of movement which may be made with the knee joint, i.e., movements of abduction and adduction on a sagittal, horizontal axis.

These movements can only be passive and like the movements of rotation, they cannot be executed with the knee extended. In this position the articular surfaces of the tibia engage with those parts of the articular surfaces of the femoral condyles that have the

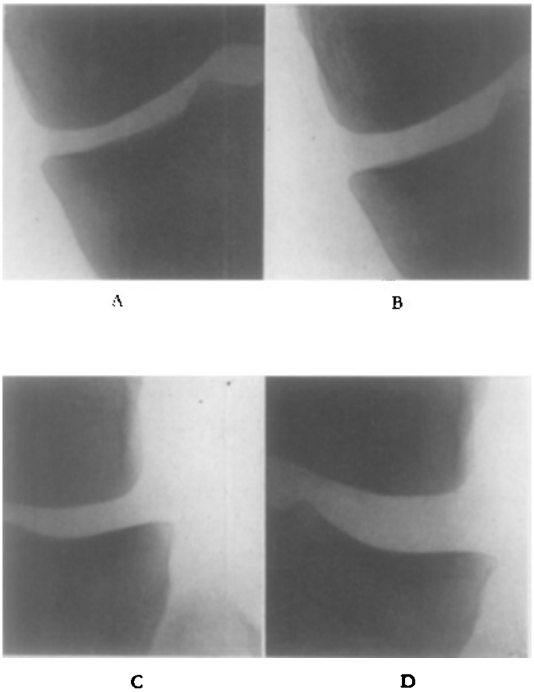


Fig. 8.

A. Medial joint compartment without abduction
B. „ „ „ with abduction
C. Lateral joint compartment without adduction
D. „ „ „ with adduction.

longest radius of curvature. Therefore, the lateral and medial ligaments are drawn tense and permit no vacillation, but as soon as the flexion begins, the radii of curvature are shortened and the ligaments relaxed and permit some abduction and adduction. The excursions of these movements are small, it is only a question of a few degrees. Adduction is always more marked than abduction, because the medial ligament is more solid, extensive, and in more intimate connexion with the capsule.

It is apparent from Fig. 8 that the height of the medial joint compartment is almost doubled in abduction and that the lateral joint compartment attains almost three times its original height in adduction.

WHAT DO THE SEMILUNAR CARTILAGES LOOK LIKE ON THE ROENTGENOGRAM?

Considering that the shape of the semilunar cartilages on the

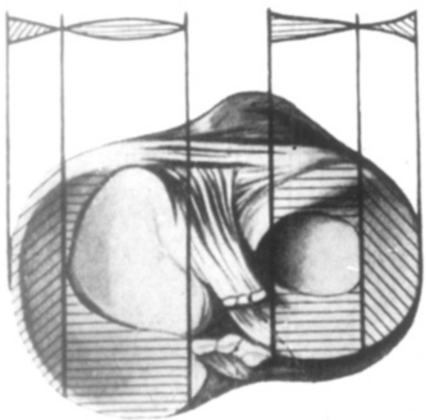


Fig. 9.
After *Laarmann.* Schematic representation of the parts of the cartilages included in the wedge figure (oblique shading) and those included in the "Spindelschatten" (transverse shading).

roentgenogram depends on the projection or projections employed, it is impossible to give a satisfactory answer to the question asked above, unless the projections are known.

Of the original 2 projections with a sagittal and antero-posterior direction of the radiation, there is general agreement that the ventro-dorsal roentgenogram is by far the most important one in the matter of semilunar cartilages. In addition, it is agreed that, if at all visualized, the semilunar cartilages will appear in this projection in the form of wedge-shaped shadows medially and laterally between the condyles of the tibia and femur. According to *Laarmann* (1937) these wedge-shaped shadows only represent a small part of the semilunar cartilages, chiefly the middle third (Fig. 9). The posterior part of the medial cartilage and the anterior and posterior

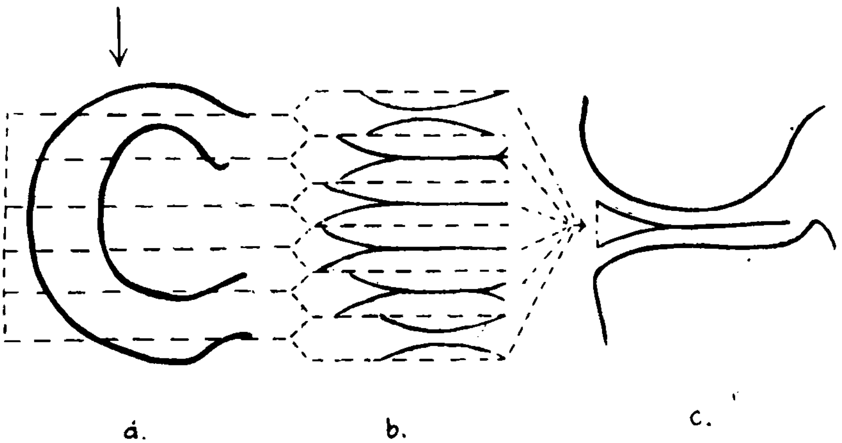


Fig. 10.
Manner in which the wedge shadow arises. (After *Schaer*).

parts of the lateral one do not form part of these wedges. These parts of the cartilages will be penetrated by the radiation transversely or obliquely. On the roentgenogram they should be seen between the tibial spine and the tips of the wedges. *Stör*, in 1933, writes: "Die im lateralen und medialen Gelenkspalt erkennbaren Keile stellen die Profile der beiden Menisci dar". (The wedges demonstrable in the lateral and medial joint space represent the profile of both semilunar cartilages). Without a doubt this may be interpreted in accordance with the opinion of *Laarmann*, that only the middle third of the cartilages, i.e., the portion which the radiation strikes lengthwise takes part in the formation of the wedge-shaped shadows and not, as understood by *Stark* (1941) that the wedge-shaped shadow represents the sum total of all sections of semilunar cartilages.

By means of a sketch of the medial cartilage *Schaer* (1938) (Fig. 10) illustrates how the wedge shadow arises. a) shows the medial cartilage from above, the dotted lines representing a series of frontal sections. In b) all the sections are seen in the sagittal direction and finally c) gives the sum total of all these cross sections collected in the characteristic wedge figure. *Schaer* can hardly believe that the widely different and in several cases far from wedge-like sections should suddenly assume the form of a wedge when collected. That is of course impossible, it only appears to be so on the film. Probably the reason is to be sought in the fact that *Schaer* exclusively employs positive contrast media. On the middle third of the cartilage, the one that forms the wedge, the contrast is penetrated in thick layers by rays in an antero-posterior direction. On the anterior and posterior part, on the other hand, where the direction of the radiation is parallel with the axis of the wedges from the apex to the base and the reverse, they only penetrate the contrast medium in thin layers which therefore are not so opaque. Thus, the wedge becomes the dominant feature of the picture, all the more so as the other portions of the semilunar cartilages may be completely eliminated as the employment of positive contrast media demands relatively hard rays.

Stark (1941), employing air instead of positive contrast and therefore using softer rays, has demonstrated that apart from the wedge shadow there will be outlined between the wedge and the spine of the tibia faint, ribbon-shaped shadows representing the anterior and posterior part of the cartilages. This ribbon-shaped shadow will usually be most distinct laterally in accordance with the larger bulk of the lateral cartilage.

It is emphasized by *Laarmann* (1937) that without a doubt large and important parts of the cartilages may be affected with pathological changes without altering the wedge-shadows of the frontal view. In addition, he is of opinion that the portion of the medial cartilage which is not included in the wedge figure of the antero-posterior view is outlined in the form of a spindle-shaped shadow. The outer tip of this shadow just reaches the tip of the wedge and its inner tip reaches medially as far as the spine of the tibia. The corresponding figure of the lateral cartilage is slightly different, lacking the inner tip and forming, together with the wedge, a figure resembling a lying x. In *Laarmann*'s opinion these "Spindelschatten" have meant a further progress to the examination of the semilunar cartilages.

In his sketches showing the significance of the projection to the X-ray aspect of the semilunar cartilages *Oberholzer* (1938) has only

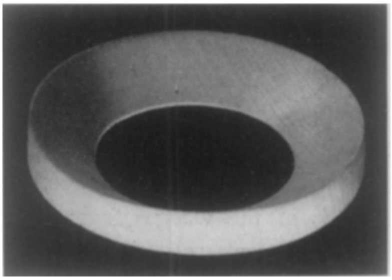


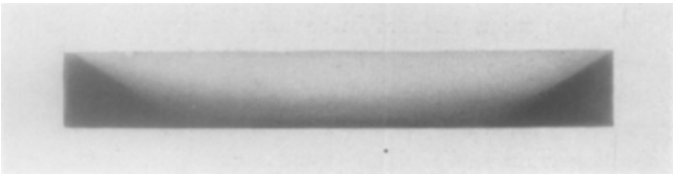
Fig. 11.
Wedge-shaped wooden ring.

had his interest focussed on the part forming the wedge. He does not even mention the other portions, but several of his films reveal the ribbon-shaped shadows distinctly.

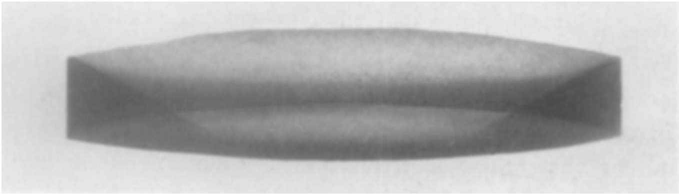
Like *Stark, Möhlmann & Madlener* (1942) consider that the semilunar cartilages appear partly in the form of a wedge shadow, partly in the form of a ribbon-shaped shadow.

The best way to realize how the various figures and shadows of the semilunar cartilages arise on the X-ray film, is to X-ray a wooden ring, wedge-shaped in cross section (Fig. 11). A true lateral view of such a ring, i.e., one in which the direction of the rays is parallel with the under surface will be seen in Fig. 12. At both sides one will see the massive outlines of wedge figures between which there is a fainter ribbon shadow due to the anterior and posterior arcs of the ring. If the X-ray beam is not exactly parallel with the under surface of the ring but forms an angle with the latter, 2 things will happen (Fig. 12 B): The wedge figure decreases in size, the distance from the base to the tip of the wedge will become smaller, more and more distinctly as the projection diverges from a true lateral one. In addition, one will see, between the anterior and posterior arc of the ring, a spindle-shaped figure with tips just reaching the tips of the wedge, its limitations superiorly and inferiorly being the inner, sharp edges of the arcs.

In a convincing manner this small experiment would appear to show that *Laarmann*'s "Spindelschatten" are the sharp, inner edges of the anterior and posterior horns, meeting laterally in the tips of the wedge. This is all the more likely, as *Laarmann*, in an effort to visualize the spindle-shaped figures, endeavours to let the central



A



B

Fig. 12.

Roentgenograms of the wooden ring with lateral projection (A) and at a slight angle.

ray strike the tibial articular surfaces at a slight angle from the cranial side. There can, therefore, be no doubt that *Laarmann*'s procedure is unsuitable. In examining these articular cartilages which are so difficult to get at, one must endeavour to make the roentgenograms as simple as possible, avoiding superfluous and disturbing outlines.

Considering these particular features applying to the semilunar cartilages, viz. that only a small part of the cartilages takes part in the formation of the wedge in a given projection, that the wedge figure decreases in size, and that superfluous and complicating outlines will appear when the central ray fails to strike the cartilages from a true lateral view, it must be endeavoured, if one is to obtain ideal radiograms, to let the central ray strike the cartilages from a true lateral view, to take several films of each cartilage in various projections, oblique views, in order that the sum total of the individual wedge figures will comprise the entire cartilage.

Sometimes the semilunar cartilages may be visualized without contrast. *Dittmar,* in 1932, reported a series of experiments aiming at roentgenological visualization of the cartilage lining of the tibial and femoral articular surfaces in various positions. Now and then he did succeed in visualizing the actual joint space between the tibial and femoral cartilage, without using artificial contrast media, only employing a special technique consisting in passive abduction and adduction combined with the usual antero-posterior view of the knee joint.

On the films thus obtained *Dittmar* now and then observed a delicate slightly arcuate translucent area midway between the femur and tibia, medially and laterally respectively. Medially and laterally a triangular shadow woud project into this translucent area.

Dittmar interpreted the translucent areas and the triangular shadows as the actual joint spaces and the semilunar cartilages respectively. In adults these translucent spots could only be visualized, if the knees were pathological, i.e., with abnormal looseness for lateral movements, but in children who have more yielding joints, they could be visualized in normal knees too. *Dittmar* goes on to state that no signs of effusion could be seen in any of the cases in which the joint space appeared. Later in the same year *Dittmar* reports a further experience, namely that the joint space will appear most distinctly, when the abduction and adduction are combined with slight flexion (about 160°). As regards the reason for the visualization of the joint space *Dittmar* presumes that, as there was no air in the joint, it is due to the synovial fluid, which in all probability occupies the joint space, having less faculty to absorb the radiation than the articular cartilage.

Independently of *Dittmar, Nordheim* (1938) also made attempts at visualizing the articular cartilages by means of extension, abduction an adduction. He observed similar translucent areas and triangular shadows, but he rejects *Dittmar*'s theory and advances another explanation of the phenomenon. *Dittmar*'s hypothesis to the effect that the translucent areas are due to accumulation of synovial fluid in the joint space presupposes a very considerable difference in the faculty of the articular cartilage and the synovial fluid to absorb the radiation, as the translucent areas are as distinctly outlined as air injected into the joint. If one could at all imagine such a difference, the synovial fluid must be extremely fatty, *Nordheim* maintains, but the fat content in the synovial fluid does not exceed 0.1 per cent., and *Dittmar*'s explanation can, therefore, not hold good.

In *Nordheim*'s opinion the translucent spot is due to the production of a comparative vacuum which must arise in all joints, when the bone ends are removed from each other without the capsule bursting or being sucked in between the bone ends. Presumably, this relative vacuum is instantaneous and cannot exceed 713 mm Hg. as the pressure of saturated aqueous vapours at body temperature is about 47 mm Hg. This partial vacuum will at once cause diffusion of the gases contained in the blood (CO_2, O_2 and N_2) from the tissue to the joint cavity, with the effect that the vacuum of the latter will be reduced, presumably rather quickly. Simultaneously with the diffusion of the gaseous substances of the blood, the vacuum will cause the formation of a transudate, increasing until the vacuum has been equalized, whereupon the gases are absorbed and replaced by fluid. The interpretation of *Nordheim* can be accepted with a single objection. It is hardly possible for a vacuum of the size stated to arise in this site, as the synovial folds are far too soft and yielding. As demonstrated by *Nordheim* himself, the translucent area does not appear instantaneously, but gradually, and is in all probability due to air which has diffused from the surrounding tissue as a result of the presumably not particularly big vacuum involved by the extension.

Nordheim has tried to visualize the joint space, medially as well as laterally, on a material comprising 100 healthy knee joints in both sexes. He found that the medial joint space and semilunar cartilage became visible in about 70 per cent. of the cases. For this end he required only moderate abduction which did not cause the subjects any discomfort. It was much more difficult to visualize the lateral cartilage. He succeeded in that in only 2 out of 30 cases, and it was necessary to employ a considerable force of adduction. The presence of an ever so slight exudate will make it impossible to visualize the semilunar cartilages on either side, and in such cases *Nordheim* recommends injection of a small amount of air (about 5 ml.) which is sufficient to visualize both cartilages distinctly.

Nordheim has also been able to visualize a distinct joint space in shoulder joints and finger joints following traction. Year Book of Radiology (1940) reports 2 cases of habitual dislocation of the hip in children in which X-ray revealed quite considerable accumulation of air in the hip joints during the dislocation.

The observations made by *Dittmar* and *Nordheim* are of great value in the examination of the semilunar cartilages and are given their due in the method worked out by *Möhlmann* & *Madlener* (1942).

The contrast medium used by *Möhlmann* & *Madlener* is ordinary atmospheric air, injected with an ordinary record syringe (20 ml.).

The usual amount injected is 60-80 ml. of air, varying according to the size of the knee joint. No attempt is made at creating an excessive pressure to press the air into the joint compartments. *Möhlmann* & *Madlener* only want a depot of air. In abduction and adduction, when the joint capsule is drawn tense and pulls the semilunar cartilage, which adheres to it on a broad base, upwards and outwards away from the tibia, until it stands out like a diaphragm between the yawning articular surfaces of the femur and tibia, the air will be sucked from this depot to surround the semilunar cartilages superiorly as well as inferiorly. At the same time it is a decisive factor, as already mentioned, that the central ray runs parallel with the articular surfaces of the tibia. It was mentioned in the description of the anatomical features of the knee joint that the tibial articular surfaces are retroverted to a different extent and that abduction and adduction are only possible in the flexed position. Therefore, *Möhlmann* & *Madlener* centre during fluoroscopy with the patient in the prone position, so that they can abduct and adduct, flex and extend until the wedge of the cartilage is clear and distinct and the radiogram can be taken. In this position it is, moreover, possible to rotate the entire limb on its longitudinal axis, so that all parts of the semilunar cartilage, including the anterior and posterior horn, may be examined. With the patient in the prone position small accumulations of fluid in the joint cavity will also sink down into the suprapatellar bursa where they cause least discomfort.

Möhlmann & *Madlener* disagree very emphatically with *Schaer* (1938) who maintains that a single frontal view is sufficient to decide whether or not there is a tear. They stress the absolute necessity of several films in various projections, if the examination is to be a success. Therefore, *Möhlmann* & *Madlener* generally take 6 views of the medial and 2 of the lateral cartilage, and they advance several examples of how radiograms of the very same cartilage in different projections my reveal completely normal conditions in some and a distinct tear in others.

PROCEDURE

Technique of Injection.

It is an advantage, that the entire examination, including the injection of the contrast material, be made in the X-ray Department on the couch where the radiography is to take place. Firstly, fluoroscopy may afford valuable information in cases where there is a doubt about the position of the needle, secondly it is natural that the person performing the radiography should also be familiar with the technique of injection, so that he is capable of conducting the whole examination—and—thirdly, experience has taught me that the technique of injection, which may seem quite banal, will nevertheless in practice cause such difficulties that numerous unsuccessful examinations, failing because of errors in the injections, can be avoided when the injection is performed by a trained examiner.

Considering that a successful filling of the knee joint is decisive to the success of the entire examination, the writer will below discuss the items which appear to be of interest in this connexion.

The writer attempts to make the filling of the knee joint as simple as possible and therefore avoids the expensive and complicated apparatus (*Wollenborg, Bircher*) designed for the purpose.

As a general rule puncture of the knee joint does not cause difficulties when the knee is distended with exudate or blood, but in the absence of such distention it may be difficult for one not trained in the method to decide with certainty when the tip of the needle is in the joint space.

Schaer (1938) recommends a puncture of the joint, under local anæsthesia, from the lateral aspect 1 finger-breadth distal to the superior edge of the patella and 1 cm. dorsal to its lateral edge, i.e., on a level with the presumed retropatellar space. In the course of the puncture he presses the left thumb against the medial edge of the patella, lifting its lateral edge from the underlying structure (Fig. 13). This makes the folded capsule on the lateral aspect tense, and now it is comparatively easy to introduce the needle into the joint, even when it is a case of a completely dry knee. After having performed the puncture a few times, one will quickly feel whether the needle is in the correct position or not.

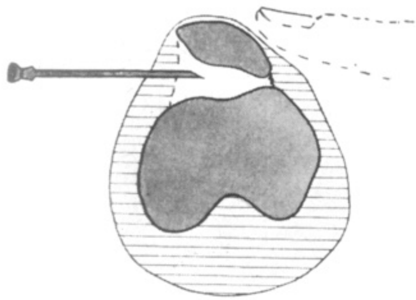


Fig. 13.
Puncture of a knee joint by the method of *Schaer.*

Bircher (1933) also recommends puncture from the lateral aspect, approximately on a level with the middle of the patella.

Scheibel (1937) inserts the needle a couple of finger-breadths above the superior edge of the patella whence he pushes it in below the latter. The reason why *Scheibel* employs and recommends this procedure is that while he used the ordinary puncture from the lateral aspect his examinations were a few times complicated by a marked periarticular emphysema. He attributes this, no doubt justly, to the air from the knee joint having escaped along the needle, because the capsule, which is rather loose on the lateral aspect, has been unable to fit the needle closely enough during the distention to prevent leakage of air. When puncturing above the patella *Scheibel* tries to pierce the quadriceps tendon which fits the needle closely, and using this technique he has never observed interstitial emphysema.

Also *Krömer* (1937), puncturing lateral to the patella, has occasionally seen peri-articular emphysema when the needle has been definitely in an intra-articular position. Like *Scheibel,* he thinks that the capsule has not fitted the needle closely.

At the outset the writer also punctured the joint from the lateral aspect, but after having observed a few instances—like *Scheibel* and *Krömer*—of emphysema inconveniencing the later interpretation, he followed *Scheibel*'s advice and abandoned the procedure.

The writer does not, however, perforate the quadriceps tendon proper which is thick and dense and therefore difficult to pierce, but inserts the needle just lateral or medial to the tendon, taking a direction towards the midline and in below the patella. At this site the puncture is easy, one can distinctly feel when the capsule is perforated, and here the tissues fit the needle so close, that there have not been other cases of the inconvenient complication mentioned above. Contact between the cartilage and the tip of the needle causes pain and should be avoided.

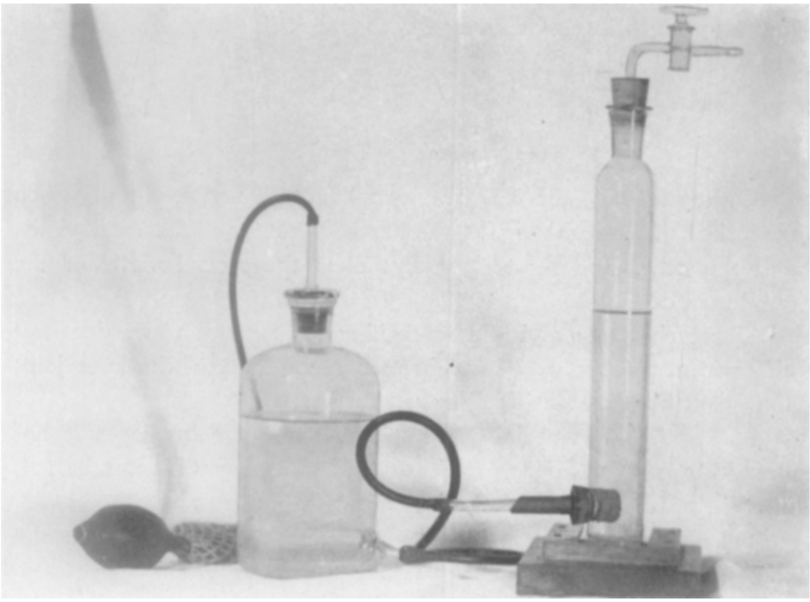
The puncture should be performed with observation of strictly aseptic precautions. First the knee should be carefully disinfected with tincture of iodine and later with alcohol. Local anæsthesia is applied to the site of the puncture (5 ml. of novocaine-adrenaline, ½ per cent. solution). To begin with the writer used an ordinary needle (8-10 cm. in length) for the puncture itself, but after this needle once became plugged by a small bit of cartilage, he substituted it with a not too fine lumbar needle which has proved very well suited to the purpose. *Stark* (1941) employs a needle with an opening not in the point but on the side. This is supposed to eliminate the risk of injecting air into a blood vessel and of blocking the needle with small plugs of tissue.

When the needle has been inserted, it is possible in various ways to ascertain whether it is within the joint. Even in cases of quite dry knees, aspiration will not infrequently draw a few drops of a characteristic, viscid fluid. Failing that, the writer tries to inject a couple of ml. of ordinary atmospheric air which passes into the joint cavity with a gurgling sound and at a quite slight pressure, if the needle is in the correct position. In case of the slightest resistance, the needle is in the wrong position, and has to be reinserted.

Schum (1933) injects a sterile saline solution. If that can be aspirated again, it means that the needle is within the joint.

Exudates must be aspirated as completely as possible before the insufflation.

For the insufflation the writer employs *Teschendorf*'s apparatus which is cheap and easy to employ. The apparatus (Fig. 14) consists of a glass bottle A and a measuring glass B (about 300 ml.),



A *Fig. 14.* B
Teschendorff's insufflation apparatus.

mutually connected inferiorly with a rubber tube. The bottle contains water sublimate which by means of excessive pressure is driven into the measuring glass until it is filled. Thereupon the measuring glass is filled with air in the reverse direction directly from the nitrogen monoxide container. The container is removed, the tap furnished with a sterile tube with a filter of cotton wool besides a mouth piece fitting the lumbar needle—and the apparatus is ready for use.

Now the insufflation may be performed easily and rapidly with a slight pressure. No measurement is made of the pressure in the joint compartment as the writer, like *Möhlmann* & *Madlener,* only endeavours to obtain a filling, and not a pressure in the joint cavity. The injection is interrupted when the outlines of the joint are obliterated and the patient feels a slight tension. This will require from 60 to 80 ml. of air.

The needle is removed, the puncture covered by cotton wool impregnated with collodion and the patient is ready for the radiography.

Radiographic Technique.

Quite naturally the radiography falls into 2 stages, one of which comprises the general views; the antero-posterior and lateral views, and the other and most important one: the special views of the semilunar cartilages.

The technique employed in making the general views does not differ from the one used in plain roentgenography of the knee joint and need therefore not be discussed further.

As regards the special views of the semilunar cartilages it has already been mentioned that the following 3 demands must be fulfilled in order to obtain satisfactory roentgenograms.

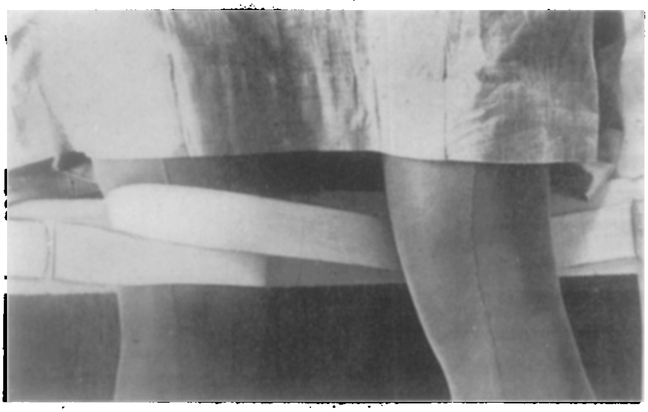
(1) The central ray must have a direction parallel with the planes of the articular surfaces of the tibial condyles.

(2) The knee joint must be abducted and adducted when the views of the medial and lateral cartilage respectively are to be taken.

(3) The knee joint must be able to rotate on its longitudinal axis, so that several roentgenograms with various projections can be made.

Considering that the X-ray tube of the fluoroscopic couch is fixed in a manner which makes the central ray strike the table at a right angle, the first demand makes it necessary that the patient should be in the prone position, as, one will remember, the tibial articular surfaces are retroverted. In this position the knee joint can easily be flexed the few degrees necessary for the central ray and the joint surfaces to be parallel. At the same time the flexion makes possible the fulfilment of the second demand, the movements of abduction and adduction, which cannot be done with the knee extended. Flexion in the knee joint alone is not, however, sufficient for the performance of these side movements. At the same time, abduction and adduction in the hip joint must be ruled out. It

A



B

Fig. 15.

A. Knee joint girdles fastened on the couch.
B. „ „ „ „ around the left knee joint.

is therefore necessary to fix the femur in a manner which prevents these movements in the hip joint, at any rate beyond a certain limit, but at the same time regard must be paid to the third demand

and therefore it is important to preserve the rotation of the entire limb, a movement which is performed by the hip joint. Such a fixation can be made most easily by means of a girdle specially made for this purpose. It is made of a broad, strong and unyielding strap fastened crosswise around the entire table at a distance of about 70 cm. from the head end. (The patient is placed with his feet at the head end). On the upper side of the girdle, slightly to one side from the centre and slightly obliquely a more narrow, but equally strong and unyielding strap is fixed. Its 2 free ends are folded around the knee joint to be examined, immediately proximal to the joint line around the femoral condyles (Fig. 15). Standing at the head end of the table the examiner takes the foot of the fixed limb and in this way it is possible for him to make internal as well as external rotation of the entire limb in the hip joint, to abduct and adduct, to flex and extend in the knee joint at will.

In the writer's experience it will pay to explain to the patient, before beginning the examination, what it is all about, and that he is to keep the limb quite relaxed and not resist the movements the examiner might wish to perform in knee joint and hip joint.

As ones interest is only focussed on one joint space at a time, the medial or the lateral one, the fluoroscopic field is made small. It is practical, as pointed out by *Möhlmann* & *Madlener* to use the same narrow aperture which is used in examining the duodenal cap, and a corresponding size in films, 15×40 cm. the capacity of which is 4 views.

Taking the examination of the medial cartilage as an example, it is performed in the following manner.

With both hands the examiner seizes the patient's foot and under the fluoroscopic screen he places the medial joint space in the fluoroscopic field with the limb in the normal anatomical position which is the starting position of the examination (sagittal direction of the rays). In slight flexion one must take care that the anterior and posterior outlines of the tibial articular surface are superimposed, a criterion that the direction of the radiation on the cartilage is straight from the side. Thereupon the crus is abducted and the shadow of the cartilage will now appear distinctly between the femur and tibia, and the first radiogram can now be taken by an assistant.

Thereupon the anterior horn is examined. The positioning is made after internal rotation as before, and 2 films are taken with a varying degree of internal rotation.

In a similar manner the posterior horn is examined in external rotation, also with 2 films. The examination of the lateral cartilage does not differ from the one now described, and will therefore not be mentioned.

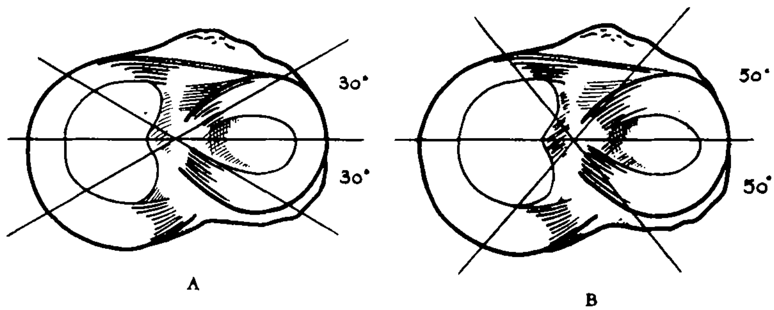


Fig. 16.

A. showing those parts of the semilunar cartilages which are medially and laterally included in the examination in internal and external rotation in the hip joint.

B. showing those parts of the semilunar cartilages included in the examination in internal and external rotation in the hip joint and simultaneous unilateral elevation of the pelvis (about 10 cm.).

The special examination comprises a total of 10 views, 5 medial and 5 lateral, but one can of course supplement these views with others in the rotation found to be desirable.

Anyone who has been performing this examination, even if only for a short time, will learn that the distance from a bad to a really good film is mainly dependent on minute variations in the positioning for which is required more care than the exertion of power.

A question as to whether it is possible to examine the semilunar cartilages in their entire extent in this manner must be answered in the affirmative. From the normal anatomical position, the starting position of the examination, the limb can be moved in the hip joint in internal and external rotation. The excursions of the rotation vary from individual to individual, depending on the anatomical construction of the hip joint. As a rule it is considered normal that the entire movement of rotation amounts to about 60°, about 30° for each kind of movement. If these movements of rotation are drawn with lines 30° in front of and behind a frontal axis through the centres of the tibial articular surfaces, Fig. 16 A shows that there is a possibility of making the views comprise the greater part of both cartilages, i.e., the central area and the immediate surroundings, whereas the anterior and posterior horn, and especially the posterior horn of the medial cartilage, cannot be included. Therefore, the excursions of the rotation must be increased by means of a rotation of the entire pelvis. This is most easily accomplished by placing a sand bag, about 10-12 cm. in height, under e.g. the right crest of the ilium when the internal rotation on the left side is to be increased, and under the left crest when it is a question of increasing the external rotation. In this manner the rotation in both directions may be increased by about 20° to a total of 50°. If the axes of these movements of rotation on the articular surfaces of the tibia are now considered, it will be seen that the examination practically speaking covers both semilunar cartilages in their entire extent (Fig. 16 B).

The rotation views taken without elevation of the pelvis will be called "slight rotation" and those combined with elevation of the pelvis "maximum rotation", medially and laterally respectively.

The radiograms have been made with Siemens "Tridoros" unit with rotating anode tube. As it is a question of soft tissue, rather soft rays have been used (50 to 55 kv.). Exposure time at 200 ma was about 0.15 second.

RISKS AND COMPLICATIONS ATTENDING THE EXAMINATION

In order to be able to recommend a method of examination with a clear conscience, one must not be content with explaining its diagnostic value, but one must also investigate whether it involves a risk to the patients. This applies particularly to an examination which, like the present one, is not of vital importance.

The risks which can be imagined to attend pneumoarthrography are the following two: infection and air embolism. The complications are also two, comprising periarticular emphysema and rupture of the capsule.

Any puncture of a knee joint involves the risk of infection. It goes without saying that one pyarthrosis arising in connexion with arthrography cannot be compensated for by any amount of correct diagnoses. It only serves to bring the method into discredit. Therefore, the writer will earnestly urge any radiologist engaged in arthrographic examinations to follow the aseptic instructions closely, so that the surgical departments may in full confidence leave the entire examination to the radiologist. If care is exerted, the risk of infection may be called slight, a thing proved by the large number of arthrographies performed in the course of time without the slightest signs of infection: *Stör* (1936): 200, *Schum* (1937): more than 800, *Laarmann* (1937): more than 500, *Bircher-Oberholzer* (1938): 2000, *Lindblom* (1944): 2000. The writer has performed the examination about 150 times without the slightest signs of infection. In this connexion it should, however, be mentioned that a few times the operations have been followed by a moderate elevation of temperature (38°-38.5° C.), but this can hardly be attributed to arthrographies made before the operation.

Air embolism threatens wherever insufflation of air is practised, for diagnostic or therapeutic purposes.

In Denmark *Blegvad* (1939) has described 3 cases of air embolism attending catheterization of the Eustachian tube followed by inflation with air, one of them even with a fatal issue.

Kelly (1914) and *Gording* (1920) have also reported several cases of air embolism following inflation of the accessory sinuses of the nose with air.

Artificial pneumothorax has also in several instances been followed by alarming symptoms, especially the initial establishment of a pneumothorax, more rarely insufflations made for the purpose of preserving a pneumothorax already existing. Eventually, it should be mentioned that *Jack* has observed sudden death in connexion with insufflation of the bladder with air.

A distinction is made between spontaneous air embolism in which case the air is simply sucked into the vessel and active air embolism caused by actual injection of air into the vessel.

According to *Lamprecht* (1938) spontaneous ingress of air into a blood vessel is possible only when the following 2 conditions are present at the same time: The vessel must yawn, and the pressure in the vessel must be negative. In that respect the most notorious veins are the jugular veins, the inferior vena cava and the veins of the uterus following evacuation.

It must be borne in mind, however, that the air injected into the joint space even by the method used by the writer who only wishes to establish an intra-articular depot of air, has some excess pressure (about 15-18 mm. Hg.). Therefore, the pressure in the veins need not be negative, but only lower than the pressure of the injected air in order that the latter may force its way into the vessel if it does yawn. Normally the pressure of the peripheral veins is lower than about 10 mm. Hg., but as there are no torn or injured vessels to yawn, one need not be concerned with the question of spontaneous air embolism.

Then remains active air embolism caused by direct injection of air into the blood vessel.

In addition to *Hoffa*'s unpublished case with a fatal outcome, *Stark* (1941) mentions that *Jacobsohn* (1919) has observed a death from air embolism following injection of oxygen into the knee joint. No further details are given about this case. *Kleinberg* (1927) has described a case of air embolism in a 19-year old male; it occurred in direct conjunction with injection of oxygen into the knee joint. This case was not, however, fatal. *Kleinberg*, who has performed numerous pneumoarthrographies without complications (1925) expressly points out that this air embolism was due to erroneous technique of injection. Already before the injection the needle had been fitted on a rubber tube in direct connexion with the oxygen container. When it was considered that the needle was in the correct position in the knee joint, the container was opened without further precautions to ascertain the intra-articular position of the needle. The patient immediately complained of pain in the heart, but in spite of that the injection was continued until the patient collapsed. *Kleinberg* himself thinks that the oxygen was injected directly into the vascular system and expresses as his opinion that pneumoarthrography performed in the correct manner does not involve any risk of air embolism.

Thousands of pneumoarthrographies have now been made without any complications, more particularly without any signs of air embolism. The writer has never observed the slightest trace of air embolism. This risk must therefore be considered extremely slight in connexion with a pneumoarthrography performed *lege artis.* No doubt it is, however, wise to keep this serious risk in mind and not to inject the air until one is convinced that the needle is in the correct position.

Of the complications periarticular emphysema is the most important one.

Schum (1933) makes a distinction between primary and secondary periarticular or interstitial emphysema. By primary emphysema he means air injected directly into the tissues surrounding the knee joint and by secondary emphysema air oozing from the knee joint into the surrounding tissues, for instance along the injection needle. Both contingencies may be avoided, if care is exerted: the injection not made until the needle is *in situ* and the knee joint punctured at a site where the capsule fits the needle closely. Periarticular emphysema, which is also mentioned by *Oberholzer* (1938) has never given rise to alarming conditions, but it may cause some tension in the thigh which, however, will subside in the course of 5 to 10 minutes, if the gas used had belonged to those which diffuse rapidly. The greatest inconvenience of periarticular emphysema is the presence of numerous strand-shaped translucent areas which are so disturbing to the interpretation of the roentgenograms, that the examination must in most cases be repeated.

A complication often mentioned but seldom observed is rupture of the capsule because of too high pressure. The writer has never experienced it, probably because his method does not require high pressure but only a depot of air in the knee joint of a pressure of about 200 mm. H_2O according to repeated measurements. Therefore, the writer is of opinion, that this complication is one which need not be reckoned with.

THE NORMAL ROENTGENOGRAMS

In order to procure a normal material the writer, like *Mandl* (1933) and *Bircher* (1933), made arthrographic studies on cadavers, following the principles of *Möhlmann* & *Madlener*'s method. In a few cases the writer succeeded in obtaining useful films, but in far too many cases the difficulties were so great because of the stiffness of the limbs and the incomplete X-ray unit of the post-mortem room that a large part of these studies must be considered worthless. Therefore, it was necessary to procure a normal material in another way, and for this end the writer followed 3 different courses which between them have resulted in good and—in the writer's opinion—satisfactory information about the X-ray aspects of the semilunar cartilages and the variations within range of the normal.

The best contribution has been obtained by the X-rays made of disc-shaped frozen sections of preparations of the knee joint. These frozen sections were cut vertically and radially through the extended knee and each section represents a sector of the cylinder formed by the entire frozen knee joint. The base of each individual section measured about 2 cm. on the medial aspect, but on the lateral aspect, where the popliteus tendon traverses the knee joint, the sections have been made narrower posteriorly in order to include all the details, and there they measure from 2 to 5 mm. Each section contains a piece of the femur as well as of the tibia, and in between a corresponding piece of the joint capsule and the semilunar cartilage. In this manner the writer succeeded in obtaining a series of extremely sharply outlined radiograms of which 5 medial and 6 lateral ones are reproduced in the present paper.

Fig. 17 sets out the roentgenograms of the 5 medial sections from a right knee one by one from before backwards. Like the arthrographic views, the individual film is taken from behind.

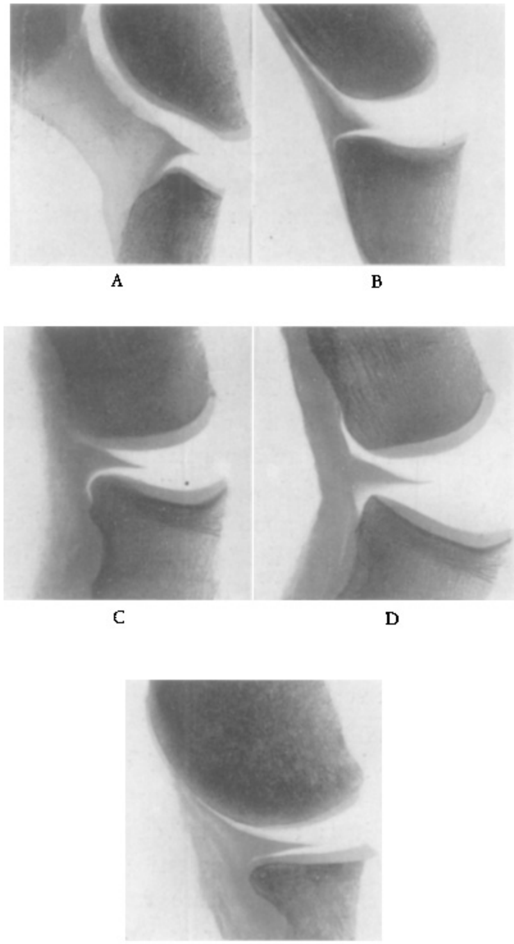


Fig. 17.
5 vertical sections from before backwards through the medial cartilage of a right knee.

A, is the anterior part of the cartilage which is rather narrow at this site. The tip of the wedge is fine and sharp. The upper joint space continues upwards, anteriorly and laterally limited by the fat pad and patella and posteriorly by the femur in the suprapatellar bursa. Furthermore, the small synovial fold of the lower joint space is visible. B shows a section slightly in front of the centre of the cartilage. At this site the latter is somewhat broader. The synovial fold in the lower part is still small, whereas it extends some way upwards along the femur superiorly. C, representing the portion approximately in the middle, shows the cartilage, rather broad at this site, with a quite level under surface and a concave upper surface prolonged evenly into the fibrous capsule. D is a section of another medial cartilage slightly behind the middle; observe the size of the synovial folds in the upper as well as lower part; furthermore it will be seen that in this case the cartilage departs upwards rather sharply from the capsule, forming an obtuse angle with the latter. In the basal part on a portion measuring 2-3 mm., the upper surface is only faintly sloping, but in the apical portion it slopes more markedly towards the quite level under surface. The thickness of the cartilaginous covering on the femur and tibia will also be seen distinctly. Right at the back the concave surface of the broad cartilage will be seen to glide evenly and without interruption into the joint capsule. E.

Fig. 18 sets out the views of the 7 lateral preparations. In front one will notice the considerable breadth of the semilunar cartilage, its slightly convex surface and the small lower synovial fold. B shows a section of the lateral cartilage slightly in front of the middle. At this site the concave surface of the cartilage continues rather far up along the comparatively thin joint capsule. C corresponds to the central part of the cartilage. In the lower part the synovial fold has become deeper and on the basal portion of the upper surface of the cartilage there is a small notch, the beginning of the popliteus tendon sheath. The section marked D has been cut a few mm. dorsal to C and shows how deep the tendon sheath has now become. The cartilage only adheres to the capsule by a small bridge inferiorly. The lower synovial fold too has become deeper. E, a few mm. behind D, reveals that now the cartilage is only connected

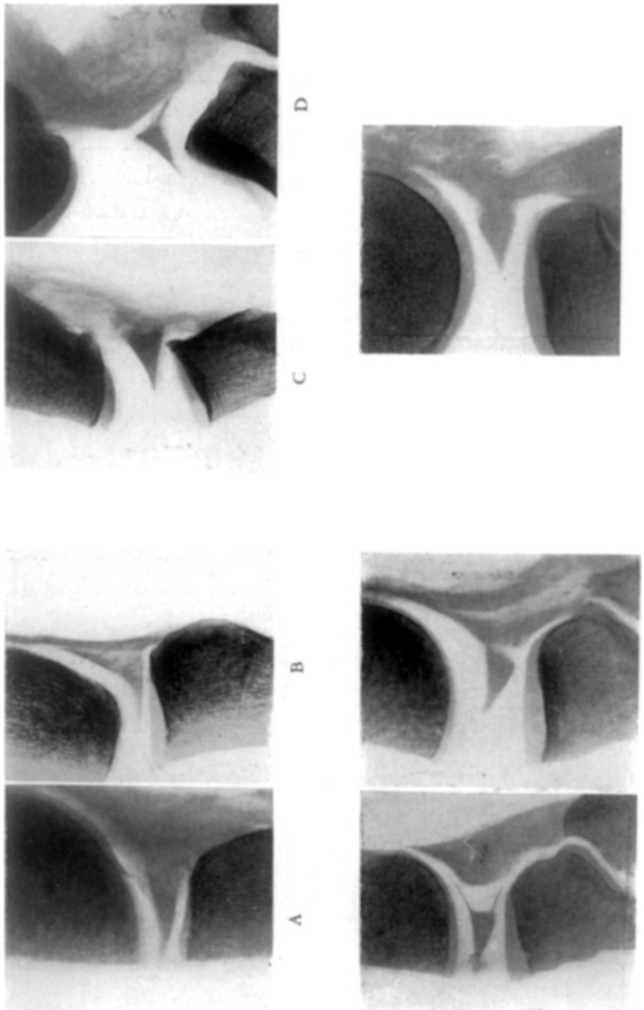


Fig. 18.
7 vertical sections from before backwards through the lateral cartilage of a right knee.

with the joint capsule superiorly and inferiorly by a couple of very delicate bridges between which the tendon sheath is situated. The base of the cartilage is slightly concave and normally—when it is not drawn towards the centre for inspection as here—it is in contact with the arched popliteus tendon which has a convex surface. Finally, it will be seen from this section that the tibio-fibular articulation is connected with the lower synovial fold of the knee joint through the popliteal bursa, situated dorsal to the tibia. F, still further to the dorsal aspect, shows broadening of the superior bridge between the cartilage and the joint capsule, whereas the inferior one is now missing, and finally G, the hindmost section, reveals the cartilage, now again in broad connexion with the joint capsule, although there are, superiorly as well as inferiorly, a couple of not particularly deep, rounded notches. The size of the synovial folds, the upper as well as the lower, can be observed directly.

In addition, the writer has obtained satisfactory information about the normal X-ray aspect of the semilunar cartilages through the cases—not so many it is true—who have exhibited completely natural conditions upon operation. Moreover, a number of non-operated cases, showing clear and indubitably normal conditions, have contributed to elucidate the minor shades and variations occurring in the semilunar cartilages.

Before proceeding to describe the special views, the writer will deal with the normal general views.

Antero-posterior View.

This is the least valuable one of the general views. It has never been of much assistance to the writer who is inclined to believe that one can do without it altogether without reducing the value of the examination. This applies particularly in those cases where plain roentgenograms have been made of the knee prior to the arthrography.

In the antero-posterior view the bony mass of the tibia and femur predominate and allow one only to see the air in those portions of the joint cavity which protrude medially and laterally beyond the bones as well as here and there in the space between the bones.

Fig. 19 shows narrow strands of air on each side of the femur, continuing upwards in the air-filled suprapatellar bursa. In the space between the femur and tibia one can see part of the articular cartilage laterally and medially, moreover the wedge-shaped shadows of

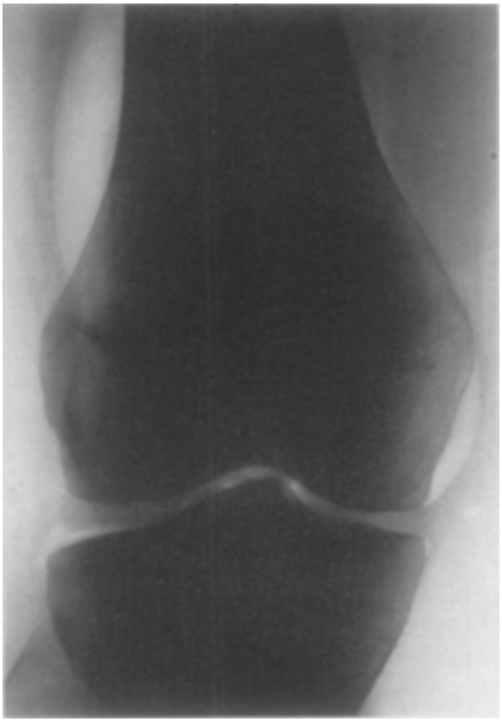


Fig. 19.
The left knee from behind.

the semilunar cartilages; and in the midline, departing from the spine of the tibia, there is a ribbon-shaped shadow representing the cruciate ligaments. In nearly all cases the lower, lateral synovial fold will be filled with air, but there is hardly ever air in the lower medial synovial fold. According to *Schum* (1933) air in the lower medial synovial fold is a definite sign of pathological changes in the medial semilunar cartilage. He states that in normal conditions the latter should be so firmly adherent to the articular surface of the tibia, that passage of air from the joint cavity proper to the synovial fold should be impossible. *Oberholzer* (1938) disagrees with him, contending that air in the synovial fold in question is not a sign of pathological conditions. The writer does not doubt that *Oberholzer* is right, but this question must be left entirely out of the discussion, as the purpose of the present investigations was to get air in between the semilunar cartilage and the articular surface of the tibia and thereby also into the synovial fold. In the antero-posterior view the lateral cartilage dominates by virtue of its considerable bulk. At the base of this cartilage one can often see a vertical translucent area representing the air-filled popliteus tendon sheath. As a rule the antero-posterior view only affords unsatisfactory roentgenograms of the wedge-shaped shadows of the semilunar cartilages, roentgenograms of no major diagnostic value, as they never comprise more than a small segment of the semilunar cartilages.

Lateral View.

This view is more useful than the antero-posterior one. It gives a good view of the suprapatellar bursa presenting itself in varying size and shape. Sometimes there will be one or more septa dividing the bursa into several compartments. The demarcation is sharp and the outlines even and soft. Moreover, one can see the space between the femur and patella and distal to that the fat pad. Its surface facing the joint is irregular and nodular. In case a moderate amount of air is used, 60-80 ml., the fat pad will, with the knee extended, usually lie close to the femoral condyles, so that its posterior surface cannot be seen. If, on the other hand, the knee is flexed up to about 90°, the flexion will press the air from the suprapatellar bursa into the joint cavity proper, forcing the fat pad to the ventral side, so that its posterior surface becomes free. The posterior synovial folds, the large superior and the smaller inferior ones, present themselves in the form of sharply demarcated, broad or narrow stripes of air parallel with the outlines of the bones. In order to avoid the inconvenience of superimposition it is important that the femoral condyles cover each other exactly; therefore the adjustment will best and most safely be made under the fluoroscopic screen. Sometimes, as in Fig. 20, communication can be seen between the knee joint and the dorsal bursae and the latter are then, consequently, filled with air.

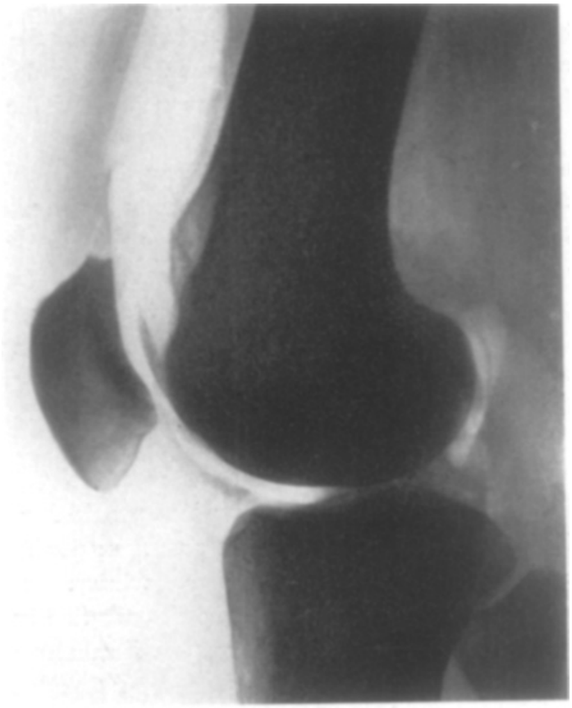
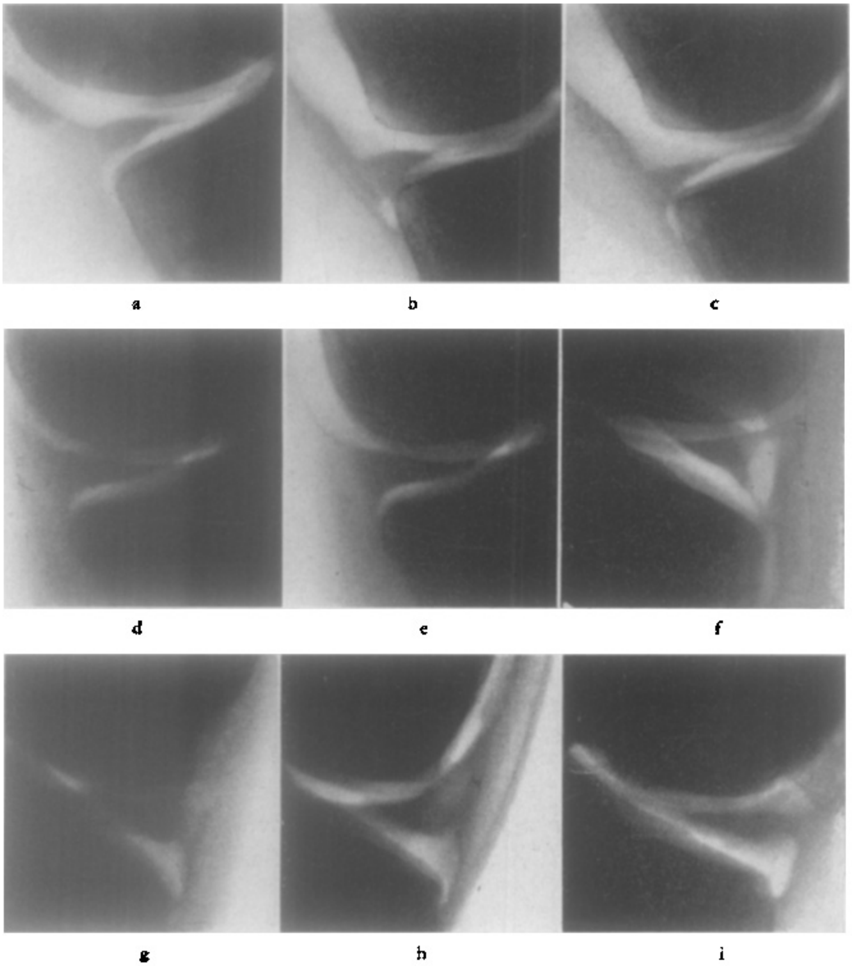


Fig. 20.
Lateral view with air in the bursa musculi gastrocnemii.

This projection does not, however, afford much information about the joint space between the tibia and the femur or the semilunar cartilages.

Special Views of the Semilunar Cartilages.

As mentioned in the chapter on the radiographic technique the writer makes 5 special views of each cartilage. The first is taken with a sagittal direction of the radiation and comprises the central part



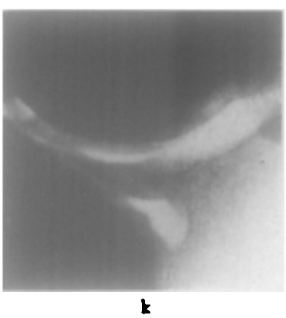


Fig. 21.

Special views of the semilunar cartilages of a right knee. a-e medial cartilage. f-k lateral cartilage.

a) maximum int. rot., b) slight int. rot., c) ant.-post., d) slight ext. rot., e) max. ext. rot., f) max. int. rot., g) slight int. rot., h) ant.-post., i) slight ext. rot., k) max. ext. rot.

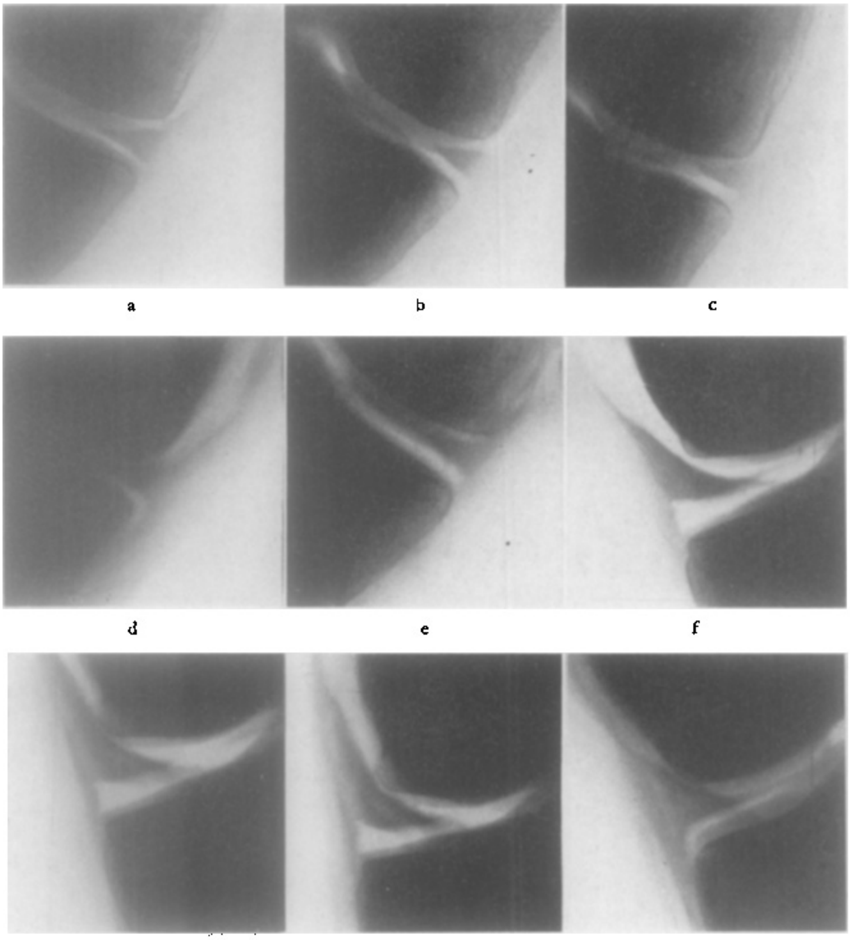
of the cartilage, the next 2 with the limb in internal rotation (slight and maximum), and the last 2 ones with the limb in external rotation, also slight and maximum. In the case of the medial semilunar cartilage, be it of the left or right knee, the internal rotation view always represents the anterior horn and the external rotation view the posterior horn. The reverse applies to the lateral cartilage, i.e., the views with internal rotation set out the posterior horn and those with external rotation the anterior horn. Figs. 21 and 22 show 2 series of films taken of normal semilunar cartilages to illustrate the shape and size of the cartilages in the same manner as the radiograms of the post-mortem specimens. The sharply demarcated shadows of the semilunar cartilages are visualized, and the slight changes in their shape are due to the various projections.

Fig. 23 presents various normal shapes of the medial cartilage. a, b, c, etc.

d is the medial cartilage from a 10-year old boy. In this case the shadow of the cartilage is thin and pointed and the lower synovial fold not yet fully developed. On the under surface of the lateral cartilage, near its base, there will often be a rounded notch f, more marked on g. This notch is an ordinary phenomenon in the anterior horn. It is usually on the under surface, but there may also be notches in the upper as well as lower part, so that the connexion between the cartilage and the capsule is pedunculated, h.

i. illustrates a well-developed popliteus tendon, a broad popliteal bursa, communicating with the tibio-fibular articulation, and lastly j + k represents two somewhat narrower tendon sheats.

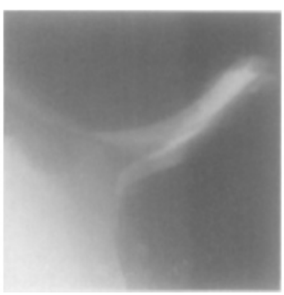
A characteristic feature of the normal medial cartilage is its sharp demarcation, the knife-like sharpness of the tip of the wedge and its broad, solid basal attachment to the joint capsule. In rare cases there will be a quite small notch anteriorly on the upper surface in immediate vicinity of the base and still more rarely there are very narrow and superficial notches on the anterior aspect of the cartilage, superiorly as well as inferiorly (see Fig. 35). As regards the lateral cartilage, which also shows sharp outlines, its anterior part may be less solidly attached to the joint capsule because of the notches mentioned, and on the posterior side it has a broad or narrow, vertical translucent area representing the sheath of the popliteus



a b c

d e f

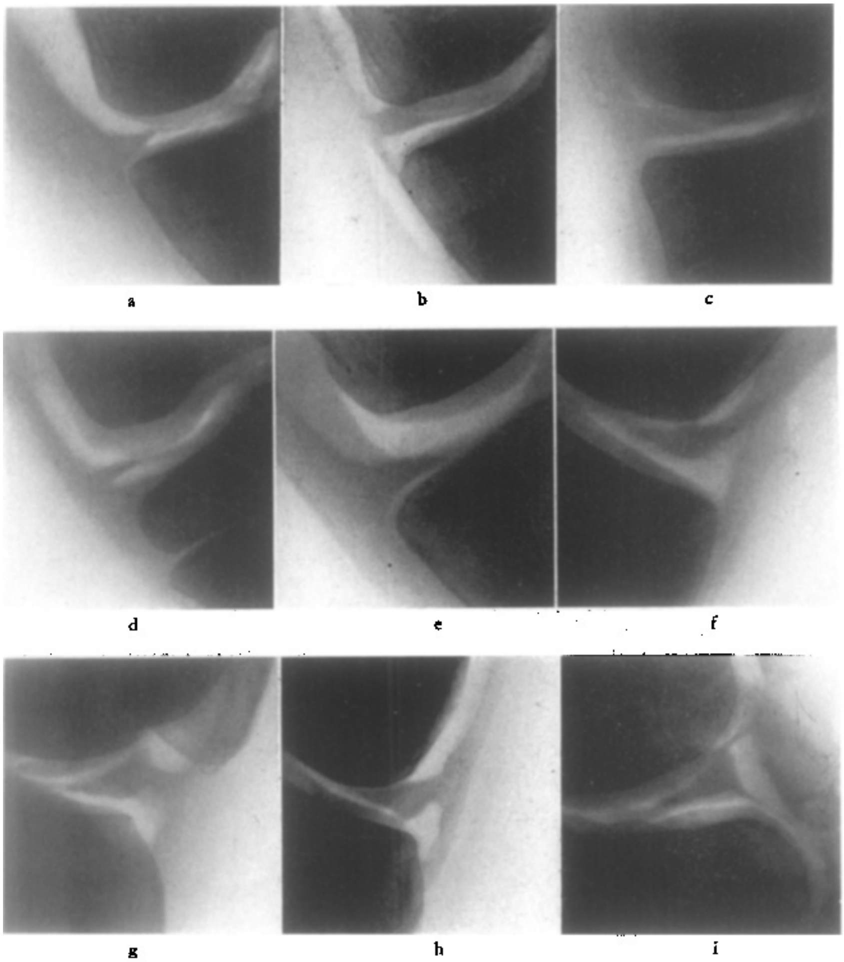
g h i



k

Fig. 22.

Special views of the semilunar cartilages of a left knee. a-e medial cartilage. f-k lateral cartilage.
a) max. int. rot., b) slight ext. rot., c) ant.-post., d) slight ext. rot., e) max. ext. rot., f) max. int. rot., g) slight int. rot., h) ant.-post., i) slight ext. rot., k) max. ext. rot.



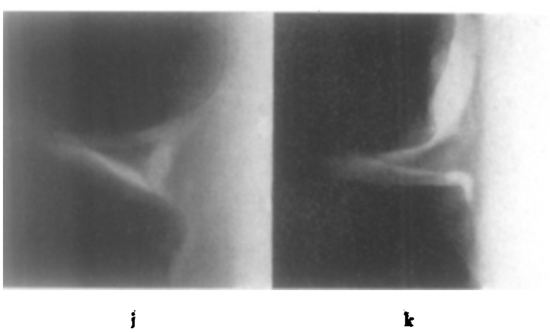


Fig. 23.
Normal variations in the shape of semilunar cartilages. a-d medial cartilages. e-k lateral cartilages.

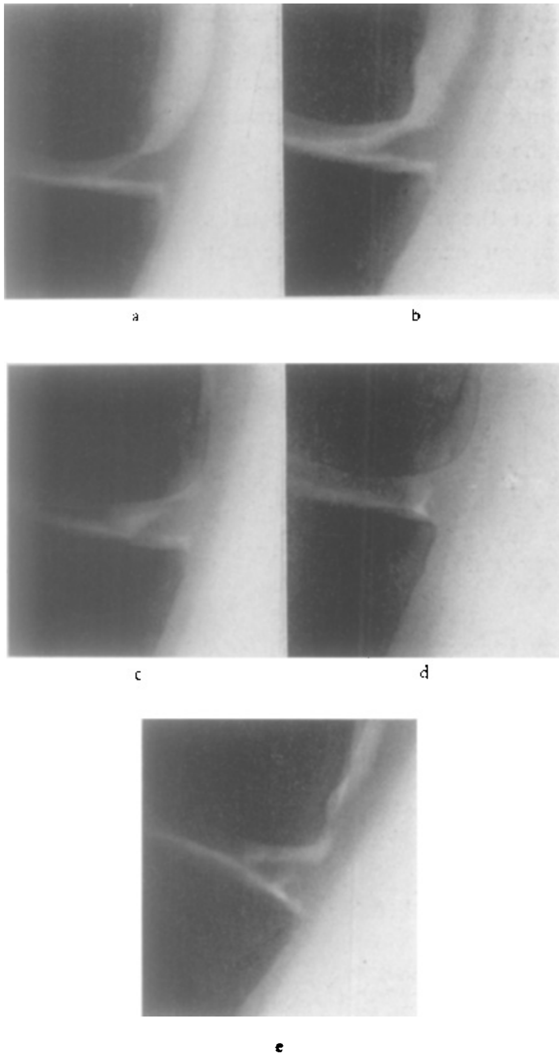


Fig. 24.

Left medial cartilage with a partial tear in the posterior horn.

a) Maximum int. rot. c) Ant.-post.

b) Slight int. rot. d) Slight ext. rot.

e) Max. ext. rot.

tendon. This translucent area is easily distinguishable from a tear on account of its even, smooth outlines.

It is apparent from the close conformity between the radiograms of the post-mortem specimens and those of the semilunar cartilages *in situ* that the method is reliable.

The applicability of the theoretical contemplations regarding the examination of the anterior and posterior horns in practice can be illustrated by an example: In one case arthrography revealed a partial longitudinal tear localized in the posterior horn of the medial cartilage (Fig. 24). This finding was confirmed by an operation which revealed a longitudinal tear in the posterior horn, whereas the anterior horn and the anterior part of the central portion were intact.

PATHOLOGICAL ANATOMY OF TORN SEMILUNAR CARTILAGES

Before proceeding to discuss the roentgenograms of torn semilunar cartilages, it might be appropriate to investigate the forms of tear which occur and their localization.

It is not at all rare to find the terms tear of the semilunar cartilage and dislocation of the semilunar cartilage used as synonyms, but they are not identical. Dislocation is a secondary shifting of the torn piece either in between the articular surfaces or inside the latter towards the spine of the tibia. In order that a dislocation can take place, there must, in other words, have been a tear, but the tear need not be complicated by a dislocation; the torn portion is often found in close contact with the remaining part of the cartilage, where it originally belonged.

Let it be established at once that the gross changes in torn semilunar cartilages are so widely different, that two cases are rarely quite identical. Nevertheless certain main types are discernible without major difficulty. The most ordinary kind is longitudinal tear, which may be total or partial, in the latter case of a varying localization. Pure transverse tear is rare.

Fig. 25, borrowed from *Schaer*'s monograph: "Die Meniscusschaden" shows the most common types as they would appear in a medial cartilage and arranged in order according to their frequency. In analogy, similar types may be encountered in the lateral cartilage, but much more rarely. The classic and most common form is the total, or more correctly, the sub-total longitudinal tear attended with dislocation of the torn portion towards the spine of the tibia, medial to the femoral condyles, where it stretches like a chord from the anterior to the posterior insertion of the semilunar cartilage a). Furthermore, the dislocated part may have turned 180° on its longitudinal axis, so that the tip of the wedge faces the joint capsule and the torn surface the spine of the tibia, b. The literature has various names for this phenomenon, the Germans call it Korbhenkel or Eimerhenkel, the Anglo-Saxon term is bucket handle fracture, and at times it is termed meniscus bipartitus. In the sagittal view the broken surfaces may be parallel with the base of the semilunar

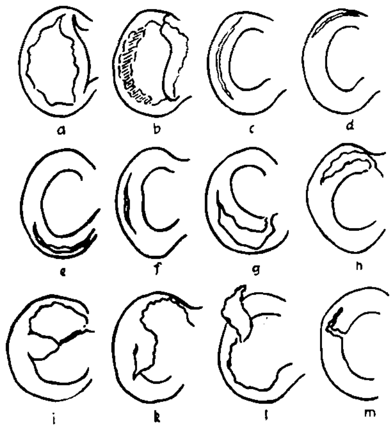


Fig. 25.
The most common forms of tear in the semilunar cartilages. (After *Schaer*).

cartilage, but more often they take an oblique course, forming some angle or other on the base of the cartilage.

As apparent from the following figures partial tears may be localized to the central portion, the anterior or the posterior horn. They are not complicated by dislocation, unless the rupture extends through the wedge-tip of the cartilage. But if this is the case the torn tongue-shaped portion will often be dislocated towards the spine of the tibia between the articular surfaces, where it gets squeezed and therefore gives rise to incarceration. The constant traumatization gradually moulds and transforms the loose portion, so that it occupies the least possible space. Therefore, an old tear of this type will exhibit grotesque, now flattened, now more vermiform shapes with irregular frayed outlines, bearing very little resemblance to the original cartilage. In rare cases the torn portion can become dislocated outwards and may sometimes be felt as a foreign body in the joint space.

In his material comprising 300 operated cases of torn semilunar cartilages *Krömer* (1942) found about 66 per cent. to be longitudinal tears. Of these about two-thirds were total with dislocation of the detached portion: bucket handle fractures. About 10 per cent. consisted of tongue-shaped pieces torn off anteriorly and posteriorly, about 4 per cent. were transverse tears, and the remainder, about 20 per cent. were made up of various combined forms of rupture.

As a rule the tears are at some distance, short or long, from the capsule, so that a minor or major part of the semilunar cartilage remains firmly attached to the capsule by its base.

Krömer states that he has never encountered a total longitudinal tear where the cartilage has been completely separated from the capsule along the entire base. The few times he has at all met with a basal tear, it has always been localized to the central portion of the cartilage on a short space, 2-3 cm.

Moreover, *Krömer* maintains that transverse tears never are total, there will always remain some millimetres in the basal portion where the cartilage is intact.

In *Mandl*'s material (1933) there were 116 total tears attended with dislocation: bucket handle fracture. Eighty times the anterior horn was the site of the tear, 19 times the posterior horn, and 30 times the central portion. There were 53 longitudinal fissures and 27 irregular tears: meniscus multifidus.

The medial cartilage is more frequently the site of a tear than the lateral one. *Sommer*'s (1929) comprehensive collected statistics, comprising about 1000 ruptures of semilunar cartilages, shows that there are 9 medial ruptures to each lateral one. According to *Mandl* (1933) the ratio in his material is 6 medial to each lateral case.

Abrahamsen (1933) reports 32 tears of the semilunar cartilages, verified by operation. Of these 28 were medial and 4 lateral. Studying the literature *Schaer* (1938) found the ratio to be about 20 medial to each lateral, and *Krömer* (1942) in his material (300 cases) found 9 medial to each lateral, whereas *Lindblom*'s material (1944), comprising more than 2000 cases, had 5 medial tears to each lateral. *Jürgens* (1929) states that the lateral cartilage is more apt to be torn in females than males, and *Schum* (1933) maintains that the lateral cartilage is torn far more often than ordinarily assumed. In his material of 96 cases he found no less than 32 lateral tears, i.e., 2 medial ruptures to each lateral one. According to *Schum* this variance with the results of other investigators is due to the improved diagnostic means obtained through pneumoarthrography. He states, moreover, that a similar result has been reached by *Horn* (1931), who consistently made a broad opening in the knee joint in all suspected cases, so that he was able to see both cartilages.

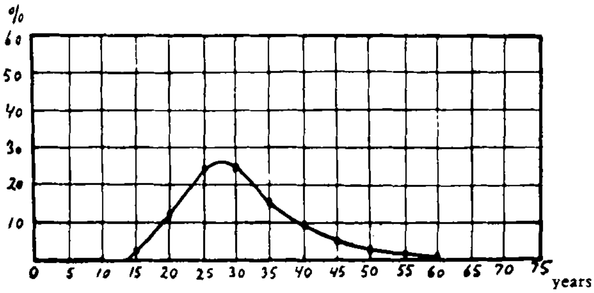


Fig. 26.
Age distribution of 170 cases of torn semilunar cartilages. (After *Schaer*).

Horn's material is made up of 67 medial and 33 lateral tears of the semilunar cartilages.

This marked difference in the ratio medial to lateral tears between the materials of *Schum* and *Horn* and those of other authors, where clinical examination has been the guidance of the surgical intervention, must, as emphasized by *Schum*, be interpreted to the effect that the symptoms of lateral tear are far less marked than those of medial tear.

Simultaneous injury to both semilunar cartilages is a rare thing. Still, *Schum* has collected 5 cases, *Demmer* has published 1 and *Horn* 2.

The comparatively more common occurrence of tears of the semilunar cartilage in persons of young age is a well-known fact which will not be discussed further. Fig. 26 sets out an age curve in

Schaer's material of 170 cases. About 50 per cent. occurred between 25 and 30 years of age. At an age below 15 rupture of the semilunar cartilages is rare, and after 40 there is a distinct flattening of the curve.

It may be mentioned as a curiosity that *Christopher* (1924) has reported a case of a tear of the lateral cartilage attended with dislocation in a boy, aged 4½.

WRITER'S MATERIAL EXAMINED BY THE METHOD OF MÖHLMANN & MADLENER

The material forming the basis of the estimation of the method advocated in the present paper comprises 149 patients on whom a total of 150 pneumoarthrographies have been performed, 1 patient having been examined twice with an interval of about 5 months. Of these 150 examinations 134 were carried out by the writer and the remaining 16 performed in the X-ray Department of Roskilde Town and County Hospital. The Chief of that Department has kindly allowed the writer to include them in this publication.

All the writer's examinations were performed in the X-ray Department of the Copenhagen County Hospital at Gentofte. The majority of the patients, or 75, came from the 3 surgical departments of the hospital. Of the remaining patients 56 are from the Orthopædic Hospital in Copenhagen and 2 were sent by general practitioners for examination. The examinations were commenced in September 1942 and finished in the autumn of 1944.

Among the 133 patients examined in the X-ray Department in Gentofte 68 have been operated on, and of the remaining, non-operated 65 cases 54 showed normal conditions, more particularly normal shadows of the semilunar cartilages upon arthrographic examination. Six exhibited distinct and unquestionable signs of a torn semilunar cartilage, but for various reasons, none of them has been submitted to operation. In 4 cases signs were found of pathological changes of the semilunar cartilages, but these changes were not so marked that a definite diagnosis could be made, and considering that the symptoms were also vague and uncertain, none of these patients has been operated on either. One case must be considered a failure, because it was complicated by a very large periarticular emphysema.

All the patients referred from the surgical departments of the hospital were hospitalized. The patients from the Orthopædic Hospital were also in the great majority of cases hospitalized. After the examination at the County Hospital they were brought back to the Orthopædic Hospital and put to bed. The remaining few ambulatory patients were also driven home and told to stay in bed for the first few days.

A few times the examination has been attended with mild pain during the first days and nights, and now and then small accumulations of fluid have been demonstrable in the knee joint, but there has never been the slightest sign of serious complications, and the writer wants to stress especially that he has never encountered a trace of air embolism or signs of infection. In the great majority of cases the temperature has remained unaffected by the examination, in some few cases it was slightly elevated on the following day.

Therefore, the writer's experience accords well with that of *Schum* (1933), *Stör* (1936), and *Oberholzer* (1938) who state that when performed *lege artis*, the procedure practically never involves danger.

The operated cases are of particular interest, as they allow of a comparison of the operative with the X-ray findings.

Of the 68 operated cases 3 are left out. Of the latter 2 exhibited loose bodies which were demonstrable without difficulty on plain roentgenograms and are, therefore, of no interest in this connexion. The third case was that of a man with a flexion contracture in the knee joint of about 90°. This condition made the examination so difficult, that it must be considered a failure. Operation revealed normal semilunar cartilages.

The remaining 65 cases are supplemented with the 6 non-operated cases mentioned above in whom the changes were so unmistakable that the writer does not hesitate to classify them with definite tears. In addition, there are 4 cases, examined and submitted to operation in Roskilde.

Accordingly, the total material of operated cases and cases not submitted to operation, but exhibiting distinct X-ray evidence of a tear, comprises 75 cases. With respect to patho-anatomical conditions these cases are, however, so dissimilar that the writer has preferred to divide them into several sub-groups on the basis of the changes found in the semilunar cartilages upon operation (69 cases).

Below the writer will briefly mention the individual groups and in the following chapter the relation between the various forms of tear as well as their X-ray aspect will be further elucidated by means of a series of roentgenograms.

The largest group is made up of longitudinal tears with dislocation of the torn part towards the spine of the tibia, i.e., bucket handle fracture. This form of tear was found in the medial cartilage of 21 patients, 17 males and 4 females. In 13 instances the lesion was right-sided and in 8 left-sided.

Longitudinal tear of the lateral cartilage with dislocation of the torn part was found in 5 cases, 3 females and 2 males. Of these tears 3 were right-sided and 2 left-sided. In all there were 26 cases of bucket handle fracture.

Longitudinal tear in the medial cartilage from before backwards, but without dislocation of the torn part was demonstrated 3 times, every time in males and twice localized to the right and once to the left knee.

The next group comprises partial longitudinal tears localized to the anterior and posterior horn, counting a total of 15 cases. Of them 11 were medial, in 9 males and 2 females. In 5 cases the lesion was right-sided and in 6 left-sided.

Partial tear of the lateral cartilage occurred only 4 times, in 3 females and 1 male. In this category the left knee was involved 3 times and the right knee once.

A total of 7 patients exhibited natural conditions upon examination, in particular the shadows of the semilunar cartilages were completely natural. Nevertheless, these 7 patients were submitted to operation on the basis of the clinical findings. In all 7 cases the semilunar cartilages were found to be natural, but 5 times there were pathological changes of another nature. In one case there was a rupture of the anterior cruciate ligament which could not be seen on the roentgenograms. In another case there was a chondroma, situated medially in the fat pad and originating in the anterior edge of the tibia. This change was not either visible on the roentgenograms, presumably because the chondroma, which was as large as a horse chestnut, was of an extra-synovial situation and only projected slightly into the joint cavity. Hypertrophy of the fat pad with longish, tattered extensions going backwards in between the joint surfaces (Hoffa's disease) was found twice. In these cases too the arthrography had been negative. In the 5th case the joint was filled with numerous, almost pea-sized, roundish cartilaginous bodies, chondromatosis, without the roentgenograms having afforded any diagnostic information. In the remaining 2 cases operation failed to demonstrate pathological changes anywhere.

In 8 instances the arthrotomy revealed natural semilunar cartilages, but pathological changes of varying nature and localization. In all 8 instances the arthrography had shown natural shadows of the semilunar cartilages, but changes which proved to accord well with the operative findings. In 2 cases it was a question of loose bodies, in 3 of cysts of the semilunar cartilages and in 3 of hypertrophy of the fat pad (Hoffa's disease).

Three patients had earlier been operated on elsewhere and consequently make up a separate group.

In 7 instances the X-ray diagnoses were wrong.

In all there were 53 tears of the semilunar cartilage, 42 medial and 11 lateral ones, with localization in the right knee in 28 cases and in the left in 25. Of the patients 39 were males and 14 females. The 42 medial tears occurred in 35 males and 7 females and the 11 lateral ones in 4 males and 7 females. The youngest patient was 10 years of age and the oldest 58. The majority of the tears (48) were fairly evenly distributed over the age groups between 15 and 40.

Bucket Handle Fracture.

This form of tear was demonstrated upon operation 26 times. Of the tears 21 occurred in the medial and 5 in the lateral cartilage. In all these instances defects in the shadow of the semilunar cartilage had been demonstrated beforehand. In 4 cases the defect was only visible in 2 of the 5 views, but in the other 22 the tear was visible in 3 or more views. In 6 of the 21 medial cases it was in addition —usually only in one view—possible to see the torn part in the space between the femur and tibia close to the spine of the tibia in the form of a roundish, uncharacteristic and rather vague soft-tissue shadow whereas 4 of the 5 lateral tears in several of the views exhibited a large and distinct abnormal soft-tissue shadow in the space between the tibia and femur. Without a doubt this great difference between the medial and lateral tears is due to the lateral fragments being considerably larger than the medial ones which arthrotomy often reveals to be rather narrow, string-shaped structures.

It has been emphasized by *Schum* (1933) that any shadow in the joint space close to the spine of the tibia should not be taken to be a dislocated fragment of a semilunar cartilage. In the antero-posterior views, for instance, the anterior as well as the posterior horn may give shadows reminding of the dislocated fragments of a semilunar cartilage. In the presence of such a shadow it is therefore wise first to make an accurate study of the outlines of the cartilage in question. If they are natural, it is out of the question that the shadow can be due to parts of the cartilage, but if there is a simultaneous, distinct defect in the shadow of the cartilage, it is presumably the torn and dislocated fragment. *Oberholzer* (1938), *Stark* (1941) and *Krömer* deal with the demonstration of the dislocated part of the cartilage as an aid in diagnosis, but at the same time they emphasize that it is not always demonstrable, not even in cases of extensive tears. The writer's experience is to the same effect. In 15 of 21 cases of bucket handle fracture of the medial cartilage the torn part could not be demonstrated.

A diagnosis of torn semilunar cartilage must, therefore, primarily be based on the shape of the cartilage. The demonstration of a shadow of soft parts in the joint space close to the spine of the tibia can never be the sole evidence of a tear, but it may now and then, especially in cases of lateral tear, serve as a further support for a diagnosis already made. Fig. 27 presents a series of schematic representations of various forms of tears and Fig. 28 the roentgenograms of a series of cases of bucket handle fracture.

The defect appears in the shadow of the cartilages in various ways. Often the natural wedge shadow is interrupted by a vertical or oblique, irregular outline giving the cartilage a blunt, plump appearance. The tip of the wedge is missing altogether.

Fig. 28 B shows the medial cartilage to be blunt, interrupted by an almost vertical and slightly tattered outline. The defect was visible in all the views of the medial cartilage and operation con-

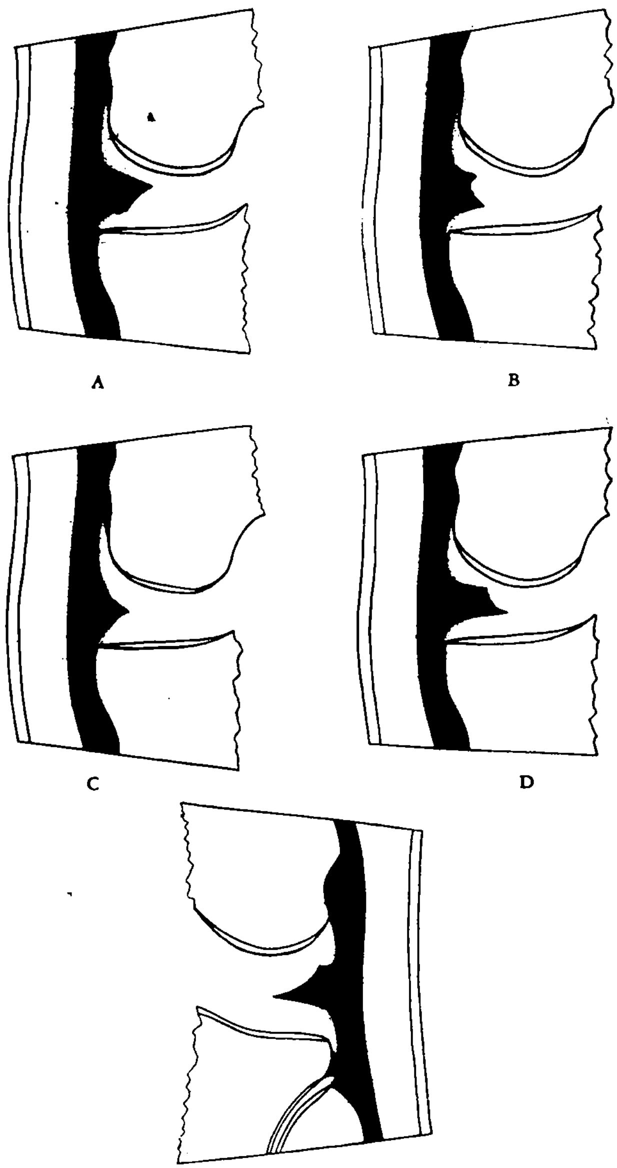


Fig. 27.
Schematic representation of various forms of tear.

firmed the X-ray finding, revealing a longitudinal tear from before backwards with dislocation of the torn part.

Fig. 28 F displays a rather short and plump shadow of the medial cartilage having on the aspect facing the joint a vertical, rather sharp demarcation with a small prominence in the central portion. The other views of this cartilage also showed mutually different defects in the shadow. Arthrotomy revealed longitudinal tear with dislocation.

Frequently the defect is concave, now facing proximad, now distad.

On Fig. 28 C the reader will see anteriorly in the medial cartilage a defect, concave superiorly, not particularly large, but distinct. This defect is also visible in the posterior part where it is, however, more vertical. Operation revealed bucket handle fracture.

Similarly Fig. 28 D illustrates a somewhat larger and more concave defect in the medial cartilage. Operation revealed the cartilage to be split longitudinally on the anterior aspect and in the middle and showed dislocation of the torn part towards the spine of the tibia.

Fig. 28 H reveals a rather small, concave defect facing proximad and lastly Fig. 28 K shows a rather deep defect facing distad. In both cases the operation revealed the cartilages to be split lengthwise and dislocation of the torn part.

More rarely the cartilage preserves a wedge-like shape, but the tattered irregularity of the outline and the short shadow of the cartilage are of the utmost importance to the diagnosis.

Fig. 28 G represents the shadow of a cartilage which has retained its wedge-shape, but it is short and plump and not quite sharp. A diagnosis of torn semilunar cartilage can hardly be made with certainty on the basis of such a single view, but as the other views displayed various defects, mostly with vertical demarcation, the diagnosis was made without hesitation. Operation confirmed the roentgen findings.

This case is an illustration of the significance of many views in various projections to the accuracy of the diagnosis.

The size of the torn part may vary considerably, from quite small (Fig. 28 H) to rather large parts of the cartilage (Fig. 28 B).

In the material now reported the lateral fragments were considerably larger than the medial ones. This is probably a consequence of the larger bulk of the lateral cartilage. It applies to both cartilages but especially to the medial one, that there will always remain a rather large basal part adhering to the capsule. Only 1 case exhibited a tear close to the base, localized to the middle two-fourths.

Total Longitudinal Tear without Dislocation of the Part Torn off the Semilunar Cartilage.

This form of tear occurs 3 times in the material.

In the first instance the shadow of the cartilage was natural, but on 3 different views there were small, irregular notches at the base of the cartilage, superiorly as well as inferiorly, but these findings did not allow of a definite diagnosis. The subsequent operation revealed the semilunar cartilage torn off from the capsule on the middle two-fourths of its base. In the second case 3 of the views revealed a slit-like vertical translucent area in the medial cartilage indicating a fissure. In the third case the first series of films presented a completely natural shadow of the medial cartilage in all the views, but in the next series, taken in more marked abduction, one of the views displayed a distinct an unmistakable tear. Fig. 29 A presents the view of slight external rotation from the first series with a natural shadow of the cartilage and B the corresponding film from the second series, showing the tear. Although the nature of the tear could not be diagnosed in the 2 last-mentioned cases, there were, nevertheless, unquestionable signs of a tear. When the 1st and 2nd case are considered, there can hardly be any doubt that this form of tear may now and then fail to appear on the films, but there cannot either be any doubt that the sideways movement, in this case the abduction, has been a factor of decisive importance to the detection of these 3 cases. In abduction the medial joint capsule will be drawn tense and thereby the basal part of the medial cartilage is drawn upwards and outwards away from the torn part and the air-filled space in between is demonstrable on the X-ray film.

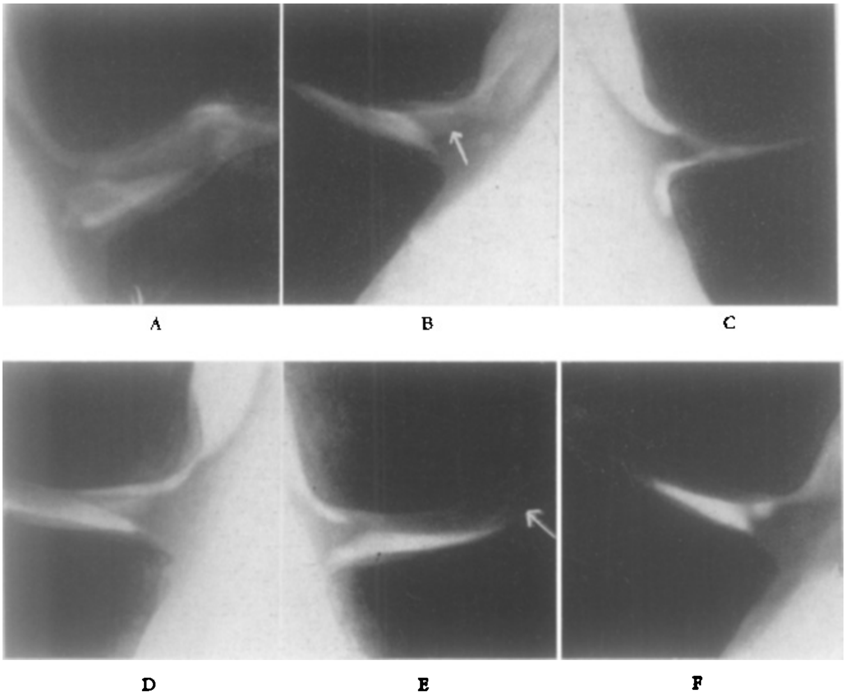


Fig. 28 A-F.

Some cases of bucket handle fracture proven at operation.

A. A tear in the left lateral cartilage with a large, abnormal soft-tissue shadow medially in the lateral joint space. (Slight int. rot.).

B. Slight, concave defect in the left medial cartilage. (Slight int. rot.).

C. Small, upwards concave defect in the right medial cartilage. (Slight int. rot.).

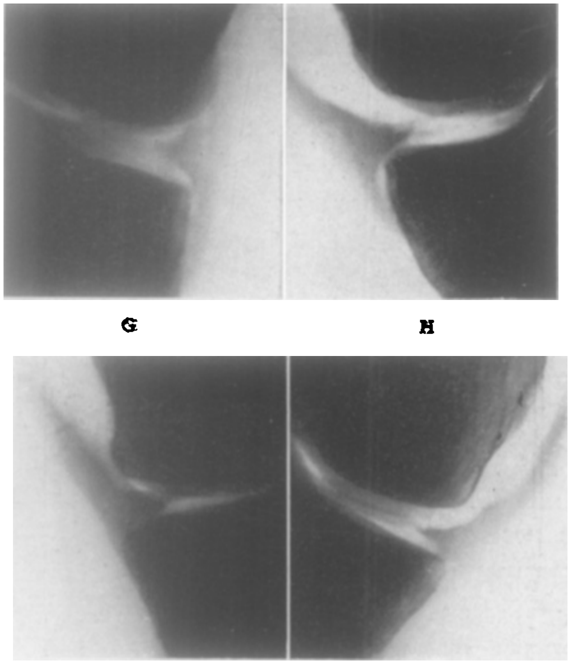
D. Irregular defect in the right medial cartilage. (Slight int. rot.).

E. Defect in the lower part of the right medial cartilage and an abnormal soft-tissue shadow in the joint space close to the spine of the tibia. (Ant. post.).

F. Large irregular defect in the left medial cartilage. (Ant. post.).

Partial Tear.

Partial tear of the medial cartilage was ascertained at operation in 11 instances, in the anterior horn in 7 cases and in the posterior horn in 4. A distinct fissure through the cartilage was demonstrable



G H

I K

Fig. 28 G-K.

G. Irregular defect in the right lateral cartilage and an abnormal soft-tissue shadow in the lateral joint space. (Ant.-post.).

H. Small, upwards concave defect in the right medial cartilage. (Slight int. rot.).

I. Small, upwards concave defect in the right medial cartilage. (Ant.-post.).

K. Large, downwards concave defect in the left medial cartilage. (Slight ext. rot.).

on the roentgenogram in 5 cases and in the remaining 6 there were defects and irregularities in the shadows of the cartilages. In only 2 cases was the torn and dislocated part demonstrable in the shape of an abnormal soft-tissue shadow close to the spine of the tibia.

Fig. 30 A shows a fissure in the posterior part of the medial cartilage, verified at operation. Fig. 30 B presents a cartilage lacking the tip of the wedge in the views in external rotation (the posterior horn), whereas the anterior view was natural. At operation the cartilage proved to be quite normal anteriorly, but posteriorly there was a longitudinal tear and dislocation of the torn part. Lastly, Figs. 30 C and D show a distinct vertical tear through the shadow of the cartilage posteriorly (both views of external rotation). Opera-

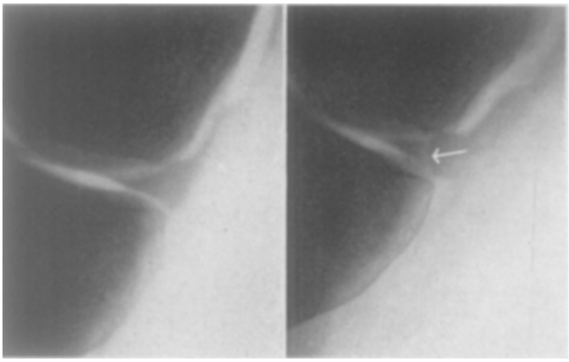


Fig. 29.
Total longitudinal tear in the medial cartilage without dislocation of the torn part.
A. Left cartilage in slight internal rotation showing no tear.
B. Same view with a more powerful abduction showing the tear.

tion revealed a tear of the posterior horn without dislocation of the torn part.

Partial tear of the lateral cartilage occurred 4 times, twice in the anterior and twice in the posterior horn. In 3 cases there was a distinct soft-tissue shadow in the space between the tibia and femur. In other words the demonstration of the dislocated part is more common and more reliable in the lateral than in the medial cartilage, also as far as partial tears are concerned. Fig. 30 E shows the shadow of the lateral cartilage, short and plump with an almost vertical demarcation towards the joint; closer to the spine of the tibia there is a large soft-tissue shadow interpreted as the part torn off the cartilage. In this instance too the subsequent operation revealed a tear posteriorly in the lateral cartilage.

Differential X-ray diagnosis of partial from total longitudinal tears without dislocation must be considered extremely difficult. A fissure visible in only one or two of the views is not sufficient to

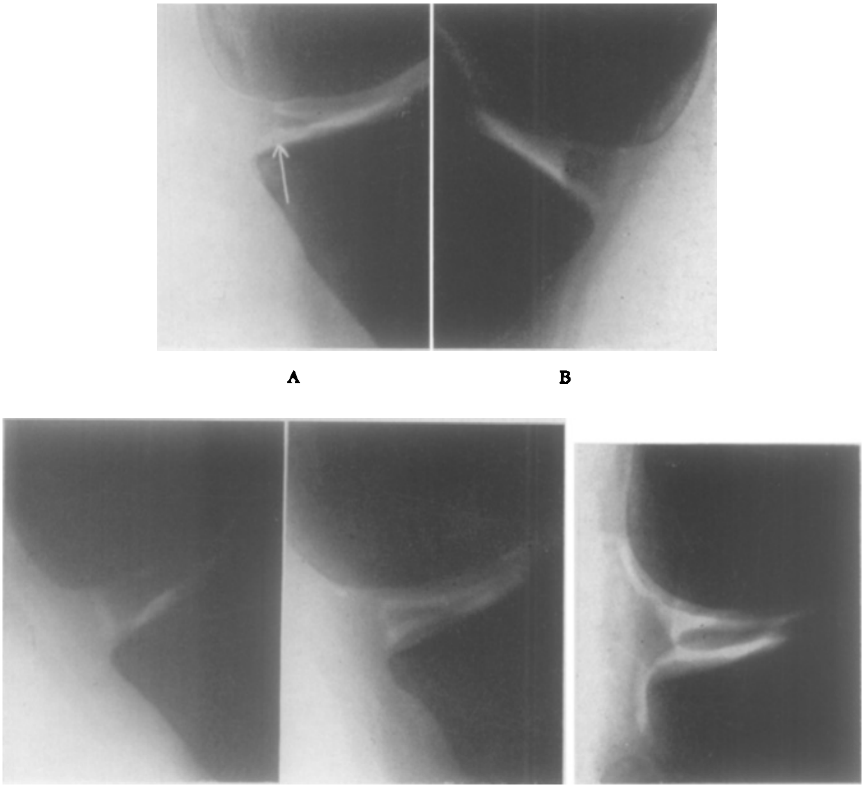


Fig. 30.

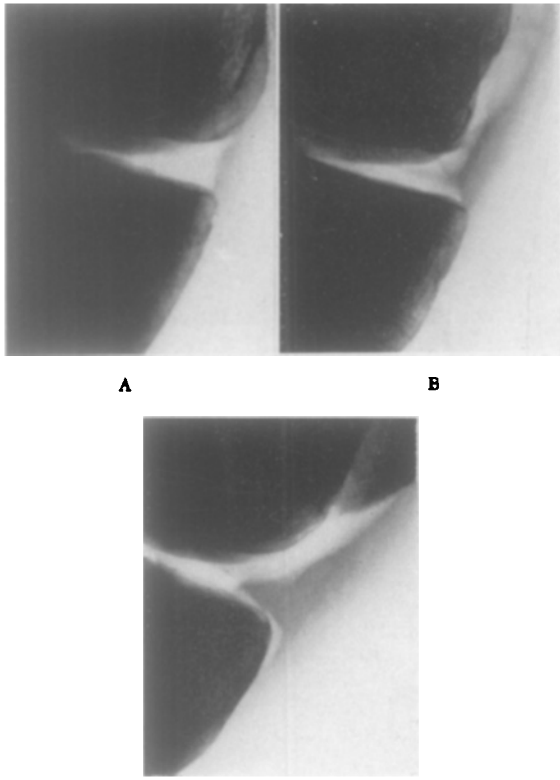
Partial tears of the medial cartilage with and without dislocation of the torn part.

A. Fissure in the posterior part of the right medial cartilage. (Slight ext. rot.).

B. Vertical defect in the posterior part of the left medial cartilage. (Maximum ext. rot.).

C. and D. A vertical slit in the posterior part of the right medial cartilage. (Slight and maximum external rotation). See furthermore Fig. 18.

E. Large, oblique defect in the left lateral cartilage with a large abnormal soft-tissue shadow in the lateral joint space. (Maximum int. rot.).



A B

C

Fig. 31.

Sequels of meniscectomy. Left knee.

A. and B. The shadow of the medial cartilage is totally missing. (Ant.-post. and slight int. rot.).

C. A remnant of a cartilage can distinctly be seen right in front. (Maximum int. rot.).

decide whether it is a case of the one or the other. It is only in the presumably very rare cases where a fissure is visible in the cartilage in all the views right from before backwards, that a diagnosis of total longitudinal tear can be made.

If the torn part, on the other hand, is dislocated, one can with greater confidence make a diffierential diagnosis between partial and total tear. This material did not contain a case in which a major or minor portion of the torn part was dislocated, while the remainder stayed *in situ*. Either the whole part is dislocated or else it remains *in situ*.

Sequels of Meniscectomy.

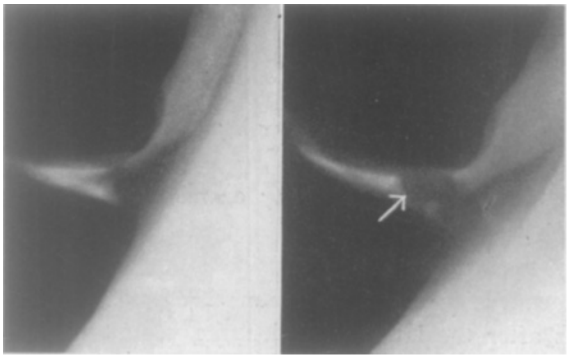
Three of the patients had earlier been submitted to operation on the semilunar cartilages.

In the first instance the X-ray examination revealed that the entire medial cartilage had been removed except the anterior horn (Fig. 31). This remnant was considered to be the cause of the patient's inconvenience and therefore removed. On follow-up about 18 months after the latter operation the patient was symptomless. In the second case, one of earlier medial meniscectomy of the right knee, X-ray revealed that apart from the marginal part of the cartilage there must remain at least a portion of the torn part of the cartilage, a finding which was proved upon operation.

Eventually, in the third case with a history of partial removal of the left lateral cartilage about 6 months previously, X-ray revealed pathological changes in the remaining basal part of the cartilage. This finding was also proved at the subsequent operation.

Torn Semilunar Cartilages not Operated upon but Diagnosed with Certainty by Arthrography.

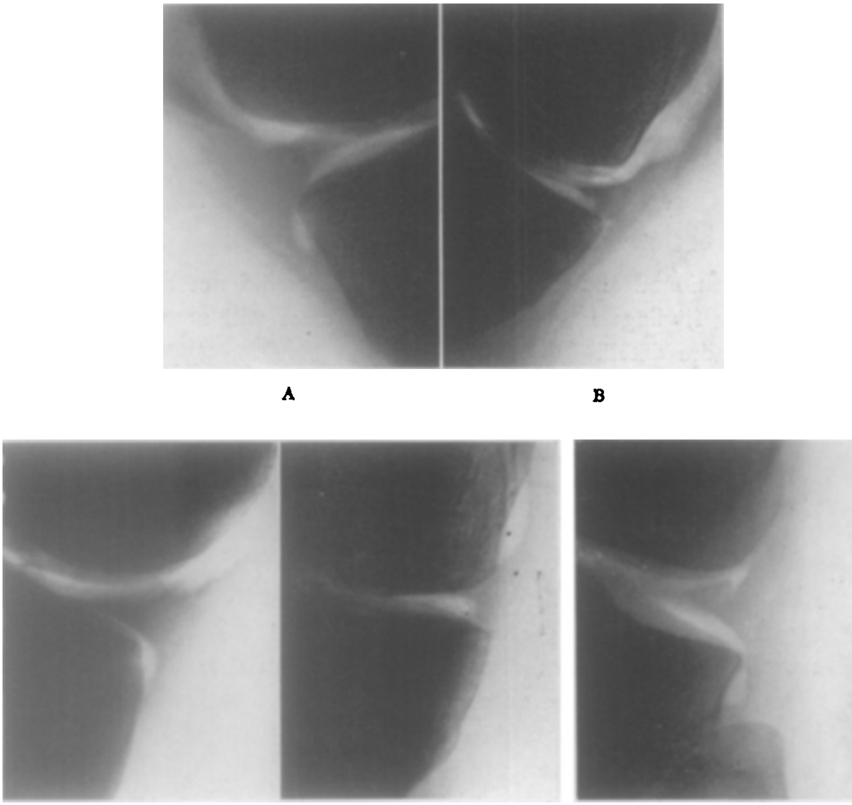
This group comprises 6 patients with 4 medial and 2 lateral tears. It is a peculiarity of one of the case histories that the reduction of the torn and dislocated part of the cartilage could be observed through the fluoroscopic screen. Fig. 32 A is a view of the medial cartilage before the reduction, showing the short, plump cartilage with an irregular, tattered, almost vertical demarcation towards the joint space. B is a view taken after the reduction in the same projection as A. Now the rather large torn part of the cartilage (↗) is visible in close relation to the basal part which adheres to the capsule. The remaining 5 cases are presented in Fig. 33. A represents a plump cartilage, almost cut off vertically, partly superimposed upon the shadow of the anterior horn. B and D show minor concave defects and C a larger upwards concave defect in the medial cartilage. Eventually, E shows a vertical fissure in the lateral cartilage.



A B

Fig. 32.
Case not submitted to operation, but showing definite X-ray evidence of torn semilunar cartilage.
A. A large irregular defect in the left medial cartilage.
B. The same cartilage following reduction of the torn part.
(Both views in slight int. rotation).

In 13 cases there were distinct accumulations of fluid in the knee joint on the day of the X-ray examination. Before the insufflation in these cases an amount varying from 10 to 60 ml. of a partly clear, yellowish, serous, partly more hæmorrhagic fluid was removed by aspiration. In no case did the small quantities of fluid which presumably remained after the aspiration inconvenience the examination, except perhaps in one case with 30 ml. of a rather viscous exudate in which the outlines of the semilunar cartilages were not quite as sharp as usual, but this condition did not prevent the interpretation.



A B

C D E

Fig. 33.

Cases not submitted to operation, but showing definite X-ray evidence of torn semilunar cartilage.

A. Defect in the right medial cartilage. (Max. int. rot.).

B. Downwards concave defect in the left medial cartilage. (Slight int. rot.).

C. Large, upwards concave defect in the left lateral cartilage. (Slight int. rot.).

D. Irregular defect in the left medial cartilage. (Slight int. rot.).

E. Slit in the right lateral cartilage. (Max. int. rot.).

DIAGNOSTIC ERRORS

As mentioned above the operative findings did not agree with the X-ray findings in 7 instances. These cases will now be dealt with in more detail.

In the 1st case the roentgenograms indicated a fissure in the anterior and basal part of the medial cartilage. Operation failed to reveal any definite signs of a fissure, but on the other hand, the middle third of the cartilage was dislocated upwards along the inside of the capsule so that it was not at all situated between the articular surfaces. Perhaps this was a case of an abnormally mobile, but otherwise natural cartilage, a *laxite meniscale* as described by *Jirasek* (1930). *Schaer* (1938) mentions one case of this condition. He expresses as his opinion that the condition is extremely rare, that the abnormal mobility is due to looseness in the otherwise firm connexion between the capsule and the base of the cartilage, and that this looseness may be of traumatic origin.

In the 2nd case one of the views revealed a somewhat tattered and irregular medial cartilage, but no signs of tear. Arthrotomy showed nothing abnormal. A later revision of the roentgenograms showed the changes described on the view in maximum internal rotation to be small and inconspicuous. In this case it is, therefore, a question of erroneous interpretation on account of lacking knowledge, and therefore the method is hardly to blame.

In the 3rd case there were X-ray signs of a total tear of the medial cartilage with dislocation of the torn part. However, the subsequent operation revealed a completely natural medial cartilage. The roentgenograms of this patient have, however, been lent out and cannot be found, so that it is impossible to comment the case further. Still, everything seems to point in the direction of an obvious diagnostic error.

In the 4th case a small and slightly irregular shadow of the cartilage and a soft-tissue shadow close to the spine of the tibia led one to believe that it was a case of tear with dislocation in the medial cartilage. In this instance too the cartilage was, however, found to be quite natural. Cases 2 and 4 urge the necessity of displaying caution in interpreting small and slightly irregular, but

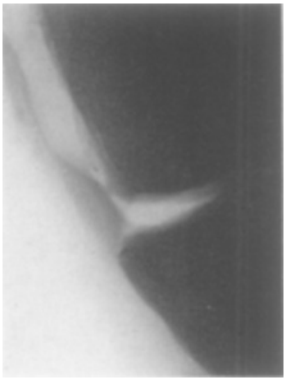


Fig. 34.
Large vertical defect in the right medial cartilage. At operation the knee was found to be natural. (Ant.-post.).

otherwise wedge-shaped shadows of the cartilages. Abnormal soft-tissue shadows in the medial part of the joint space should also be judged with caution.

In the 5th case arthrography revealed considerable changes of the medial cartilage (Fig. 34), as only its base was visible. Arthrotomy showed a natural medial cartilage and besides osteochondritis dissecans of the external femoral condyle with a loose body and mild degenerative changes in the lateral cartilage. On the roentgenograms the changes in the medial cartilage are very marked and can only be interpreted as being of a pathological nature. As they could not, however, be seen upon arthrotomy, the method must have failed completely in this case.

In the 6th case arthrography revealed indentations superiorly as well as inferiorly at the base of the medial cartilage in the antero-posterior as well as the view in slight internal rotation (Fig. 35). The lateral cartilage was found to be natural. Revision of the films shows the same condition. Upon arthrotomy the medial cartilage was found to be natural, but in the anterior part of the lateral cartilage there was a longitudinal tear measuring about ½ cm. It is apparent from this case that the medial cartilage may normally

Fig. 35.
Small indentations in the superior and inferior part of the left medial cartilage close to its base. Operation proved the finding. (Slight int. rot.).

have notches superiorly as well as inferiorly at its base. This must, however, be a rare variation, as it was encountered only once in the present material. The failure to demonstrate the tear in the anterior horn of the lateral cartilage is no doubt due to the fragment having been in so close contact with the basal part of the cartilage that the air has been unable to force its way into the tear.

In the 7th case the roentgenogram revealed, approximately in the central part of the cartilage, a tear in the shadow parallel with its upper edge and about 4-5 mm. in depth. Operation revealed a completely natural cartilage.

SUMMARY CONSIDERATIONS REGARDING THE ROENTGEN EXAMINATION OF THE SEMILUNAR CARTILAGES ACCORDING TO THE METHOD OF MÖHLMANN & MADLENER

Möhlmann & *Madlener* have succeeded in finding a procedure which allows of a really systematic interpretation of both semilunar cartilages in practically all cases. The advantages of this method are due to the fact that, apart from making use of earlier technical improvements, *Möhlmann* & *Madlener* have laid particular stress on the anatomical features of the semilunar cartilages, and their knowledge of the latter has enabled them to set the semilunar cartilages out on the roentgenogram far more distinctly than was possible previously.

In clear and perspicuous roentgenograms the method illustrates the difference between the anatomical structure of the medial and lateral cartilage. In addition, it has made it possible to discern a number of normal variations, particularly those localized to the lateral cartilage.

Moreover, experience has shown that all marked changes in the cartilages, bucket handle fracture and localized longitudinal tear with dislocation are demonstrable with considerable accuracy in several views of each patient. In addition, it is often possible to state the localization and extent of these changes. In a small number of cases it has also been possible to diagnose those changes in the cartilages which appear less distinctly on the roentgenograms, i.e., total and partial longitudinal tears without dislocation. The examination requires only very simple instruments, and the complications and risks imaginable in connexion with it appear to be avoidable when care is exerted. It must, however, be pointed out that the performance of the examination as well as the interpretation of the films requires routine and experience and that continued employment of the method will presumably increase the accuracy of the diagnosis.

Regrettably, we lack a real basis for comparison in order to estimate the superiority of this method above other methods of arthrography. The writer is, however, convinced that it is a most valuable addition to the clinical examination, as it will usually be able to decide whether there is indication for operation or not in cases of doubt.

SUMMARY

In the introduction the writer deals with the difficulties of deciding in all cases, by clinical examination alone, whether a knee joint injury is due to torn semilunar cartilages or not. Moreover, brief mention is made of the chief methods which have been tried for this purpose: auscultation, arthro-endoscopy, plain roentgenography, and arthrography. Of all these methods the last-mentioned one has proved to be most tempting and promising, but at the same time it has often been rather disappointing and difficult to perform.

Then follows a historical survey, partly of the contrast media which have been employed in the various stages in the development of arthrography, partly of the radiographic technique.

The first arthrographies were performed by means of negative contrast media in the form of gases. Later when positive contrast media were introduced, they were also used for arthrography, and on this basis 4 different procedures gradually developed: (1) Filling of the joint cavity with negative contrast media, oxygen, nitrogen or atmospheric air, (2) massive filling of the joint cavity with positive contrast media, (3) injection of small amounts (2 to 10 ml.) of positive contrast media, and (4) a combination of (1) and (3), simultaneous application of positive and negative contrast media.

Of the positive contrast media comprising iodized oils and water soluble contrast media, the oils quickly proved to be inapplicable for 3 reasons. They had an effect of marked local irritation, their distribution within the joints was very defective, and lastly the absorption of the oil was so slow that remnants were demonstrable in the joint cavities years after the examination.

Among the 4 methods mentioned, massive filling of the joint cavity with positive, aqueous contrast media has now practically speaking fallen entirely into disuse. The reason is partly that the

aqueous contrast media also cause local irritation, particularly when employed in large quantities, but mainly that the massive contrast shadows dominate the picture and hide the details of the soft tissues.

The remaining 3 methods still in use have been employed with more or less success. On the basis of the literature it is, therefore, impossible to find out which of the 3 methods should be preferred. It may be stated, however, that the investigations of recent years appear to be making increasing use of negative contrast media or simultaneous application of positive and negative media: the combined method. It is pointed out that as far as the quality of the roentgenograms is concerned, it makes no difference whether the gas used is nitrogen, atmospheric air, oxygen, carbon dioxide or nitrogen monoxide, but that it is practical to use a rapidly diffusing gas. In that way one can avoid leaving the needle in the joint during the examination or making a new puncture in order to empty out the gas. Nitrogen monoxide, oxygen and carbon dioxide, all with a suitable rate of diffusion (24 to 48 hours), are recommended.

For a long time little interest was displayed in the radiographic technique. Gradually it became evident, however, that it was not only the nature and amount of the contrast media which was decisive, but the radiographic technique also played a part, and an addition of great value was the introduction of oblique views.

The writer proceeds with anatomical considerations regarding the semilunar cartilages and those parts of the knee joint which play a part in the roentgen visualization of the semilunar cartilages.

On the basis of earlier investigations it is demonstrated that the shape of the semilunar cartilages on the roentgen film depends largely on the direction of the X-rays. If the X-rays strike the cartilage right from the side, the central ray running parallel with the under surface of the cartilage, the latter will appear as a wedge-shaped figure. If, on the other hand, the cartilage is struck by the rays at some angle or other, the wedge-figure is diminished, the distance from the base to the tip of the wedge is shortened, and at the same time there will appear on the picture several arcuate intersecting outlines, complicating the interpretation. It is therefore important that the central ray should always run parallel with the under surface of the semilunar cartilage. Moreover, considering that each view only includes a small segment of the entire cartilage, it is of great significance to obtain so many views of each cartilage that the sum total of the individual wedge-shaped figures includes the entire cartilage from anterior to posterior horn.

A description follows of the method of *Möhlmann* & *Madlener* combining the conditions mentioned above for obtaining good films, i.e., a parallel course of the central ray with the under surface of the semilunar cartilages, several views in different projections during abduction and adduction in the knee joint (which movements simply suck the contrast into the above-mentioned, now yawning joint spaces) and positioning under the fluoroscopic screen before each individual view is taken.

The technique of the injection is described and mention is made of the various procedures used to make certain that the needle is within the joint. The *Teschendorff* insufflation apparatus is described. Thereupon, the writer proceeds to the various demands made on the roentgen examination in order that both cartilages may be visualized in their full extent and deals with the technique used to fulfil these demands.

Then the writer points out the risks and complications which the examination might be imagined to involve. In the first place it is a question of the risk of infection and air embolism. A search of the literature has proved that these risks are extremely slight, and when the intervention is performed *lege artis* they can probably be avoided altogether. Moreover, mention is made of periarticular emphysema, and it is emphasized that this complication, so disturbing to the interpretation of the films, can be avoided when the recommended technique of injection is complied with. Finally, the writer touches upon rupture of the capsule caused by too high pressure in the joint space, stating that this complication may be entirely disregarded, as the method used only aims at obtaining a depot of contrast medium with a very slight excess pressure in the joint cavity.

The normal X-ray aspect of the semilunar cartilages is described. These normal views have been obtained partly by X-raying a series of disc-shaped frozen sections of post-mortem specimens, partly by arthrographic studies of knee joints which have exhibited natural cartilages upon later arthrotomies. Illustrations are given of some variations in the shape of the cartilages within normal limits, especially those localized to the lateral cartilage.

The pathological anatomy of torn semilunar cartilages is dealt with.

Thereupon, the writer gives an account of his own material examined by the method of *Möhlmann* & *Madlener.* This material includes 149 patients on whom a total of 150 pneumoarthrographies have been performed. Sixty-nine patients have been submitted to operation and they form the basis of the estimation of the diagnostic value of the method, considering that a direct comparison has been made of the roentgen findings and the operative findings. In addition, there are 6 patients who exhibited definite roentgen signs of a tear, but who were not operated on for various reasons. Thus, the actual material comprises a total of 75 cases. All the examinations have been carried out without the slightest signs of complications.

The roentgenograms showing torn semilunar cartilages are reviewed. It appears, that not only all major changes, bucket handle fracture with dislocation of the torn part and partial longitudinal tears with dislocation of the torn part, were demonstrable with considerable accuracy, but the minor changes, total and partial longitudinal tears without dislocation, could also be diagnosed in practically all cases. It is, however, emphasized that the last-mentioned forms may escape detection when the torn fragment is in close contact with the basal part that adheres to the capsule and an example is reported.

In all cases where the examination revealed normal shadows of the semilunar cartilages, the following operation also showed normal cartilages. Moreover, the examination also proved reliable in some additional cases who had earlier been submitted to meniscectomy.

Finally, the writer mentions a few diagnostic errors.

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