ACTA ORTHOPAEDICA SCANDINAVICA

Supplementum 68

From the Ortopedic clinic, Lund, Sweden. Head: G. Wiberg

Shape of the intercondylar groove normally and in recurrent dislocation of patella

A clinical and x-ray-anatomical investigation

BY HÅKAN BRATTSTRÖM

EJNAR MUNKSGAARD COPENHAGEN 1964

Translator W. F. Salisbury
Statistical advisor: R. Ericsson, FK

Printed in Sweden
LUND 1964
BERLINGSKA BOKTRYCKERIET

Contents

Introduction

Lorsqu'on recherche dans les auteurs anciens ou modernes l'origine des doctrines assez généralement admises aujourd'hui sur les luxations de la rotule, on est surpris de trouver entre eux un tel désaccord, et une telle disette de faits avec une telle abondance d'opinions.
(Malgaigne 1836)

Recurrent dislocation of the patella refers in this work to only those instances where, on at least two occasions, the patella has temporarily left its normal place on the ventral side of the femur between the condyles and for a longer or shorter time has become displaced on to or over the lateral femur condyle. The dislocation will have been directly observable by the patient or others, or it will, from the anamnesis, undoubtedly appear that it has been a question of a patellar dislocation (the release mechanism, the sudden insufficiency of the extensor mechanism of the knee, hemarthrosis, tenderness over the medial surface of the joint, x-ray changes medially, etc.).

It is a relatively rare condition. Despite this, many works have been written on the subject, discussing mainly the surgical treatment, and it is remarkable that a condition so relatively rare as dislocation of the patella should have given rise to over 100 different methods of operation. However, most of them are modifications or combinations of about ten basic procedures.

Regarding the causes of patellar dislocation, one has been more reserved, although several anatomical changes in the skeleton and the extensor mechanism have been described by some authors as cause of patellar dislocation, by others as result of patellar dislocation: genu valgum, patella alta, under-developed vastus medialis, changed femur torsion, etc.

Nearly all authors who have investigated the subject are also of the opinion that the size and formation of the lateral femur condyle might be changed in patients suffering from recurrent dislocation of the patella.

The patella glides by flexion-extension of the knee in a sulcus formed by the continuation of fossa intercondyloidea on the ventral side of the femur, where it is bordered by the medial and the lateral femur condyle, respectively.

A clear connection has been stated to exist between the size of the lateral femur condyle and the occurrence of the dislocation of the patella.

Normally, the lateral condyle is higher than the medial; it reaches further ventrally when the patient stands; it rises higher than the medial over the bottom of the sulcus and thereby prevents the patella from becoming displaced laterally.

At the dislocation of the patella, this lateral condyle is said to be "lower than usual", "under-developed", "flattened", "not so high as usual", "approximates the medial condyle in height", etc., whereby it might be easier for the patella to become displaced laterally.

I have been unable to discover any investigation (satisfactory in this respect) of the normal anatomy, the normal size and form of the two femur condyles, and consequently no investigation that shows whether and in what manner the normal anatomical conditions have been changed in patients with recurrent dislocation of the patella.

The purpose of the present investigation was:

1. Under standardized conditions to investigate by x-rays a number of femoro-patella joints in healthy persons and to obtain objective measurable expressions of the formation and size of the osseous parts of the femur condyles.
2. Under the same standardized conditions to investigate patients who have or have had recurrent dislocation of the patella in order to see whether any characteristic anatomical deviations from the normal can be found.
3. By dividing the patient material according to different principles (male-female, traumatic-nontraumatic, etc.) to see whether these possible deviations are more or less expressed in different groups and thus contribute towards characterizing these groups.

Definitions, Abbreviations, Symbols, Tables. Statistical methods

A. *Definitions*

Dysplastic changes (of the femur): the height of the lateral condyle (possibly also the medial) above the bottom of the intercondylar groove is lower than usual (where applicable, this means: lower than the mean of the normal material) and/or the sulcus angle, L+M, is larger than usual (where applicable, this means: larger than the mean of the normal material).

(Femoral) dysplasia is used synonymously with the above.

Illusory dysplasia: created by increased outwards rotation or torsion of the condyle section (see p. 48).

Flexion—extension in the knee: the initial position with extended knee=0°.

Recurrent dislocation of the patella: the patella has on at least two occasions momentarily left its usual place in the intercondylar groove and for a longer or shorter time been displaced on to or over the lateral condyle.

Dislocation and luxation are used synonymously.

Q-angle: the angle, with its apex at the patella, formed between ligamentum patellae and the extension of the quadriceps-resultant distally. Fig. 7 B p. 31.

B. *Abbreviations, Symbols, Tables*

LC and MC: approximate expressions for the extension of the lateral and the medial condyle ventro-dorsally (see p. 71).

l, m, l_t, m_t, d, LC, and MC are expressed in mm. } see fig. next page and
C_p, C_t, L, M, and L+M are expressed in degrees. } text pp. 68—69.

The figures in the tables within parentheses after dx and sin give the number of knees or of patients belonging to each column.

The figures within parentheses after the column numbers of the tables indicate, where they occur, the numbers of the columns that lie as basis for the column involved.

Column numbers 1 and 2, which in *all tables of measured results correspond to the normal values* of the right and the left side, have, from considerations of space, been omitted in some tables, but are given on next page.

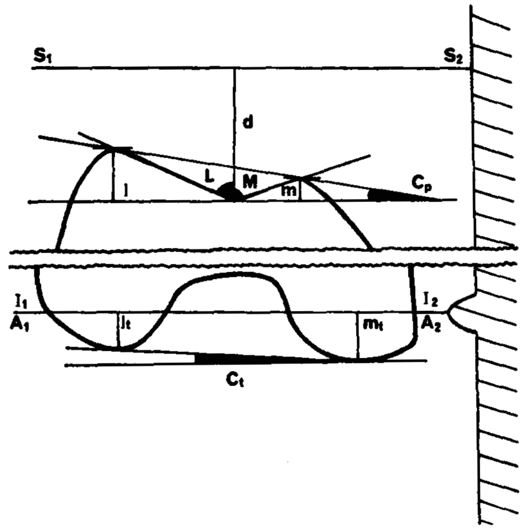


Fig. 22. Drawing (one knee only) that shows the distances and angles which have been measured. (x-ray pictures show both knees.) See text for symbols.

Col.	1	2	1	2
	100 normal females		100 normal males	
	dx	sin	dx	sin
l	10.08±0.19	9.11±0.17	11.60±0.18	10.66±0.20
m	5.59±0.16	5.87±0.15	6.40±0.16	7.33±0.18
C_p	6.10±0.30	4.36±0.26	5.95±0.26	3.83±0.30
L	69.39±0.38	70.77±0.38	69.31±0.35	70.68±0.35
L+M	141.79±0.60	142.36±0.61	142.78±0.51	141.90±0.54

C. *Statistical methods*

Statistical calculations of mean errors and dispersion were made according to current methods (Dixon & Massey 1951).

When different groups of patients were compared with one another, and the difference between the means of the groups of l, m, C_p, L, and L+M (see Symbols) was calculated, the difference was tested two-sidedly.

The difference is said to be statistically highly significant (***) when it is 3.29 times its mean error (= "1 ‰ level"); statistically significant (**) when it is 2.58 times its mean error (= "1 % level"); and statistically probable (*) when it is 1.96 times its mean error (= "5 % level").

When comparing the normal material with different patient groups, the test for l, m, L, and L+M (not C_p) was performed one-sidedly and the significance limits were 3.09 ("1 ‰ level"); 2.33 ("1 % level"); and 1.65 ("5 % level").

If the difference between two means is less than either of the mean errors of the means or less than 1.5 times the mean error of the normal material, no significant difference was considered to exist, and the mean error of the difference was not calculated.

If in small groups ($n<25$) significant differences were obtained with ordinary mean error calculations, the mean error of the difference was also calculated with the aid of the greatest dispersion and the t-test was made. Where deviations from the first calculated significance emerge, this is advised in a footnote to the table or in the text.

CHAPTER I

Historical review

Thestrup Andersen (1955) states that when one delves into the literature concerning the dislocation of the patella, one is first impressed by the colossal amount of casuistic information, which, on the basis of one or two cases, describes the etiology, the symptoms, and the treatment without advancing anything new. This, I wish to endorse unreservedly. In the following will be given only a summarized report of certain trends of the literature concerning patellar dislocation, as well as reports of the more important works. Where this has been considered suitable, a brief historic review has been given in the appropriate chapters.

One finds that already Galenos (129—200) gives a description of the condition, and he indicates also a method of bandaging intended to keep the patella in place.

During the middle-ages and up to the middle of the 19th century, descriptions were given of traumatic dislocations and their repositioning. The first to give a collocation of the cases so far published is Malgaigne (1836) who describes 25 cases. Streubel, 30 years later, is able to assemble 120 cases, partly his own and partly from the literature. In 1921, Karl collects the cases described to date: a total of 296.

Up to the end of the 19th century, the interest is concentrated upon the *etiology and the classification of the dislocations connected with it.*

The basic classification is:

1. Congenital, i.e. caused mainly by some congenital displacement or change in the skeleton or the soft parts.
2. Traumatic, i.e. caused mainly by a direct trauma.
3. Pathological, i.e. caused mainly by some pathological change, which is in turn caused by some illness or accident: polio, fracture, rickets, arthritis, etc.

This classification is thus based upon the etiology and is used with variations by several authors: Friedländer (1901), Wiemuth (1901), Soliero (1906), Ewald (1906), Finsterer (1909), Karl (1921), Conn (1925), Cole & Williamson (1934), Hauser (1938), and Houkom (1942).

Other authors classify according to the clinical picture into acute, habitual, and/or recurrent dislocations (Aldibert 1894, Lückerath 1919, Kapel 1936, and Blumensaat 1938). The different nomenclature used in German and French literature must be mentioned here. By habitual dislocation, the French mean one that occurs every time the knee assumes a certain position, which can well be physiological. This form is also called pendular dislocation or permanent dislocation.

On the other hand, German authors usually mean by habitual dislocation that which is defined by me in the introduction as recurrent dislocation of the patella.

These main groups vary and are classified and assembled in different ways by different authors without the discussion apparently being fruitful.

Around the turn of the century, the interest is concentrated more upon *therapeutic questions* and chiefly on surgical therapy. It is surprising that the methods of operating most usual today were already published then: Roux 1888 (who moved the attachment of ligamentum patellae medially), Goldthwait 1899 and 1904 (who wholly or partly moved ligamentum patellae medially or distally), and Krogius 1904 (whose muscle-fascia plastic method spread rapidly). In the same year, 1904, Graser published his supracondylar inwards rotating osteotomy. Heusner in 1902 described his method where he, being the first to do so, used one of the muscles from the back of the knee joint (m. semitendinosus) in order to draw the patella medially.

During the following decades, the surgical technique continues to be the main theme, and several operation procedures and modifications are described, most of them with good primary results.

Other conditions are also subjects of interest. Lückerath (1919), Hohlbaum (1921), and Zanoli (1926) are of the opinion that the flattening of the lateral femur condyle, mentioned by many, was due to changed rotation or torsion of the femur. Jaroschy (1924) and Knutsson (1941) aroused interest in *the x-ray investigation of the femoro-patellar joint* and the appearance of the x-ray picture, and Wiberg (1941) studied the same joint by x-ray and by autopsy.

Blumensaat published in 1938 a large work on dislocations of the patella, where he discusses thoroughly the earlier literature and reports the current view of the subject. The work does not in itself present anything new, but has through its thorough survey of the literature and its "weight" made a considerable impression upon the discussion. The method he describes for deciding whether a patient has a high-standing patella (patella alta) has proved valuable.

Beginning in the 1930's, *larger follow-up series* of patient material were published and have since been continued (Kapel 1936, Macey 1937, Wallinkoski 1942, Sjövall 1943, McCarroll & Schwarzmann 1945, Seedorff 1946, Felländer 1949, Harrison 1955, Böhi 1957, Jerre & Knutsson 1958, Heywood 1961, Karlholm 1961, Rolander 1961, Hellum 1962, Cerwenka 1962, and Nicod & Nikolakakos 1963).

Most series, however, are relatively small, composed of a maximum of 50—55 patients, and are lacking in uniformity regarding etiology, classification, and treatment; it is therefore difficult to make comparisons. In 1950, Marion & Barcat published a large work on dislocations of the patella. They have by questioning colleagues in France and abroad collected 218 cases (including their own patients) to which they add 273 cases from the literature of exhaustively described "luxations spontanées", i.e. "not purely traumatic cases", and have thus obtained 491 cases, which they analyze with respect to etiology, pathologic anatomy, clinic, operation methods, results, etc. This work and the discussion it gave rise to has been of great importance, but its weakness was that it was not a uniformly followed up and appraised material.

Thestrup Andersen in 1955 published a work on dislocation of the patella, where he examined journals and pictures of 315 patients, who had during 1920—1951 been treated in orthopedic wards in Denmark. He thereafter personally post-investigated (clinically and roentgenologically) 292 of these patients. He discusses etiology, x-ray pictures, classification, therapy, prognosis, and heredity. This is by far the largest uniformly followed up material published to date.

As appears from the above, Scandinavian authors have often made pioneering contributions, generously acknowledged in non-Scandinavian literature.

CHAPTER II

The anatomy and physiology of the femoro-patellar joint

The following brief description of the anatomy and physiology treats only data of importance in this investigation.

Femur. The femur shaft terminates distally in the two condyles, the lateral and the medial. Together these form the two articular surfaces against partly the tibia (facies tibialis femoris) and partly patella (facies patellaris femoris). These articular surfaces merge into each other, but in about 50 per cent of the cases, there can be seen a suggestion of a border, linea terminalis (Fick 1911). On x-ray pictures taken laterally, there is seen in about two-thirds of investigated knee joints an impression in the contour of the bone at this border, usually interpreted as an impression of the anterior meniscus edge in the femur condyle (Ravelli 1949, Vogler 1962).

Dorsally and dorso-distally, the condyles are separated by a deep, non-cartilage covered fossa intercondylica. This passes in the ventral part of facies tibialis femoris into a deep cartilage covered sulcus, which continues on the ventral side of the femur and forms a part of facies patellaris femoris. Fig. 2. It is there shallow, but separates clearly the two condyles. The patella glides in this sulcus with the ridge that divides the articular surface of the patella into two facets.

The ventral, half-moon shaped, articular surface of the femur thus is concave medio-laterally and convex proximo-distally. It extends 2—3 cm proximally on the ventral side of the femur, calculated from the joint line, somewhat more on the lateral condyle than on the medial condyle. The lateral condyle is wider seen from the front, but if the femur shaft is considered from a vertical position, the medial condyle reaches further distally. Because the femur shaft of the normal standing person lies at an angle of 8°—10° to the plumb line, the two condyles will lie approximately level. (See Fig. 1.)

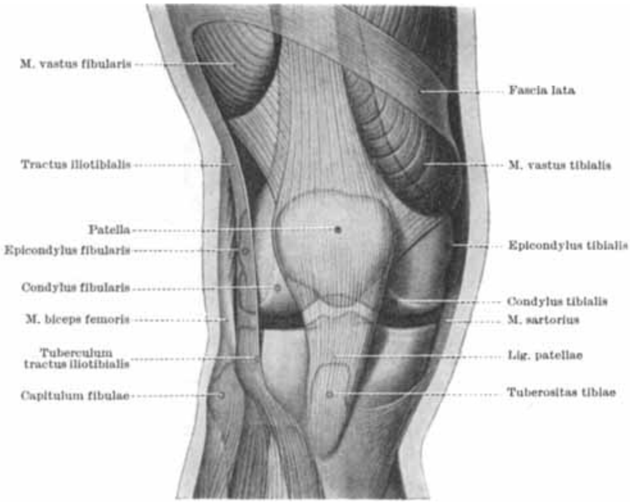


Fig. 1. Skeleton and muscles round the knee joint. (From Lanz & Wachsmuth: Praktische Anatomie.)

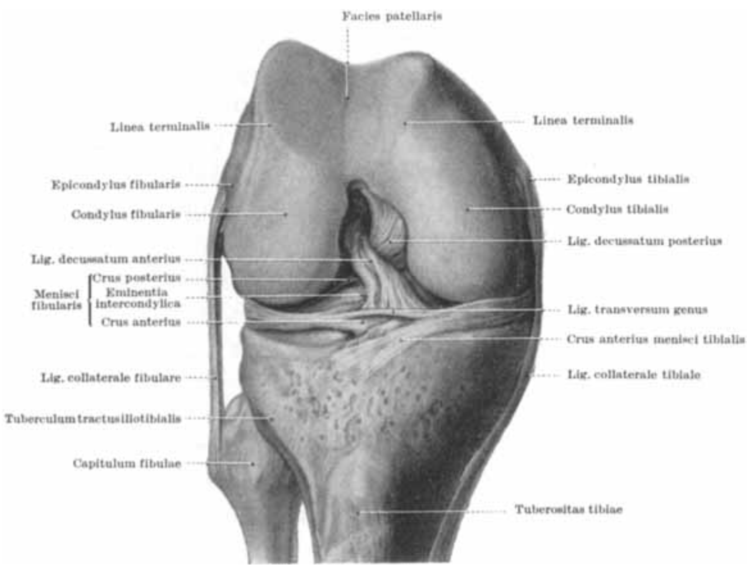


Fig. 2. Knee joint without most of the soft parts, flexed 90°, showing the distal femur end. (From Lanz & Wachsmuth: Praktische Anatomie.)

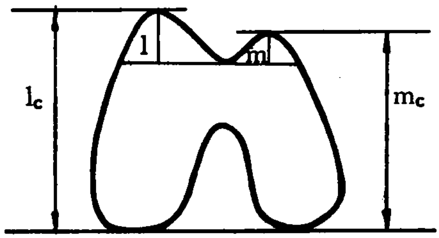


Fig. 3. The distal femur end.
lc=the extension of the lateral condyle ventro-dorsally. mc=the extension of the medial condyle ventro-dorsally. l=the height of the lateral condyle above the sulcus bottom. m=the height of the medial condyle above the sulcus bottom.

Concerning the size of the condyles in dorso-ventral direction, their "depth", it states in the textbooks that the lateral condyle is larger than the medial (the lateral condyle [lc] is larger than the medial condyle [mc]—Fig. 3) and especially that the part of the lateral condyle which forms the lateral wall [l] in the above-mentioned sulcus should be higher than the medial [m]—Fig. 3). Comparative anatomy has shown that, broadly speaking, it is only homo that extends completely the knee, and homo has also relatively the deepest sulcus (E. Payr 1928). Thus, for example, in the gorilla, facies patellaris femoris is an almost flat surface in medio-lateral direction (Malkin 1932, Böhm 1935). According to Böhm, this form is found in the human embryo and also in the newborn. It is first at about age 12 years that we get the characteristic form with ventrally protruding condyles with a sulcus lying between. Rovira & Barrios (1951), however, maintain that this form appears already in the fetal stage, and that from and including 3—4 fetal months, the lateral condyle is dominant.

The contour of the articular surfaces of the condyles is formed by the articular cartilage, which varies in thickness. On facies patellaris femoris, it is thickest centrally, about 3.4 mm, and thins out towards the sides (Kopsch 1940).

Patella. The patella is a flat, heart-shaped bone with the apex directed caudally. All its sides, except the dorsal, are covered by different parts of the quadriceps tendon and ligamentum patellae. The dorsal surface facing facies patellaris femoris is, except for the apex, completely covered by cartilage. It is divided by a longitudinal ridge into two facets, one lateral and one medial. On so-called axial x-ray pictures of the knee joint (see Fig. 14 p. 55) the lateral facet in normal persons is always larger than the medial (the relation lateral/medial is on average 1.4 and somewhat larger in female than in male—Brattström 1960). An unfortunate mistake has crept into Lanz & Wachsmuth's textbook of anatomy: In the text on page 241, it says that the ridge is displaced "fibularwärtz" and on picture number 196 on the same page, the same mistake occurs. This has resulted in some misunderstanding, mainly in German orthopedic literature.

Both the facets and the ridge are covered with cartilage. On the ridge, one finds the thickest cartilage of the body, up to 6.4 mm (Fick 1911). On an axial x-ray picture, the lateral bone surface is always concave, whereas the medial varies, sometimes being concave, sometimes convex, and sometimes flat.

Muscles and ligaments. Of the four muscles of the quadriceps, rectus femoris and vastus intermedius pass with nearly all their fibres into a common tendon, the quadriceps tendon, to which also the largest parts of vastus tibialis and fibularis are attached. The quadriceps tendon is attached to the base of the patella, except for some superficial fibres, which pass by the ventral side of the patella and then pass over into ligamentum patellae. This ligament is about 2 cm wide and 3—5 cm long and extends from the point of the patella to tuberositas, where it is attached on a broad base. Fig. 1.

The distal parts of vastus fibularis, possibly combined with some fibres from rectus, do not connect with the quadriceps tendon, but pass into tendon fibres, retinaculum patellae longitudinale fibulare, which immediately laterally pass the patella and attach to tuberositas tractus iliotibialis, partly intertwined with tractus iliotibialis. Fig. 4.

In the same manner, retinaculum patella longitudinale tibiale is formed by the distal parts of vastus tibialis and a few fibres from rectus, and passes medially of the patella and attaches to the tibia immediately medially and above tuberositas tibiae. Fig. 5.

Under these longitudinal retinacula patellae, which are thus the continuation of muscles and consequently can extend actively, there are transverse fibres, retinacula transversalia, which issue from the fibular and tibial femur epicondyles and attach to the nearest patellar edge.

The *longitudinal retinacula* partly play an active role at the end phases of the extension of the knee (Merkel 1925, Nicoll 1943, Smillie 1946) and partly contribute, by their course, to retain the patella in its

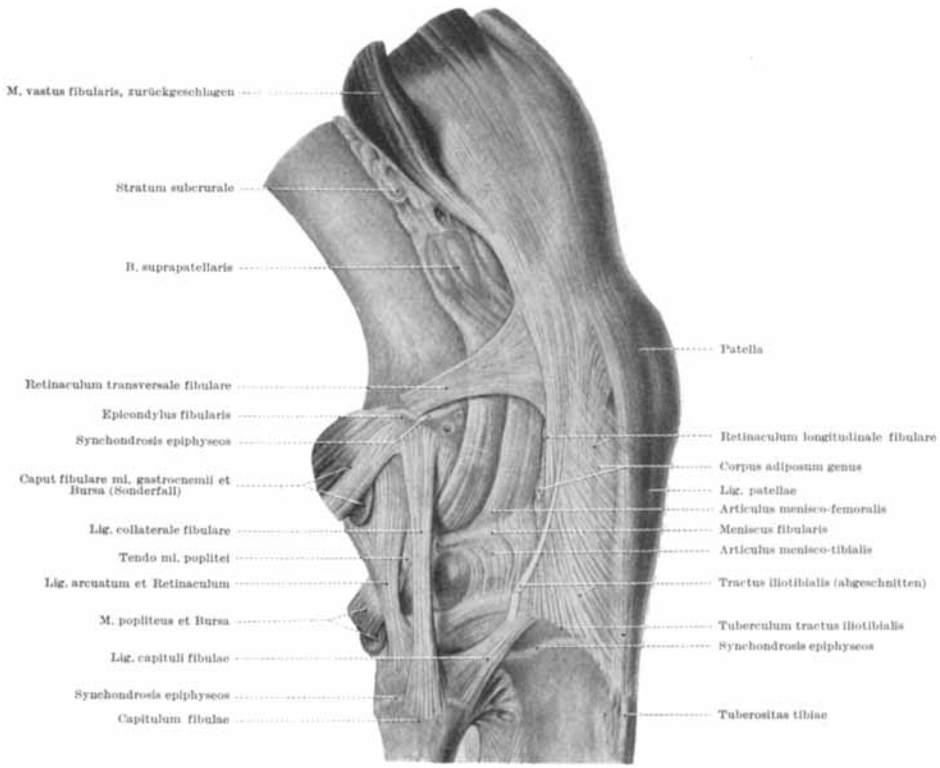


Fig. 4. Fibular side of the knee joint muscles and ligaments. (From Lanz & Wachsmuth: Praktische Anatomie.)

sulcus between the condyles during knee movements. The *transverse retinacula* border the movement of the patella sideways, and as reins check tendencies towards side displacements.

Position of patella vertically. **With extended knee and contracted quadriceps, usually only the caudal edge of the articular surface of the patella has contact with the most proximal part of the cartilage covered facies patellaris femoris. The greater part of the patella rests against the ventral synovia-covered surface of the femur, and the apex is found about 2—3 cm above the tibia plateau. If the quadriceps is allowed to relax, but the knee still remains extended, the patella, by reason of the tissue turgor (and in a standing person also through the force of gravity), falls caudally, somewhat medially, and possibly somewhat ven-**

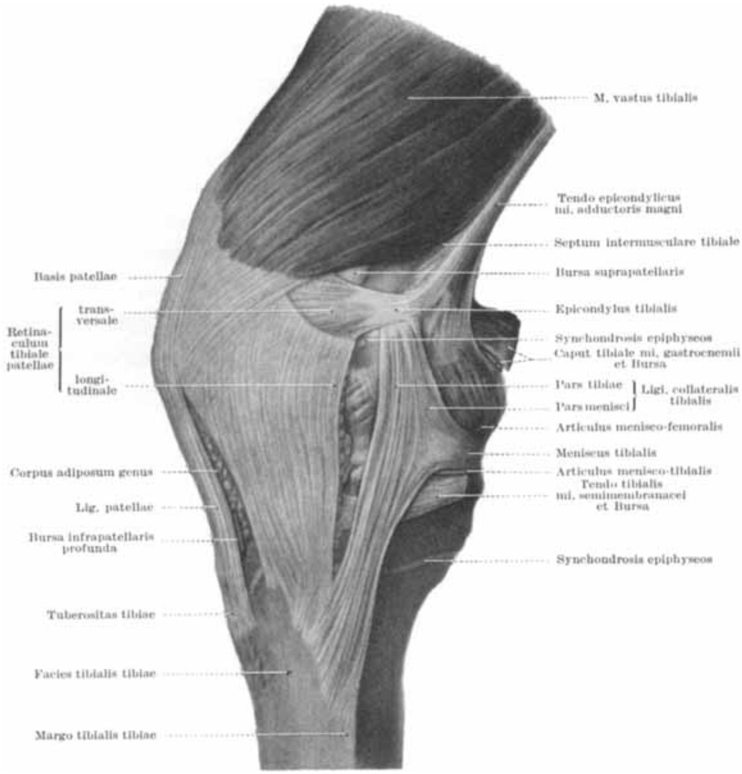


Fig. 5. Tibial side of knee joint with muscles and ligaments. (From Lanz & Wachsmuth: Praktische Anatomie.)

trally. Thus the patella will lie with its apex level with the joint line. With extended knee and relaxed quadriceps, the patella can be passively moved, both caudally-cranially and laterally-medially, about 1—2 cm in each direction. In some persons, this passive mobility is greater, and in records of patients with dislocation of the patella, "abnormal lateral mobility of the patella" or similar is often reported, but these appraisals are based upon the experience of the investigator. I have been unable to find exact measurements of the normal mobility.

With extended knee and without movement occurring between tibia and femur, one can, by alternately contracting and relaxing the quadriceps, move the patella up and down. This is called in German literature "Patellar-spiel". According to Payr, this "Longitudinal-spiel" can amount to a movement of 2—4 cm.

Valgus. Q-angle. Human beings have a physiologic valgus position in the knee of 8°—10°, usually some degrees more in the female because of her broader pelvis. The quadriceps extends along the femur, and because the tuberositas tibiae is situated in the centre line of the tibia, the extensor mechanism formed by *quadriceps' resultant* + *patella* + *ligamentum patellae* will form a valgus angle, which immediately prior to full extension is about 175 degrees. At the so-called end rotation of the tibia, this bone rotates outwards some degrees, and thereby tuberositas tibia is moved laterally, and this valgus position is increased a further few degrees. *The supplement angle to this valgus angle in the extensor mechanism is in the present work called the Q-angle.* Fig. 7 B, p. 31. If we proceed from the fully extended knee and then bend it, in the first phase an inward rotation of the tibia in relation to the femur takes place, a suspension of the so-called end rotation. The Q-angle is thereby partly straightened.

Femur torsion. The femur torsion implies that a vertical plane through the transverse axis of the femur condyles on a standing person and a vertical plane through the caput-collum axis do not coincide, but form an angle averaging 12° with each other. One usually says that the collum stands outwards torqued or anteverted in relation to the condyle plane: we have a so-called anteversion angle of 10°—12°.

Theortically three facts contribute to the collum axis not being in the condyle plane:

a. Torsion of the femur diaphysis: antetorsion or retrotorsion.
b. The collum points forwards or backwards in relation to the proximal end of the diaphysis and the trochanter region: anteversion or retroversion in a circumscribed sense, or anteposition or retroposition of collum.
(c. Ante-flexion or retroflexion of the collum itself: this factor plays no role in normal conditions.)

Torsion and version cannot in practice be separated from each other, and most anatomists, clinicians, and roentgenologists treat the concepts as synonymous: the anteversion angle is an expression for the femur torsion (Lanz & Wachsmuth 1938, Billing 1954); this applies also in the present work.

In an isolated femur, this angle is measured by lying the bone with the posterior extent of the condyles horizontal (this plane is in the following called THE POSTERIOR CONDYLE PLANE), and one measures the angle that the collum axis forms with the horizontal plane or the posterior condyle plane (Martin 1914, Stracher 1961). Great individual variations exist, and the angle between 0° and 24° cannot be regarded as pathologic. One has earlier always referred this changed angle to the proximal end of the femur and spoken of an increased or reduced anteversion angle for collum femoris, which has been presumed to play a large role at dislocations of the hip, among other things. In recent years, however, it has been clearly seen that a changed angle need not necessarily mean a changed torsion of solely the proximal end: it can also be the distal end; i.e. the femur condyles which through torsion have changed their position. For practical reasons in order to obtain, among other things, a clearly defined position that makes measurements possible, the posterior condyle plane has been retained as initial position.

The femur torsion begins intra-uterinely. In a two-month fetus, a negative anteversion occurs; i.e. caput points behind the posterior condyle plane. In a four-month fetus, they are on the same level; at six months, a 15° positive torsion occurs; i.e. caput points in front of the posterior condyle plane; and at partus, there is about 30° positive torsion (Böhm 1935). During the following years, a detorsion takes place so that in the adult there is a positive torsion averaging 12° (Böhm 1935). As mentioned above, these measurements are for practical reasons related to the posterior condyle plane. According to Böhm (1935) and Fründ (1953), among others, the femur shaft actually lies in a neutral position; the distal condyle end is torqued 6° inwards, and the proximal collum end is torqued 6° outwards.

As will be seen later, some authors have attached importance to whether torquing has occurred in the distal or proximal femur end, regarding recurrent dislocation of the patella.

Patellas movement by flexion. A normal knee joint has an active range of mobility of about 130° regarding flexion/extension. Passively, one can bend a further 20° to 30°; i.e. a range of mobility of about 155°. During this flexion/extension, the quadriceps is so contracted that ligamentum patellae is extended and the patella lies at a fairly constant distance from tuberositas tibiae. The patella usually stands at the beginning of the flexion, as mentioned earlier, exactly at the opening of the sulcus, which is formed between the ventrally protruding parts of the condyles. The patella runs in this sulcus on its longitudinal ridge.

During the first 80° flexion, the entire articular surface of the patella is mainly in good contact with the articular surface of the femur. This means that the pressure exercised between the patella and the femur is practically evenly distributed between the ridge and the two joint facets (Wiberg 1941). All the time, however, the contact with the medial facet is concentrated to a smaller surface, partly by the medial facet's being smaller, partly by its being flattened or convex, or articulating with a convex articular surface of the femur. On the other hand, through the Q-angle (see p. 20) the largest pressure will usually be found between the lateral articular surfaces of the femur and the patella. This predominance of the pressure laterally increases at further flexion according to Wiberg's investigations.

The patella at about 90° flexion leaves facies patellaris femoris; and at maximum flexion, the cranial parts of the patella, the so-called bend facets, extend close to fossa intercondyloidea. Normally, the ridge of the patella does not reach "bottom" after a 90° flexion; the entire pressure is concentrated upon the two facets, mainly upon the lateral.

In the initial position and during the first 70°—80° of the flexion, one can clearly see and palpate the edges of the patella. Because the sulcus becomes not only deeper but also wider, the patella sinks in between the condyles, and on a knee bent at right angles, the contours are round and even, and the contours of the patella can be palpated only with difficulty. In some persons, the contours of the patella remain clear also at 90° flexion; the patient has pointed knees. (This condition is discussed in Chapter XII in connection with the concept patella alta.)

Other movements in the knee. At extended knee, no rotation or other movement occurs between tibia and femur, but the slightest flexion results in an inwards rotation of the tibia, and we quickly get an active and passive rotation capacity in the knee joint, according to the following table (partly Hjortsjö 1959):

	Inwards rotation	Outwards rotation
Extended knee	0	0
At 30° bend	<5°	30°
At 60° bend	5°	35°
At 90° bend	5°—10°	40°

The patella has a path of between 6 and 8 cm. Through the formation of the articular surface of the femur, the patella glides at the flexion also some mm laterally, which occurs continuously during the whole flexion (Wiberg 1941, de Sèze & al. 1951).

Patella retention. Different factors normally contribute to retaining the patella in its place in order to prevent it from dislocation:

1. Quadriceps with ligamentum patellae. Through muscular contraction, the patella is pressed against the femur and the sulcus.
2. Retinacula patellae longitudinale et transversale. Articular capsule.
3. Those parts of the medial and lateral condyle that protrude ventrally and form the walls of the sulcus for the patella to glide in.
4. Air-pressure.

The nature and the function of the patella. This has been much discussed. Most authors are of the opinion that it is a sesamoid bone formed in the quadriceps tendon by the mechanical strains at flexion and extension (Haxton 1944, Cave & Rowe 1950, de Palma & Flynn 1958) whereas others say that the patella is formed independently of the quadriceps tendon and the function of the joint (Drachmann 1872, Bernays 1878, Kazzander 1894). Brooke (1936—37) thinks that the patella is a phylogenic rest, which has no functional importance. He has attempted to show by experiment with corpses that the function of the quadriceps is improved after removal of the patella.

Daunegger already in 1880 and Meyer in 1883 point out that if one accepts that the patella is not a real bone but as a sesamoid bone is a part of the extensor musculature, one cannot really call the condition of the bone's having left its path a luxation of the patella, but a dislocation of the tendon. However, for practical purposes, they accept the diagnosis: dislocation or luxation of the patella.

Concerning the function of the patella, many different views have also been expressed. The theory is usually advanced that through the position of the patella in the extensor mechanism, the quadriceps has a more favourable angle of attack, a better lever when it functions (Payr 1928, Lantz & Wachsmuth 1938, Haxton 1944—45, Cave & Rowe 1950, Fürmeier 1953). Furthermore, it has been maintained that the cartilage covered articular surface of the patella glides more easily against the femur and distributes the pressure against it better than a tendon would. Fürmeier has shown, moreover, that the patella has great importance for the normal functioning of the knee joint and for the pressure not only between the extensor mechanism and the femur, but also in the tibio-femoral joint.

Other authors have maintained that the patella lacks meaning and could be dispensed with. Some support their theories by experiments with cadavers (Brooke 1936—37, Freehafer 1962), others upon favourable results obtained at patellectomy for fractures, chondromalacia, and other diseased states of the patella (*inter alia* Blumensaat 1936, Brooke 1936—37, v. Rosen 1939, Friberg 1941, McFarland 1948). Brooke's work has played a great role and has been the incentive for several orthopedists and surgeons to remove the patella at fractures.

As Scott (1949) and de Palma & Flynn (1958) among others, have pointed out, the clinical series have often a relatively short observation time. If one waits long enough, according to these authors, changes of osteo-arthrosis nature appear. A closer discussion of these questions lies beyond the scope of this investigation.

Summary

A brief description of some anatomical and physiological data of importance in this investigation is given.

CHAPTER III

Recurrent dislocation of the patella

A. *Clinical picture*

Definition

Normally, the extensor mechanism glides with the patella in the sulcus on the ventral side of the femur, the patella maintaining continual contact with both lateral and medial condyle. At recurrent dislocation of the patella, as the concept is used in the present work, the patella, with the extensor mechanism of the knee, *temporarily* leaves, on at least two occasions, its normal place on the ventral side of the femur between the condyles and glides for a longer or shorter time up on to or over the lateral femur condyle. At this temporary dislocation, there is an acute insufficiency of the extensor mechanism, and the knee usually gives way. The patella sits riding on the lateral condyle or glides down on the lateral side of the femur.

In patients with osteo-arthrosis in the femoro-patellar joint, it often happens that the patella permanently loses contact with the medial femur condyle and "subluxates" laterally, and moves at flexion/extension in this subluxated track. The condition has been *developed gradually*, and the patient usually has no symptoms other than those conditioned by the arthrosis deformans. Subluxation or "lateralization" of the patella is not discussed in this work. "At luxation it is the medial facet that gives the pathology, at subluxation it is the lateral patellar facet" (Debrunner 1957).

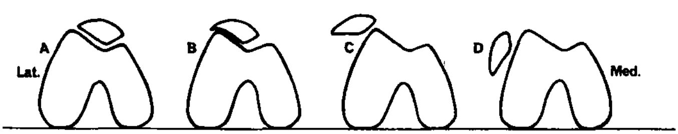


Fig. 6. A. Patella in normal position in the intercondylar groove. B. Lateralization or chronic subluxation at osteo-arthrosis in the femoro-patellar joint. C., D. Different types of patellar luxation.

The patella dislocates almost always laterally. It has even been questioned whether medial dislocations occur (Thompson & Bosworth 1947 and Debrunner 1957) but several authors have given detailed descriptions of dislocations medially, therefore, this probably occurs, although exceptionally (Karl 1921, Kapel 1936, and Meyer 1929).

Classification

The question of the classification of patellar dislocations has been the object of much interest, and several different classifications have been proposed. Etiology and frequency of dislocation have been used as bases for classification. In these classifications, almost always two groups arise: the CONGENITAL in its wider meaning and the ACQUIRED. By the CONGENITAL is generally meant that the prerequisite conditions of the dislocation, in the form of the patellar structure, sulcus structure, the femur torsion, genu valgum, poor fixation medially, etc. are inborn, and sooner or later, usually after a trauma insignificant for a healthy knee joint, result in a dislocation. Characteristic of these congenital dislocations might be early age at the initial dislocation; bilateral occurrence; often hereditary anamnesis; overweight in the female; dysplastic changes, as seen in the x-ray picture; and the almost atraumatic course. Thestrup Andersen considers that in 10 per cent of the congenital dislocations, there occur also other congenital articular defects or bone defects. By congenital dislocation in restricted meaning ("real congenital dislocation") is meant that the dislocation itself occurs at partus, and the patella rests on the outside of the lateral condyle.

The ACQUIRED would be due either to a severe trauma (traumatic dislocations) or to changes following infection, polio, prolonged knee exudate, fracture, or similar (pathologic dislocations) (Lückerath 1919).

Naturally, there are isolated cases that undoubtedly belong to one or other of the groups, a factor that would have importance in selecting treatment method, but the borderline cases are too many for the classification to be satisfactory. Among other things, it is most often extraordinarily difficult to decide whether a trauma has been severe or not.

In the literature dealing with dislocation of the patella, so-called PERMANENT dislocations are also referred to; this, to different authors, often means different things:

1. The "real" congenital dislocation; i.e. the patella at birth is dislocated on the outside and does not reset spontaneously.

2. Later acquired dislocations, which have not been reset, but where the patella remained on the outside of the lateral femur condyle.
3. Habitual or pendular dislocations; i.e. the patella dislocates at a decisive movement that lies completely within the normal mobility pattern of the knee joint.

It is not always clear in the works of other authors whether these permanent dislocations are also included, but they are so few that they have no great importance in a large material. Regarding the different meanings that German and French authors ascribe to the diagnosis "habitual dislocation", see p. 12.

Wiberg proposed in 1941 a classification into three groups, dependent upon the degree of femoro-patellar dysplasia, as seen in the x-ray picture. Similar lines of thought are found in Sjövall (1943), Felländer (1949), Thestrup Andersen (1955), and Rolander (1961), but here too the borderlines between the groups are not well defined. This difficulty of being able with certainty to refer a case to one or other group has caused many to hesitate about classification (Sommer 1928, Janz 1930, Payr 1934, Dickson 1936, Sjövall 1943, and Cotta 1959). Others attempt a classification according to anatomic or physiologic variant that can occur and can be suspected of causing the dislocation, in order thus to be able to offer the therapy adequate in every particular instance (Moreira 1939, Herzog 1947, Lacheretz 1951, Brisard 1950, Tavernier 1950, Trevor 1957, Debrunner 1961, and Max Lange 1962).

One of my main tasks was, by classifying the material into different groups according to principles used by earlier authors, to show possible differences between these groups in the formation of the femur condyles, and thus to contribute to characterizing these groups.

Occurrence

Recurrent dislocation of the patella is a relatively rare condition. This is evident from the quite small patient material presented by most authors.

Thestrup Andersen has collected 315 case histories of patients, all of whom have over a period of 30 years (1920—51) been treated in the Orthopedic special wards in Demnark under the diagnosis luxatio or subluxatio patellae. Storck (*cit.* Böhi) reports that of scarcely 50,000 patients who have visited the Orthopedic clinic at the University in

Berlin, 36 had recurrent dislocation of the patella (0.73 ‰) and Schneller (*cit.* Böhi) reports on behalf of the Orthopedic clinic at the University in Wien that 17 patients out of approximately 65,000 (0.26 ‰) had this condition. Debrunner (1957), who was particularly interested in the condition, has in his private clientele 1.87 per thousand.

In the Orthopedic clinic in Lund during the years 1945 to 1961 (both dates inclusive) approximately 28,000 persons were treated as inpatients, of whom 44 female and 20 male (fully 2 ‰) had recurrent dislocation of the patella, according to the earlier given definition.

Böhi calculated that the dislocations of the patella total about one per thousand of the orthopedic clientele, a figure that can be accepted.

Sex

The recurrent dislocation of the patella is about twice as common in the female as in the male (Kapel 1936, Vallinkoski 1942, Sjövall 1943, Seedorf 1946, Felländer 1949, Marion & Barcat 1950, McNab 1952, and Thestrup Andersen 1955). If classification into congenital and acquired (mainly traumatic acquired) is attempted, the dominance of the female appears even more clearly in the congenital group, whereas in the traumatic, the male dominates (Kapel 1936, Thestrup Andersen 1955, and Nikolai 1960).

Right—Left—Bilateral dislocation

In a large number of instances, the condition is double-sided. In others, a certain dominance of left-sided dislocations seems to occur. From the reports of authors who classify their material into right-sided and left-sided dislocations, I have found nothing to suggest a predominance of *right*-sided dislocations. In the two largest materials published (Marion & Barcat and Thestrup Andersen) the proportion of double-sided is 30 per cent and 35 per cent, respectively; and of unilateral, the left-sided is 54 per cent and 53 per cent, respectively. Of 26 unilateral, Sjövall reports 69 per cent left-sided and Böhi (1957), who describes 47 cases, reports 36 per cent double-sided, and that 62 per cent of the unilateral are on the left side.

Thus approximately one-third of recurrent dislocation of the patella conditions are double-sided, fully one-third left-sided, and scarcely one-third right-sided.

Age of onset

The condition usually first occurs at age 15 years: in the female somewhat earlier, in the male somewhat later. That the age is later in the male can be thought due partly to later skeletal maturity and partly to traumatic injuries at increased age being more usual in the male. No age, however, goes free.

Earlier diseases

Several patients state that before the first dislocation they have had symptoms in the knee, feelings of insecurity, or that the knee has "felt as if it would give way" or similar. Sometimes there occurs in the anamnesis a report of severe exudate in the knee joint, either infectiously or traumatically conditioned. An exudate of this nature that is permitted to remain for some time could be thought to impair and to some extent cause atrophy and lack of tone in the soft parts.

In congenital dislocations, there occurs in approximately 10 per cent simultaneous joint or bone defects in other parts of the body (flat-foot, luxatio coxae, dysplasia acetabuli, kyphoscoliosis, spina bifida, syndactylia, etc.) (Bauer & Göttig 1936, and Thestrup Andersen 1955).

Etiology

In the sections referring to the classification of the dislocations and to the earlier diseases, trauma and chronic exudates have already been hinted at concerning the etiology of recurrent dislocation of the patella.

Heredity: Several authors have described families where the condition could be traced for two or three generations (*inter alios*, Caswell 1865, Schou 1893, Wiemuth 1901, Bogen 1904, Hübscher 1909, Wrede 1911, Moore 1930, Bauer & Göttig 1936, and Mumford 1947).

Bauer & Göttig (1936) analyzed 18 families with "congenital" dislocation of the patella and expressed the opinion that a dominant hereditary tendency is involved, which is not inherent in the X-chromosome, but has a different penetrance factor in male and female. That should explain the sex difference. A general over-mobility in the body joints and flaccidity in the ligaments are common in patients with hereditably conditioned tendency, according to Bauer & Göttig.

Marion & Barcat find a family occurrence of dislocations of the patella in seven per cent of their material, but they point out that if one obtains a thorough anamnesis where these problems are discussed, this figure will certainly increase considerably.

Thestrup Andersen (1955), who has devoted special attention to the question of heredity, finds in his material of over 300 patients no less than 64 with a family occurrence of dislocation of the patella, in some instances up to four generations. This implies that approximately 25 per cent of what Thestrup Andersen calls congenital dislocation of the patella have a positive family anamnesis; the figure for his entire material is approximately 20 per cent.

Trauma: Most patients report some kind of trauma at the first dislocation. Purely traumatic dislocations, however, must be rare and presuppose a direct and severe tangential assault in medio-lateral direction (e.g. a bumper striking the patella). From here, we consider transitions via less severe, direct blows, severe, indirect assault (tackling during football games, jumps in athletics) to mild, indirect assault (careless dancing, jumping sideways, and similar). By these indirect assaults, it could be that the easily flexed lower leg rotates outwards with tuberositas tibiae and thereby increases the Q-angle (see p. 20), and the strain being too great, the patella dislocates. Possibly a severe and partly uncontrolled quadriceps contraction assists the dislocation. Occasionally a few patients deny any trauma: "walked quietly along when the leg gave way".

Apart from the trauma, some other factor must usually be involved, and several different reasons have been adduced for the patella to dislocate.

Q-angle. The valgus angle, which occurs normally in the knee joint and, at extended, end rotated knee, also in the extensor mechanism including the patella, results in the patella at the contraction of the quadriceps being forced laterally. In that case, it is easy to explain the dislocations of the patella by an increased valgus position. Several authors have shown that patients with dislocation of the patella often have an increased Q-angle (p. 20). This increased valgus position can be due to different causes.

1. Increased valgus position in the skeleton (Malgaigne 1836, Aldibert 1894, Trendelenburg 1900, Wiemuth 1901, Goldthwait 1904, Xoudis

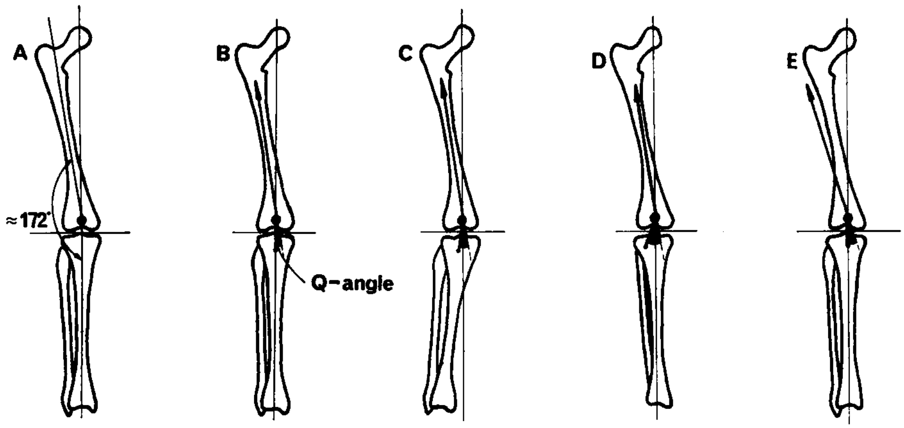


Fig. 7. Different causes of increased Q-angle. A. and B.: normal conditions. C. Q-angle increased on account of increased valgus position in the skeleton. D. Q-angle increased because the ligamentum patellae is attached more laterally than usual (e.g. tibia stands outwards rotated in relation to the femur). E. Q-angle increased because the quadriceps resultant goes more laterally than usual (disturbed muscular balance).

1924, Friedland 1927, Stracher 1936, Blumensaat 1938, Moreira 1939, Haukom 1942, Swynghedauw & Laine 1945, Smillie 1946, Felländer 1949, Lacheretz 1951, McKeever 1951, Thestrup Andersen 1955, Le Coer 1956, von Rosen 1959, and Lange 1962). Other authors attach no particular importance to genu valgum, and maintain that they have not observed anything of that nature in their patients (Borchard 1901, Finsterer 1909, Bade 1934, Kapel 1936, Blanco 1949, and Jerre & Knutsson 1958, and to a certain extent Marion & Barcat 1950). Some consider the genu valgum secondary to the dislocations (Gocht 1918, Janz 1930, Bade 1934, and Pruvot 1950, and to a certain extent Marion & Barcat 1950) and say that it is due to the fact that at dislocated extensor mechanism, the quadriceps serves as an abductor and pulls the lower limb into valgus position, or that the Q-angle is also increased by some other cause, and that the quadriceps then pulls the skeletal parts into valgus position. Thestrup Andersen points out in a 1959 publication that he has operated upon two patients who before the operation had genu valgum and whose legs after the operation became straight, despite his having carried out only soft-part operation. Fig. 7 C.

2. Tuberositas tibiae can be situated unusually laterally on the tibia

(Smillie 1946, Brisard 1950, Tavernier 1950, Francillon 1950, Rohlederer 1951, Harrison 1955, Le Coer 1956, and Boni & Motta 1960). Fig. 7 D.

3. The tibia with tuberositas tibiae can stand outwards rotated in relation to the femur at extended position (so-called "décalage" according to Isermeyer 1867, Appel 1895, Zanoli 1926, Moreira 1939, Févre 1950, and Fürmeier & Breit 1952). Other authors maintain that this outwards rotation occurs when the patient has flexed 15°—20° in the knee (Streubel 1866, Wiemuth 1901, Hildebrand 1902, MacAusland & Sargent 1922). Fig. 7 D.

4. If the femur condyle part with the patella is thought of as being fixed, the femur shaft with its muscle origins can be outwards torqued and the quadriceps resultant thus will pull laterally (Friedland 1927 and Moreira 1939). Or, what is the same thing, one can also imagine the shaft with the muscle origins as being fixed and the condyles with the patella torqued too much inwards. This increases the Q-angle, but the lateral condyle is at the same time relatively more protruding, which should counteract the dislocation. This detail is discussed more thoroughly in Chapter IV, concerning the height of the lateral condyle. Fig. 7 E.

5. Quadriceps resultant normally pulls lengthwise in relation to the femur. In an otherwise normal course of muscles and tendons, it can, because of pathologic weakening of the medially pulling muscles, go more laterally, and thus increase the Q-angle and the risk of dislocation. We get the same effect by increasing the lateral-pulling powers. Fig. 7 E.

This weakening medially could be due to the muscle itself, in the musculature of vastus medialis, being in poor condition (Gocht 1918, Böhler 1918, Blanco 1949, Brisard 1950, and McKeever 1951). The weakening can also be due to the poor condition of the connection of vastus medialis to the extensor mechanism. It can have been lacerated at the first dislocation, been atrophied by prolonged exudate in the knee joint, been damaged at a medial parapatellar operation incision (Smillie 1946). In these circumstances, the medial structures partly connected to vastus medialis, such as the medial capsule and retinacula patellae longitudinale et transversale, are also damaged (Tenney 1908, Whitelock 1914, Gallie 1935, Stracker 1936, Kapel 1936, Dickson 1936, Felländer 1949, and Watson Jones 1955). These structures play a considerable role in retaining the patella in its place. They can also be constitutionally flaccid in some persons (Dalla Vedova 1909, Wagner 1932, Gallie 1935, and Bauer & Göttig 1936).

Contrariwise, one can, by an unusually powerfully developed vastus lateralis (Duchenne 1867, von Meyer 1883, Payr 1934, and Lacheretz 1951) or by fibrous, shrivelled threads in capsule and ligament on the lateral side, upset the balance and give the quadriceps resultant a more lateral course (Malgaigne 1836, Guerin 1842, Daunegger 1880, Dalla Vedova 1909, Strube 1934, Ober 1935, Smillie 1946, Pruvot 1950, and Jeffreys 1963). Pruvot uses the expression "torticollis du genou".

Change of the Q-angle at the movement of the knee: Kiesselbach (1954, 1956) pointed out how the position of the patella and the direction of pull in the lengthwise direction of the ligament is changed at flexion of the knee joint, and what role this plays in the origin of the dislocation of the patella. At extended knee and contracted quadriceps, the latter pulls with a force in the patella whose resultant forms a definite angle, the Q-angle, with the lengthwise direction of the ligament (see Fig. 7 B), whose extension divides the musculature into a larger lateral part and a smaller medial part. A component strives to pull the patella directly laterally and another, somewhat smaller component strives to pull the patella directly medially. When the knee now is bent, the patella glides laterally, as mentioned earlier, and tuberositas tibiae turns with its ligament attachment medially, because the end rotation of the tibia is suspended, and simultaneously tuberositas tibiae is carried distally because of the flexion. The movements of both patella and tuberositas tibiae contribute towards reducing the Q-angle. The predominance of the laterally-pulling component is reduced; at approximately right-angle flexion it will be equal to zero (Kiesselbach). At continued flexion, the angle changes to negative: we get a medially-pulling component that dominates instead. Because of the distal displacement of tuberositas tibiae, the cranially-pulling component has increased so powerfully that the medially-pulling component is relatively small; thus no dislocation medially ever occurs. The risk of dislocation would, in the opinion of Kiesselbach, be greatest at extended or slightly flexed knee, because:

1. the patella has not yet quite glided into the sulcus and obtained support from the bone;
2. the laterally-pulling powers are greater than the medially-pulling;

3. the laterally-pulling powers are great in relation to the cranially-pulling.

The therapeutic procedures, which originated from Kiesselbach's reasoning, will be referred to later. (See Chapt. IV.)

Patella shape. Apart from trauma and increased Q-angle, other factors have been quoted as causing dislocation of the patella; among them, the form and size of the patella. Bogen (1906) points out that many patients with permanent congenital dislocation have conspicuously small patella.

Jaroschy (1924) points out that the patella is thicker than normally, and says that such a patella "verständlich" dislocates easily; however, he suggests no reasons why.

Krömer (1937) states that the patella in these patients, to judge from an axial x-ray picture of the knee joint, often has a large concave lateral facet and a small convex medial facet that almost forms a right-angle with the lateral. This form is later in German literature called "Jägerhüteform", although Krömer himself does not use this word. He considers that this form facilitates the dislocation.

Wiberg in 1941 published a work about the appearance of the femoropatellar joint in patients with dislocation of the patella. There he classifies the knee joints into three groups according to the different degree of dysplasia (see Chap. IV) as seen in the axial x-ray picture; he also considers the form of the patella. These lines of thought are again, partly, encountered in other works (e.g. Sjövall 1943, Marion & Barcat 1950, da Silva 1951, Fürmeier & Breit 1952, Thestrup Andersen 1955, Fründ 1958, Merle D'Aubigné & Ramadier 1959, and Rolander 1961).

Patella alta. Deviations in vertical direction of the position of the patella have also been given as cause of dislocation of the patella. Normally, the patella lies, at extended knee and relaxed quadriceps, with its apex level with the joint line, in order, at contraction of the quadriceps, to be pulled 2—3 cm cranially ("Patellar-spiel"). Here only the most caudal parts of the articular surfaces of the patella ("the extensor facets") and the ridge will make contact with corresponding surfaces on the femur. The bone resistance to a dislocation is consequently small in this position. If ligamentum patellae is longer than normal, i.e. more than 3—5 cm, the patella will lie completely over facies patellaris femoris and be altogether without bone support laterally. First when the patella by flexion in the knee joint has been drawn caudally "it runs into" the sulcus and gets this bone support. A high standing patella of this nature is called patella alta vera (Murk Jansen 1930). In extended position and during the first degrees of flexion, the patella in patients with patella alta might thus be more "vulnerable", be more easily dislocated, especially as the quadriceps pulling laterally is, according to Kiesselbach, strongest in this position. This high standing patella, patella alta vera, is considered by, *inter alios*, Murk Jansen (1930), Moreira (1939), Tavernier (1950), Lance (1950), Wiles (1951), McKeever (1954), Thestrup Andersen (1955), and Harrison (1955) as one of the main causes of the dislocation of the patella, whereas MacAusland & Sargent (1922), Kapel (1936), Haukom (1942), McCarroll & Schwartzmann (1945), Smillie (1946), Blanco (1949), Francillon (1950), Lacheretz (1951), da Silva (1951), Fürmeier & Breit (1952), Max Lange (1962), and Debrunner (1962) only ascribe to patella alta a certain importance. Marion & Barcat mention patella alta only in passing, and Thompson & Bosworth (1947) directly deny the importance of patella alta.

No fixed borderline between normal and pathologic position of the patella in the vertical plane exists. The first to occupy himself with the question was Schultess (1899), who described some spastics with high standing patella. He pointed out that, with the knee flexed at right-angle or pointed angle, the patella sits normally sunken between tibia and femur; however, in these spastics it sits as an extension of the femur.

Peltesohn (1901) and Blenche (1902) have the same basis for their estimation, whereas Boon-Itt (1930) describes an involved method for estimating the position of the patella in the vertical plane with the aid of an x-ray picture taken laterally.

Blumensaat (1938) has described a method for deciding whether patella alta occurs or not. This is used by, among others, Wiberg (1941), Fürmeier & Breit (1952), and Thestrup Andersen (1955). Blumensaat's method necessitates that, on an x-ray picture of the knee joint taken laterally, the sclerotic line formed by the cortex on the bottom of fossa intercondyloidea be extended so that this line cuts across the patella or its extension. Fig. 8. This line, called Blumensaat's line, normally meets apex patellae when the knee is flexed 30 degrees. Provided the apex lies above Blumensaat's line at this flexion, the diagnosis patella alta is established.

Most authors fail to indicate how they determine whether patella alta

Fig. 8. On an x-ray picture of the normal knee, flexed 30°, apex patella lies on the extension of the sclerotic line formed by the bottom of fossa intercondyloidea (Blumensaat's line). u=the angle between this line and the longitudinal axis of the femur (see text).

exists. Thestrup Andersen, who uses Blumensaat's line, diagnoses 207 of his 286 patients with dislocation of the patella as having patella alta, even after allowing a margin of about 5 mm above Blumensaat's line before characterizing the condition as such (Personal communication).

Femoral dysplasia. As well as different forms of increased Q-angle, femoro-patellar dysplasia (Knutsson 1941) is the pathologic-anatomical change that has been most indicated as cause of the dislocation of the patella, chiefly that the lateral condyle "lies lower" than normal: it does not offer the patella the support needed to prevent dislocation laterally.

Because it was my main purpose to investigate more closely this femoral dysplasia, I will report earlier investigations in this sphere, as well as the present view, in a special chapter (see Chapter IV), the dysplasia being mentioned here merely to complete the picture.

Wiberg and Thestrup Andersen include in the femoro-patellar dysplasias also patella alta and those changes of the form of the patella mentioned earlier that often result in an incongruity in the femoro-patellar joint.

Where does the patella dislocate?

The patient can usually indicate the position in the knee where the dislocation occurs.

Dislocation in flexion position. This is undoubtedly the most usual. It is related to, among other things, the fact that the extensor mechanism seeks the shortest course between its origin and insertion. This attempt results in the patella's being pulled *laterally* because of the earlier mentioned valgus angle (Q-angle) and at flexion position after dislocation also backwards.

The outwards rotation capacity of the tibia as soon as the knee is flexed plays a large role. Especially the first 10°—20° of the flexion is critical because the lateral-pulling powers are greater than the medial-pulling (Kiesselbach 1956) and the patella has not yet completely run into the sulcus, especially if patella alta exists (Wiemuth 1901, Böhler 1918, MacAusland & Sargent 1922, Hoffmeister 1928, Sommer 1928, Kapel 1936, Moreira 1939, Trevor 1947, Ståhl 1950, Wiles 1951, Teal 1954, Böhi 1957, Debrunner 1961, and Max Lange 1962).

Wrede (1911), Böhler (1918), Jerre & Knutsson (1958), and Cerwenka (1962) point out that the dislocation can happen down to 90° flexion.

Houkom (1942) and Lewin (1952) maintain that it is during *extension movement* that the dislocation usually occurs, about 20° before full extension. The essential might be the slightly flexed knee and the contracted quadriceps: whether it is under flexion or extension probably plays no role.

Dislocation in extension position. This does not occur, according to McKeever (1954), whereas v. Meyer (1883) and Daunegger (1880), according to the literature, say that it is the most usual form.

The end rotation of the knee at full extension and the traction of the muscles in this position (Kiesselbach 1956) would favour a dislocation in extended position, but at the same time, the patella will in most cases lie cranially to the opening of the sulcus and cannot dislocate because it has no bone support at the sides. Ligamentum patellae, which then runs in the sulcus, is flexible and follows the course of the sulcus rather than dislocates. Dislocation in extended position unquestionably occurs but is unusual.

Course

First luxation. As earlier mentioned, nearly all patients refer to trauma as cause of the first dislocation. When the anamnesis is examined, one finds that it is only in isolated instances that a powerful, direct assault on the inner side of the patella has caused the dislocation. Considerably more frequent is the effect created by the condition fixed-foot—slightly flexed knee—inwards rotation of the body and the thigh; i.e. an increase of the Q-angle with dislocation as a result. The patient gets an acute insufficiency of the knee extensors, "the knee gives way", and the patient usually falls. The patella can sometimes spontaneously reset, but often the patient himself or somebody available must render aid. Sometimes the patient comes to hospital with the patella still dislocated. The dislocation is very painful, and afterwards the patient is often tender at the medial edge of the patella, indicating injury in the soft parts there. The medial structures wholly or partly are lacerated at dislocation: retinacula patellae longitudinale et transversale, articular capsule, connection of vastus internus to the quadriceps tendon and patella (Kapel 1936, Smillie 1946, and Thestrup Andersen 1955). Several authors have stated how important it is that this acute injury in the medial structures be allowed to heal and recommend it be set in plaster for a time after dislocation (Schloffer 1906, Whitelock 1914, Gallie 1935, Kapel 1936, and Watson Jones 1955); and Thestrup Andersen (1955) recommends exploration and suture in order to prevent a recurrence. One has also discussed the risk of stretching with consequent atrophy and flaccidity of the soft parts, which the traumatic exudation in the knee involves.

Sometimes the soft parts can at dislocation escape damage, but the attachment at the medial edge of the patella is lacerated, carrying with it a larger or smaller osseous fragment. This gives a very characteristic x-ray picture at the so-called axial view (Jaroschy 1923). Ståhl (1950) has pointed out that fractures of the patella can occur at dislocation under other circumstances too: 1) A piece of the patella can be "planed off" by the lateral condyle when the patella glides back; 2) At dislocation caused by direct assault, the violence can cause a compression fracture of the patella medially; 3) When the patella sits on the outside of the lateral condyle, it is often the medial facet of the patella that is the contact surface, and at attempts to reset, we can get a compression fracture there; 4) Lacerated fracture can occur on the medial edge of the patella, according to earlier description.

An analysis of the x-ray picture can in doubtful instances determine whether the diagnosis dislocation of the patella is valid.

In connection with the dislocation, a hemarthrosis usually develops.

The further course can develop vastly differently in different cases, owing partly to the prerequisite conditions for dislocation existing primarily before the dislocation, and partly on how this first dislocation with injuries in the soft parts has been treated.

A few patients never again experience a recurrence of dislocation of the patella, whereas most, after a longer or shorter time, get a recurrence; then it usually follows a lesser violence than at the first dislocation. Thus the development continues, the patella dislocates more and more easily with increasingly shorter intervals, until eventually it perhaps happens more than once a day, if the patient fails to learn to avoid the provocative movement. Usually, however, a patient nowadays comes under treatment before the condition has developed so far.

Between the dislocations, the patients are often unsure, have "feelings in the knee", "think the knee will give way", "do not quite trust the knee joint", and this feeling of insecurity can for these, often young and active persons, be a severe handicap, partly in certain professions, and partly by preventing them from taking part in, for example, dancing and sports.

The condition is double-sided in about one-third of the cases. It is not unusual that, because the patient is convalescent after dislocation or surgical treatment of one knee, the other knee is more loaded and dislocates too. On the other hand, it happens that a patient with double-sided dislocations gets well in both knees after a successful operation in one of them. Here the mechanism is reversed, the patients gets a steady leg (that operated upon) and can then take the weight off the other.

Diagnosis

The diagnosis is usually easy, even though the patella has been reset. The patient cannot always describe directly how the patella sat on the outside of the lateral condyle, but a diagnosis can usually be obtained by means of the anamnesis with heredity, release mechanism, earlier episodes of the same type, and the description of the actual occurrence with its acute knee insufficiency. The diagnosis is confirmed afterwards partly by the clinical investigation: hemarthrosis, tenderness at the medial edge of the patella, possible palpable defect there in the soft parts, and high standing patella, which is possibly hypermobile laterally. In doubtful cases, x-ray examination can be decisive: femoro-patellar dysplasia of varying type and degree, and possibly typical fractures of the patella (Ståhl 1950).

The condition, however, is relatively unusual and not all doctors are familiar with it.

In some instances, the diagnosis can be difficult for the specialist too.

B. *Therapy*

Spontaneous cures. Conservative treatment

Some cases cure spontaneously after several dislocations (Mumford 1947, McNab 1952, Böhi 1957, and Debrunner 1957). By spontaneous cure is meant those instances where the dislocations cease to recur. The patients usually have other knee troubles. It is here often either a question of the patient having learnt to avoid the dislocation provoking movement or of degenerative changes in the form of osteo-arthrosis or indurations, which give less mobility and thereby increased stability.

However, Heywood, who in 1961 published a material concerning 106 knees in 92 patients who had dislocated the patella, has obtained a good and lasting effect through quadriceps-training in 15 patients: all these patients were young.

In some instances where surgical treatment is for one reason or another unsuitable or where the patient refuses it, one tries conservative therapy, which, according to Thestrup Andersen, is suitably divided into active and passive treatment. The active consists mainly in training the quadriceps. The passive treatment consists of different bandaging, of which the usual elastic bandage or knee bandage has often a good effect. More or less complicated orthopedic bandages have also been constructed and are used beneficially by some patients (e.g. Haudek's bandage).

Among the conservative methods might also be mentioned that described by Hugh Owen Thomas in 1892: by every week banging the atrophic lateral condyle in two patients, he stimulated it to "growth" and thus cured the dislocations (*cit.* Cole & Williamson 1934).

Treatment by operation

"The operation I performed was largely of an experimental nature and was done in the following manner..." (Robertson 1912).

"The treatment of recurrent dislocation of the patella has been a fertile field for the growth and development of the surgical ingenuity" (Haukom 1942).

These two quotations describe the situation rather well. More than 100 different operations have been mentioned. Cotta (1959) reports 137, of which, however, most are larger or smaller modifications of about ten basic procedures or combinations of these. An account of these operations is outside the scope of this work: those interested are referred to the work of Blumensaat (1938). In Chapter IV, those surgical treatments related to the shape of the femur condyles, mainly the apparent or real dysplasia of the lateral condyle, are more closely reported.

Some of the most usual operation methods used in Scandinavia are depicted in Fig. 9 and Fig. 12. Some operation methods are also men-

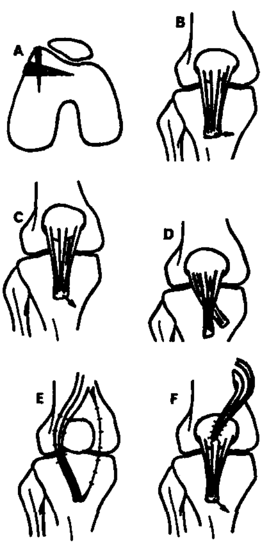


Fig. 9. Some of the most notable operation methods used for recurrent dislocation of the patella. See also Fig. 12, p. 51. A. Raising the lateral condyle according to Albee (1915). B. Removal of the attachment of ligamentum patellae medially according to Roux (1888). C. Removal of the attachment of ligamentum patellae medially-distally according to, *inter alios*, Hübscher (1909). D. Removal of the lateral part of the attachment of ligamentum patellae medially; the so-called Goldthwait II (1904). E. Combination operation according to Krogius (1904). F. Combination operation according to McCarroll & Schwartzmann (1945) using m. semitendinosus.

tioned there that are directly associated with the femoral dysplasia (see Chap. IV).

The patients who form the basis for my investigations come from the Orthopedic clinics in Lund, Malmö, Kristianstad, Hälsingborg, and Copenhagen. They are mainly operated on according to the following:

Lund and Kristianstad: modified muscle-fascia plastic according to Krogius (see Fig. 9). The modification consists partly of the ligamentum patellae being routinely transferred medially-distally, and partly of the distal shank of the "lambeau" being severed for operation-technical reasons.

Malmö and Hälsingborg: removal of the ligament attachment medially-distally. Often called Hauser's operation, but described in principle by Goldthwait (1904) and Hübscher (1909).

Copenhagen: ligament removal according to Goldthwait II (see Fig. 9) or combination operation according to McCarroll & Schwartzmann (see Fig. 9).

C. *Prognosis*

The course of a recurrent dislocation of the patella can go in different ways. Some heal spontaneously, others dislocate very seldom, giving no trouble in the meantime, whereas some suffer increasingly frequent dislocations and, moreover, experience trouble during the intervals.

Every dislocation is more or less damaging to the knee joint, the cartilage is damaged, we get a hemarthrosis or hydrops, or we can get fractures of the patella. As end result of the recurrent dislocations, we often get osteo-arthrosis in the femoro-patella joint as well as in the tibio-femoral joint. The dysplasia in the form of patella alta contributes also to this, as do different changes in the form of the femur and the patella that usually occur in this condition. In trying to avoid this, early operation is recommended. Possible damage to the soft parts is treated surgically at the first dislocation (Schloffer 1906, Whitelock 1914, Kapel 1936, Watson Jones 1955, and Thestrup Andersen 1955) and at possible recurrence, the treatment demanded by the particular case is used.

More than 100 different operation methods have been suggested, which is usually a sure sign that the ideal operation is not yet to hand. When one reads the works of different authors, however, one is impressed by the fact that good primary reports accompany the large number of operation methods used on so few patients. It is, for several reasons, very difficult (from the literature) to form an opinion of the prognosis at surgical treatment:

1. Most published investigations contain only few cases.
2. Different authors use different classifications, and there is no uniform nomenclature.
3. The observation time is usually quite short; it is the primary results of the operations that are appraised. The long-term prognosis with regard to osteo-arthrosis, function in the femoro-patellar joint, dislocation recurrence, etc. has not attracted the same interest.

Greater follow-up series with observation periods exceeding a whole year are rather unusual. Where they exist the optimism that marks the primary operation reports seems lamentably lacking. Marion & Barcat have surveyed the literature and find that in the published series with an observation period exceeding one year (chiefly Marziani 1930, MacAusland & Sargent 1922, Horwitz 1937, Haukom 1942, Vallinkoski 1942, and McCarroll & Schwartzmann 1945, and in Scandinavian literature Kapel 1936, Sjövall 1943, Seedorf 1946, and Felländer 1949) the recurrence frequency is nearly 20 per cent.

Marion & Barcat's own material—they have an observation period exceeding three years—reveals that almost every third case suffers a recurrence of dislocation. Because of the nomenclature confusion, it is difficult to analyze in detail, but several authors point out that the greater the role the initial trauma has played in the first dislocation, the better is the prognosis, and the greater the anatomical changes that occur in, for instance, the form of femoro-patellar dysplasia, the greater the risk of recurrence (*inter alios*, Felländer 1949, Jerre & Knutsson 1958, and Rolander 1961).

Thestrup Andersen also reaches similar conclusions in his large follow-up series.

It is not only the recurrent dislocations, however, that are of interest. Many patients complain of other troubles: pains, immobility of the joint, instability, and swelling. Osteo-arthrosis in the femoro-patellar joint is usually seen on the x-ray picture in such cases.

The writings of the authors mentioned above suggest that approximately one-third of the surgically treated patients suffer a recurrence of the dislocation, one-third get other knee troubles, and the remainder are in the main trouble free. Patients with femoro-patellar dysplasia are considered to have worse prognosis than others.

Böcker stated already in 1904 that every case must be analyzed so that the surgical treatment can be individualized; this principle is emphasized by other authors (Wagner 1932, Herzog 1947, Tavernier 1950, Debrunner 1961, and Max Lange 1962).

D. *Summary*

A survey of the clinical picture, the treatment, and the prognosis of recurrent dislocation of the patella is given.

CHAPTER IV

The femoral dysplasia

A. *Definition*

Knutsson (1941) is the first to use the concept femoro-patellar dysplasia, although the changes underlying the concept have been known and described for a long time. By it, Knutsson means that the characteristic osseous profile of the femoro-patellar joint on a so-called axial x-ray picture, i.e. with the beam directed in the patella's longitudinal axis, is changed in a typical manner. The lateral condyle, which normally rises markedly above the bottom of the intercondylar groove and is higher than the medial condyle, is smoothed down and approaches the medial in height. In pronounced instances, the height of the two condyles above the groove is reduced, facies patellaris femoris becomes cylindrical, i.e. the sulcus is so very shallow that it is scarcely visible (see Fig. 10).

This bony appearance on the x-ray film resembles that found in embryos and newborns, and is partly also found in, e.g. the gorilla (Böhm 1935).

Parallel with this *femoral* dysplasia is also a dysplasia of the *patella*. This can be noted in the characteristic change in the appearance of the patella as seen on an axial picture: the marked ridge, which runs in the longitudinal direction of the patella somewhat tibially to the middle, is displaced more and more tibially and is at the same time usually less marked, so that in the most dysplastic cases, we have an almost flat surface on the patella which articulates against an almost flat or rather a cylindrical surface on the femur. This femoro-patellar dysplasia at dislocations of the patella has been studied by, among others, Wiberg (1941), who used the degree of dysplasia to classify the dislocation of the patella.

Fellländer (1949) and Thestrup Andersen (1955) use the concept femoro-patellar dysplasia: the latter includes also patella alta in this.

As mentioned above, the changes lying behind the concept femoro-

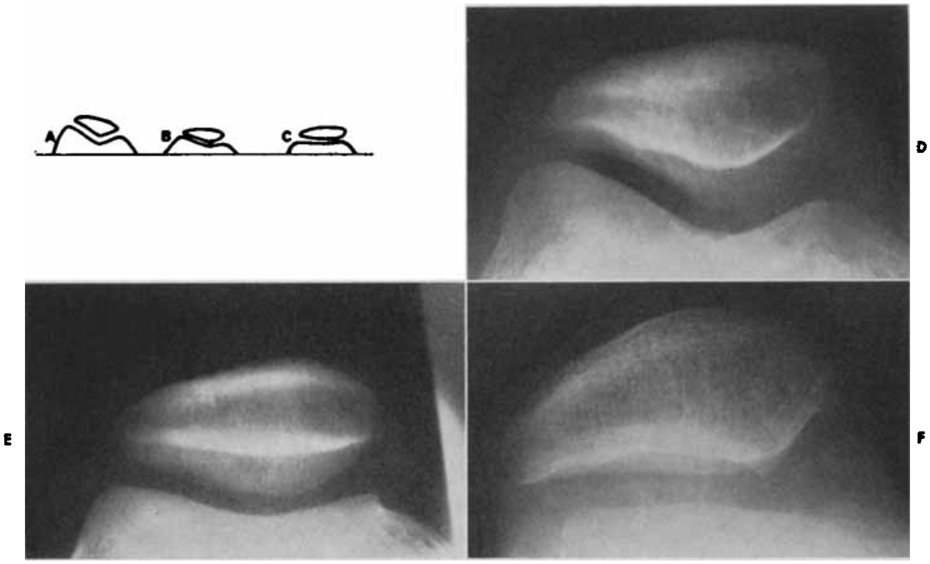


Fig. 10. Different degrees of femoro-patellar dysplasia as it appears on an axial x-ray picture according to Knutsson. A/D, Normal; B/E, moderate dysplasia; C/F, pronounced dysplasia.

patellar dysplasia were known long before the concept was created. The low lateral condyle was the main object of much interest before x-ray examinations were possible, and it has been thought by several authors (see p. 48) to be the principal reason for dislocation of the patella.

Those authors who earlier used the concept dysplasia about the femoro-patellar joint based their appraisements upon an estimation of the shape of the intercondylar groove on axial x-ray pictures taken by various methods. As will be demonstrated more closely in Chapter V, these methods are impaired by several elements of uncertainty, with the result that the above-mentioned appraisements also are uncertain.

In this chapter, I use the concept femoral dysplasia to mean that the lateral condyle does not seem to shoot so far ventrally as it does normally in relation to the sulcus bottom. For reasons I give on pp. 55—58, no more exact definition can be given here. When some authors mention also a lower medial condyle and other changes, this is referred to specially.

B. *History*

Already in 1802, i.e. before the start of the roentgen epoch, Richerand describes three instances of dislocation of the patella and points out that in all of them the lateral condyle was lower, and he sees this as the reason for the dislocations.

Isermeier (1867) lays the foundation for one of the many subjects of controversy which marked the discussion of the dislocations of the patella in that he certainly acknowledges the dysplasia, but considers it secondary to the dislocations. This view is shared by many authors, chiefly in the early literature: Bade (1903) considers that mainly at "traumatic dislocations" the lateral condyle is in the beginning more or less normal compared with the medial condyle (possibly the entire distal femur end is more gracile than usual) but is "rubbed down" by the repeated dislocations; Böhler (1918) expresses the opinion that it is a pressure atrophy of the lateral condyle, and Friedland (1925) too believes that the dysplasia is secondary.

The arguments against the dysplasia's being secondary were proffered already in 1901 by Wiemuth: 1) it cannot be a "rubbing down" or "pressure atrophy" because the cartilage on the lateral condyle is intact; 2) some patients with very frequent dislocations have completely normal lateral condyles; 3) and at the "real congenital" (existing at partus) dislocations, dysplasia is often present. In addition, Malkin (1932), among others, has pointed out that only man walks with extended knees and with the thereupon resulting "end rotation" of the tibia in relation to the femur. This end rotation increases the Q-angle (see p. 20) and increases the pressure of the patella against the lateral condyle, and as long as this pressure lies within physiologic limits it stimulates the growth of the lateral condyle. Consequently, man alone has a lateral condyle higher than the medial under normal circumstances. Sheep and cattle, on the contrary, have the medial higher; in apes the two condyles are similar in height. At certain forms of dislocation, for example the real congenital, this physiologic stimulation might not occur, and we thus have secondarily a low lateral condyle (Malkin 1932).

The discussion of the degree and type of the femoral dysplasia was put upon a more solid basis after it became possible to reproduce roentgenologically the femoro-patellar joint on so-called axial pictures (Jaroschy 1923, 1924 and Knutsson 1941) (see Fig. 13).

Sorrell (1942) denies the dysplasia. He states that he has never seen it in any of the many patients he has operated on. A somewhat more moderate attitude is adopted by Trevor (1957): dysplasia occurs "rarely".

Most authors, however, think that dysplasia plays a big role for the origin of the dislocation. (MacAusland & Sargent 1922, Wagner 1932, Stracher 1936, Kapel 1936, Galloway 1937, Macey 1937, Wiberg 1941, McCarroll & Schwartzmann 1945, Steindler 1946, Smillie 1946, Herzog 1947, Brisard 1950, Lacheretz 1951, McKeever 1954, Watson-Jones 1955, Thestrup Andersen 1955, Jerre & Knutsson 1958, Merle d'Aubigné & Ramadier 1959, and Max Lange 1962.) Later on, I return to the therapeutic treatment that these ideas have given rise to.

Is the dysplasia illusory?

In 1909, Hübscher describes some instances of dislocation of the patella and maintains, after having explored the knee joints, that the femoral dysplasia, described by so many authors, is not real but is due to a decreased inwards torsion of the distal femur end resulting in the lateral condyle's *seeming* to be lower than the medial (see Fig. 11).

Fiebach in 1911 presented the directly opposite view: the essential is an increased inwards torsion of the distal femur end. The lateral condyle is thereby forced "in under" the patella, resulting in a pressure atrophy of the condyle; thus, a dislocation of the patella occurs secondarily.

Dreesmann (1908) and Lückerath (1919) think along the same lines as Hübscher, but as Hohlbaum (1921) says about these two authors: "Eine Verwirrende Vermengung der Begriffe 'Rotation' und 'Torsion' tritt . . . zutage." Both consider, however, that the lowering of the lateral condyle is illusory; Hohlbaum is of the same opinion, but for other reasons. He thinks that in these patients we often have an increased anteversion angle, i.e. increased torsion of the femur. This condition

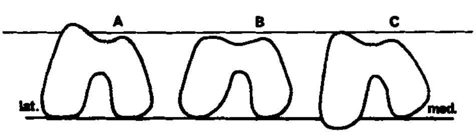


Fig. 11. The distal femur end. A. Normal. B. Actual lowering of the lateral condyle. C. Illusory lowering of the lateral condyle caused by increased outwards rotation or torsion (or decreased inwards rotation or torsion).

plus the insufficient balance in the musculature, which he considers the increased anteversion brings about, results in a forced outwards rotation of the femur at flexion in hip and knee joint. Through this forced outwards rotation of the femur, the pull on the patella by the quadriceps will be more lateral and at the same time oblique, so that it will "turn" the patella out of the sulcus by raising the medial edge of the patella. This lateral pull would successively stretch the medial reins and cause the lateral reins to shrink, all contributing to favour the origin of a dislocation. By means of the outwards rotation of the femur, the lateral condyle becomes relatively lower and provides less resistance to the dislocation. If now the soft parts have gradually stretched on the medial side and shrunk on the lateral side, then, according to Hohlbaum, it only needs a powerful but completely physiological quadriceps contraction for the patella to be "turned out of its position" and to dislocate.

Hohlbaum's work is difficult to grasp and speculative. It is not based upon convincing investigations.

Zanoli (1926), on the other hand, maintains that the dislocation is due to an outwards rotation of the tibia and an "inwards rotation of the distal femur end". Whether by that last expression he means an inwards torsion of the condyle section (which increases the Q-angle providing the patella follows in its groove) is not altogether clear, but his opinions appear to have been accepted by several Italian authors (Zurria 1934, Masseroni 1952, Vinditti 1954, and Vinditti & Forcella 1958).

Those authors who would see the femoral dysplasia as illusory, wholly due to changed torsion or rotation of the femur, ignore what has sometimes earlier been pointed out that *not only has the lateral condyle been lowered, but the entire articular surface* has been smoothed down, both on the patella and on the femur; thus, producing that fetal form indicated by Böhm. There is no doubt, however, that several of those instances that clinically and roentgenologically have been described as dysplastic *could* be due to a changed femur torsion or rotation.

If the lateral condyle is poorly developed ventro-dorsally as well as cranio-caudally, there is a low lateral wall in the sulcus as well as an increased valgus angle in the knee. Both these changes have been considered to be dislocation producing.

C. *Therapeutic views of the femoral dysplasia*

The femoral dysplasia with its low lateral condyle has been blamed for dislocations of the patella. It has been felt desirable to strengthen in some way this lateral condyle, to make it higher, or somehow to build up the poor support. Different methods, reflecting the earlier-mentioned views of dysplasia, have been tried.

Pollard (1891), Kirmission (1898), and Drew (1908) described isolated instances where they found a shallow sulcus at the operation, and by chiselling out tried to give the patella a suitable groove to glide in. Murphy (1914) complements the method by introducing fat and fascia tissue in order to prevent femoro-patellar ankylosis. These methods have only historical interest.

Trendelenburg (1900) strikes out in another direction in that he makes an osteotomy in the lateral condyle, "breaks it up", and then fills the defect with ivory.

Luxembourg (1914) mentions a procedure, which he ascribes to his chief Bardenheuer: He makes a 1 1/2 cm deep cleft in the lateral condyle close to the anterior edge of facies patellaris and puts in a 3 1/2 cm long fibula splinter. The description of the operation is very brief, and there is no mention of whether a raising of the articular surface was attempted (as in the case of Trendelenburg and later Albee) or whether he wanted to build up an osseous dislocation barrier in the form of a bone lip, but apparently the effect was both.

Bone barriers of this type (without raising facies patellaris) are recommended by Samson (1928), Estor (1933), Stracher (1936), and Saegesser (1949) where suitable.

Albee (1915) describes a method whereby on the outside of the lateral condyle he chisels in under its ventral articular surface (facies patellaris), lifts it ventrally, fills the defect with a wedge of bone from the tibia, and secures it into position with a bone spike in the edge of the articular surface (see Fig. 9 A, p. 41).

Albee's operation has been widespread and several authors recommend it, although at the same time there is a warning concerning technical difficulties involved in the procedure (Wagner 1932, Cole & Williamsson 1934, Morwa 1934, Swynghedauw & Laine 1945, Steindler 1946, Tavernier 1950, Lewin 1952, Trevor 1957, and Debrunner 1957).

Strong criticism, however, has also been voiced. Francillon (1950) maintains that Albee's operation is, mechanically, completely wrong.

On the axial picture it looks attractive, but if the condyle is seen laterally, there must be one or two stages in the articular surface which has been raised like a plateau. Lacheretz (1951) has similar misgivings about Albee's operation, and personally I agree with Francillon and Lacheretz.

A variation of this osteotomy on the lateral condyle is described by Brisard (1950), who in patients with patella alta—where the patella, after the knee has been flexed 10°, still lacks support from the lateral condyle—chisels an incision *above* the lateral condyle caudally, lifts the corticalis forwards, and puts a transplant in the pocket. Brisard himself calls his operation "Albee superior".

Graser (1904) chooses another method when he wishes to raise the lateral condyle: he makes a supracondylar osteotomy on the femur and rotates the condyle section *inwards* (see Fig. 12 B). This method attracted several followers, but, as with Albee's operation, a warning was voiced principally concerning the difficulties of mobilizing the knee after the long period of inactivity (Finsterer 1909, Schantz 1910, Drehmann 1921, Max Lange 1951, and Rütt 1959). According to these authors, the method ought to be reserved for difficult cases, an attitude adopted by Graser himself.

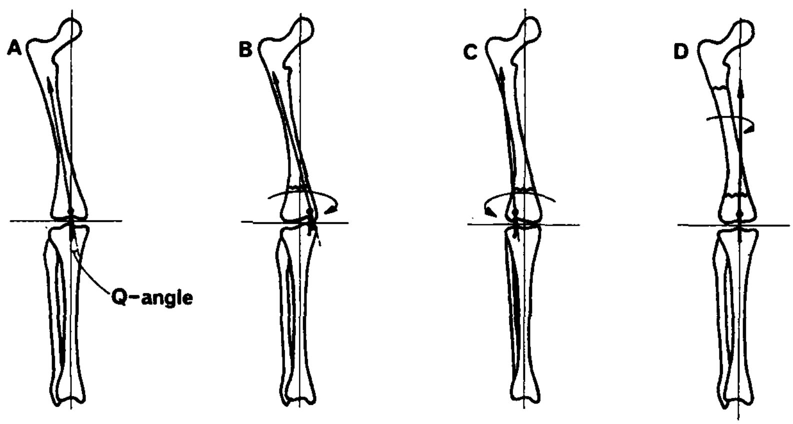


Fig. 12. The effect on the pull of m. quadriceps and on the Q-angle (see text) of different proposed rotation osteotomies. A. Normal Q-angle. B. Supracondylar *inwards* rotation osteotomy according to Graser (1904). Q-angle increases. C. Supracondylar *outwards* rotation osteotomy according to Fürmeier (1953) and Kiesselbach (1956). Q-angle reduces. D. Rotation osteotomy according to Vinditti & Forcella (1958). Q-angle reduces.

As earlier mentioned, the opinion was expressed that the dislocation might be due to an increased inwards torsion of the distal femur end including the patella (or an inwards rotation of the femur and the patella in relation to the tibia). This results in an increased Q-angle and an increased danger of dislocation. Graser's *inwards* rotation osteotomy would thus be completely illogical and ought instead to be replaced by an *outwards* rotation osteotomy to decrease the Q-angle (see Fig. 12 C) (Lacheretz 1951, Fürmeier 1953, and Kiesselbach 1956).

Max Lange (1951) recommends in severe cases "osteotomy according to Graser", but from the text it appears that he means outwards rotation osteotomy.

The Italians Vinditti & Forcella (1958) go a step further: they recommend supracondylar plus subtrochanteric femur osteotomy, and thereafter inwards rotation of the femur shaft freed in this manner, including about 4/5 of the origin of the quadriceps musculature (see Fig. 12 D). In this way, they accomplish a reduction of the Q-angle. The method does not appear to have attracted any followers.

Femur osteotomy is a big operation that demands prolonged aftertreatment. I have not encountered any instance of recurrent dislocation of the patella that justified my suggesting an operation of this nature to the patient.

D. *Summary*

Almost all authors who have concerned themselves with the subject agree that the ventral part of the lateral condyle is low in patients with recurrent dislocation of the patella.

Whether this is due to a *real, substantial* decrease in the height of the lateral condyle above the bottom of the intercondylar groove or to changed torsion and/or rotation conditions, producing an illusory lowering, is disputed. This question could not be resolved with the prevailing roentgen-examination technique.

Because of this, the theoretical fundament of therapy directed against dysplasia has become unclear and is disputed. The proposed operations have had only limited scope; they are technically difficult and call for long convalescence; also the enthusiastic advocates wish to reserve the operation for special occasions.

An attempt to determine the extent of a possible dysplasia and whether this dysplasia is real or only illusory was one of the main purposes of the present work.

CHAPTER V

Roentgen examination of the distal femur end and the femoro-patellar joint by so-called axial picture

A. *Earlier methods*

The ordinary frontal and lateral pictures of the knee joint can give valuable information, to a trained roentgenologist, concerning the form of the femoro-patellar joint (see *inter alios*, Ravelli 1949, and Vogler 1961). However, for the problems I discuss here, the so-called axial picture of the femoro-patellar joint is of supreme importance. The patella usually dislocates (see Chapt. III) when the knee is slightly flexed, i.e. when the patella lies against facies patellaris femoris, and it is this part of the articular surface that is of interest in this connection. The first to describe a method of obtaining such an axial picture is Settegast (1921). In Grashey's roentgen atlas he is named the originator of the examination method wherein the patient lies prone with maximum flexed knee (see Fig. 13 A). This method is still in frequent use. It demands good mobility in the knees and gives a picture of fossa intercondyloidea and of facies tibialis femoris, but not of the sulcus and of facies patellaris femoris. Jaroschy and Altschul in 1923 together describe a method wherein the patient lies supine with the knee flexed about 60° and the cassette along the upper surface of the thigh and the tube at the foot end (Fig. 13 B). This gives a better picture of facies patellaris femoris. The method named after Jaroschy has been modified so that the patient lies prone, but retains the flexion in the knee (see Fig. 13 C). The methods of Jaroschy and Settegast have been used by several authors and seem, with various modifications, still to be the most used (Krömer 1937, Moreira 1939, Schinz *et al.* 1952, Harms 1953, Levitin & Colloff 1956, Files 1959, Clark 1962, and Cerwenka 1962).

The methods have definite disadvantages. If one wishes to have the roentgen beams at right-angles to the cassette, it requires a flexion of more than 90° in the knee, which is often clinically impossible to accomplish, and which, moreover, gives a picture of the patella in fossa intercondyloidea and not in the sulcus.

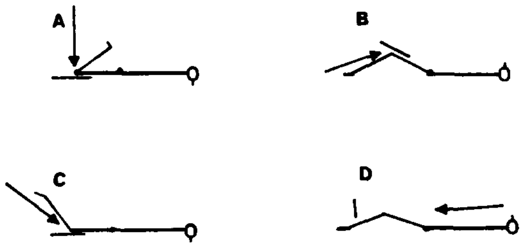


Fig. 13. The roentgen beam at different methods of taking so-called axial picture of the femoro-patellar joint. A. according to Settegast. B. according to Jaroschy. C. according to modified Jaroschy. D. according to Knutsson.

However, if one attempts by a *small* flexion in the knee to obtain a picture with the patella still in the sulcus, the beam has a too-large divergence from the rigth-angled reception angle to the cassette, which lies along the upper surface of the thigh. A distorted picture results.

Knutsson (1941) describes a new method: the patient lies supine and flexes the knee about 40°. The tube is at the head of the patient, and the cassette is at about right-angles to the x-ray table immediately below the middle of the lower leg. The central beam is not quite parallel with the x-ray table; it is lowered 1—5° distally (see Fig. 13 D). By this method, one obtains a right-angled reception angle to the film and the patella is taken longitudinally. This results in a good picture of the sulcus with the patella. Normally the picture is taken with 40—50° flexion, but if the patient has mobility difficulties, usable pictures can be got with only 30° flexion. The angle between the femur and the central beam is about 25° with a flexion in the knee of 40° and an angle between the central beam and the x-ray table of 0—5°.

This axial picture obtained by Knutsson's method has been used by, among others, Wiberg (1941), de Séze & al. (1951), McNab (1952), Fründ (1958), Åndersen, Baumgartl & Gremmel (1961), Rohlederer (1962), and, to some extent, Thestrup Andersen; the latter, however, also uses Jaroschy's technique with the patients in prone position. Köhler & Zimmer (1956) recommend Knutsson's method. The patient material of Marion & Barcat (1950) is irregularly investigated, but mostly according to Jaroschy.

Fürmeier (1953, 1961) has modified Knutsson's technique so that with retained flexion in the knee of about 40° he raises the heels and instead has the beam direction parallel with the table. He therefore also has the angle between the femur and the central beam about 25°. Fürmeier has the patient keep the legs together with the feet and knees touching and exposes both knees at the same time.

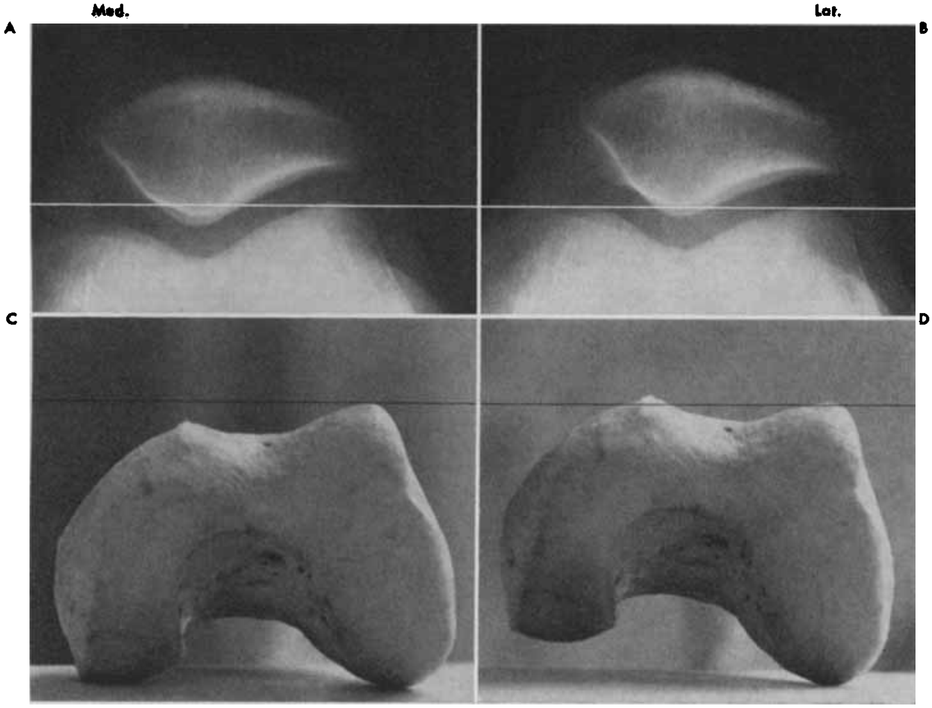


Fig. 14. A and B: axial x-ray pictures according to Knutsson. The same knee, but different investigation occasions. Because of increased outwards-rotation, B seems more dysplastic than A. C and D: ordinary photograph of skeletal preparation to show the importance of rotation for the ventral contour of the condyle section.

With Knutsson's investigation technique, good information is obtained concerning the axial appearance and form of the patella and also of the femur articular surface. However, it gives uncertain information regarding the height of the condyles, and this is one of the most important matters at the dislocation of the patella.

A person lying in the position described by Knutsson can, for example, happen to make a very slight *outwards rotation* in the hip joint —a matter of less than 5°—and thereby *"lower"* the lateral condyle in relation to the medial condyle, and this can produce on the x-ray picture the impression of a "dysplastic" joint (Fig. 14). Or a patient with a low lateral condyle can by a slight *inwards rotation* in the hip joint (unnoticeable by the roentgen staff) happen to get a completely *"normal appearance"* of the femoro-patellar joint.

For the past eight years in the Roentgen Diagnostic Clinic II, Lund, a routine axial picture according to Knutsson has been taken at practically all knee examinations; thus, considerable experience of the method has been obtained. Several patients have been examined by axial picture on at least two occasions. Naturally a patient usually lies in the same position at the different examinations, but various factors (changed x-ray staff, more or less pronounced pain, etc.) have caused many patients to adopt a posture giving different impressions concerning the height of the lateral condyle on different examination occasions.

Here must also be mentioned the source of error that appears if the edge of the cassette does not always stand horizontally, i.e. parallel to the x-ray table. When inspecting an x-ray picture, one will often put the horizontal plane parallel with two edges of the film and the vertical plane parallel with the other two edges, and will presume that the cassette at the exposure stood horizontally. With a good cassette holder, this source of error might be unimportant, but in clinics where axial pictures are not a part of everyday routine, it might be usual for a support to be erected on both sides of the lower leg and the cassette placed upon these, in which case the risk exists of an obliquely placed cassette (Fig. 15).

When appraising an x-ray picture and deciding that, for example, the lateral condyle is low, different appraisers base their opinions upon different factors. The experienced investigator uses the mental picture he has of what an axial picture looks like. Another may judge the lateral condyle in relation to the medial condyle. Most investigators, however, judge more or less consciously in relation to a line, running parallel with the edge of the film, through the sulcus bottom. We have no clearly defined initial position; all these appraisal bases are uncertain.

This can explain the lack of agreement between the x-ray findings and the operation findings, pointed out by Hall (1962).

These sources of error refer to the procedure at taking and interpreting x-ray pictures, and thus vary at different examinations. Even if we can now standardize the examination technique and so interpret the pictures that these sources of error are eliminated, there remains a further possibility of getting a wrong idea of the shape of the intercondylar groove: the distal femur end can, owing to rotation or torsion conditions in the investigated person, stand in a way that makes the lateral condyle seem "lower" than what the appraiser considers normal (see Fig. 11, p. 48, and Fig. 24, p. 73). Whether in those circumstances

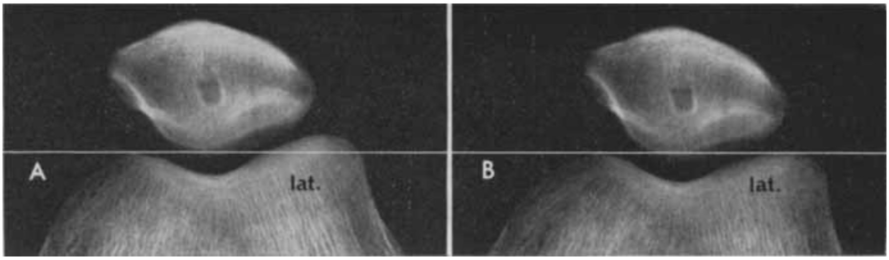


Fig. 15. Two consecutive pictures of a *fixed* skeletal preparation to show the importance of the casette's being placed horizontally. A. The casette edge was horizontal at exposure. B. The casette edge formed an angle to the horizontal line at the exposure, but this cannot be seen on the film; the film edge is automatically (but wrongly) thought to represent the horizontal line. Thus the femur end seems more dysplastic (illusory dysplasia). By a "picturous rotation" like this, but in the opposite direction, a *real* dysplasia can be camouflaged.

one can speak of a true dysplasia and a real lowering, or call it an "illusory lowering" is a question of definition. In this work, this dysplasia, which is thus due to increased outwards rotation or outwards torsion of the condyle section, is called *illusory*.

Knutsson's method is usually sufficient for *practical* purposes, but is too uncertain if it is desired to study the shape of the intercondylar groove in detail.

The same sources of error and disadvantages apply to a greater or lesser extent to the other methods. Fürmeier's method of x-raying both knees at the same time and keeping the knees and the feet together should, however, increase the possibility of obtaining the same leg position at repeated examinations of the same subject and appears attractive.

Summing up. The objections to using the axial pictures taken by current methods in order to study the intercondylar groove can be summarized thus:

1. The position of the leg can vary from subject to subject and on different occasions. This can affect the appraisal to a considerable extent.
2. The position of the cassette at the exposure can play a role at the appraisal of the horizontal line.

3. No clearly defined reference point or reference line is found in the appraisal of the condyle heights.
4. The methods give no idea of whether a faulty position of rotation or torsion has played a role.

B. *The author's investigation technique*

Because I wished to study the femoral part of the femoro-patellar joint, the current investigation technique was not satisfactory, as can be judged from the foregoing.

I must demand of the method:

1. That the femur is retained in the same position at each examination, irrespective of whether the same individual or another is examined; or that one can disregard possible deviations from this position, or can correct them when measuring on the x-ray pictures.
2. That the possible deviation of the cassette from the horizontal plane does not play any role.
3. That one has clearly defined reference points or reference lines that permit exact measurements.
4. That the measure gives an idea of the position in space of the entire distal femur end, and not only that of facies patellaris femoris.

Apart from a uniform positioning of the patient at the examination, one should preferably photograph the anterior and the posterior condyle area at the same time on the same film with the horizontal line projected on to it. This would mean that, for example, one photographed in the femur's longitudinal axis with the cassette at the knee (see Fig. 16 A). Because this is at present impracticable, I have, instead, on the same occasion, taken two pictures with the knees flexed at about 90°, *one of the ventral condyle area and the other of the dorsal.* The pictures were taken with a roentgen tube at the foot end and the cassettes at the popliteal spaces and on the front surface of the thighs (see Fig. 16 B).

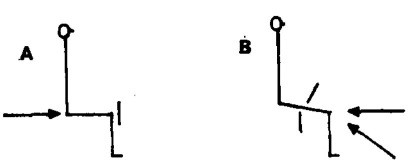


Fig. 16. A. The roentgen beam at the theoretically ideal investigation method of the distal femur end. B. The roentgen beam at the author's investigation method.

Examination arrangements and x-ray procedure

The picture of the posterior area was taken with horizontal beam direction. Because of the soft parts of the thighs, it was not possible to have the same beam direction in the two pictures. It was found that 30° was the smallest angle between the two central beams that would enable me with confidence to get these pictures routinely. If the angle was made smaller, I ran the risk that the tangent ray through the ventral condyle area did not meet the upper cassette, especially if the flesh and the musculature were powerfully developed and thus raised the cassette (see Fig. 17).

The method requires either two roentgen tubes, or one tube that can easily be swung round an axis and thus be used for both pictures. Most

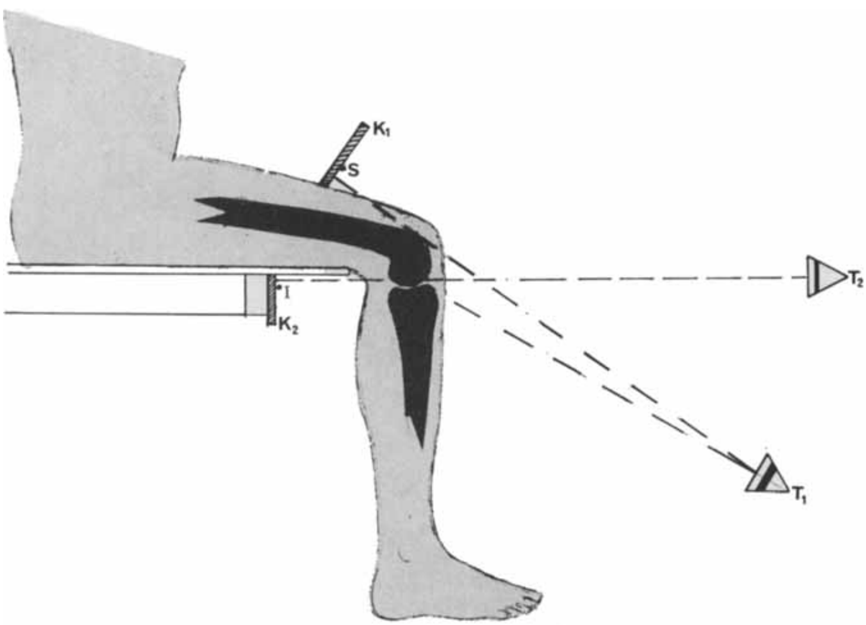


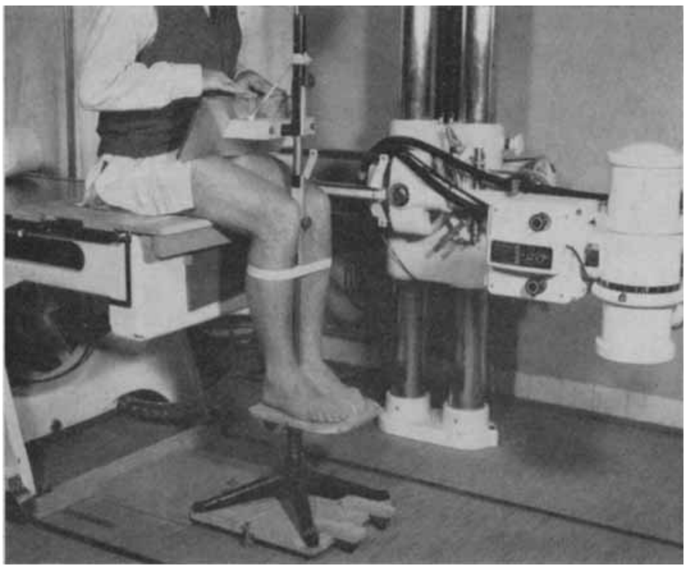
Fig. 17. The course of the beam and the patient's position at the author's investigation method.

T_1 = the roentgen tube 30° below the horizontal plane for the ventral picture.
T_2 = the roentgen tube in the horizontal plane for the dorsal picture.
K_1 and K_2 = casettes.
S = Superior steel wire (see text).
I = Inferior steel wire (see text).

tomographs meet this latter requirement, and because I had access to a tomograph of the type Danatom A, this was used.

The x-ray examination is carried out as follows (Fig. 18, 19, 20): on the foot end of the x-ray table, a wooden lamella is fixed. This protrudes about 10 cm from the narrow end of the table and is covered on the surface with lead-impregnated rubber. In the lamella, immediately at the narrow end of the table, there is a slit that runs parallel with the edge of the table. Through this slit an envelope packed non-screen x-ray film is set. The film thus lies firmly against the end of the table (see Fig. 18).

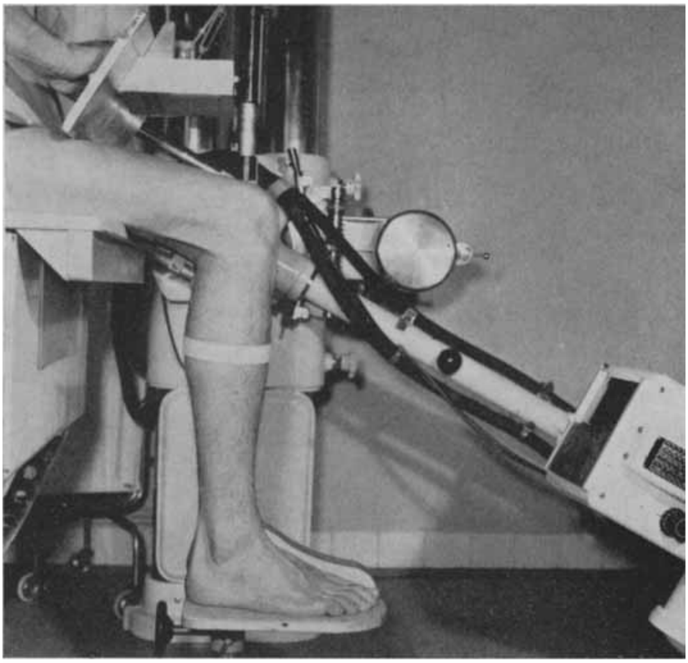
On the underside of the lamella, at the front edge of the slit and parallel with the slit, is stretched and secured a fine steel wire I_1—I_2 (*I*nferior). See Fig. 17 and 19. The lamella is so adjusted that the wire runs horizontally. This is checked with a water-level each time the lamella is set on the table. The steel wire thus produces a horizontal line on each picture of the dorsal condyle section.



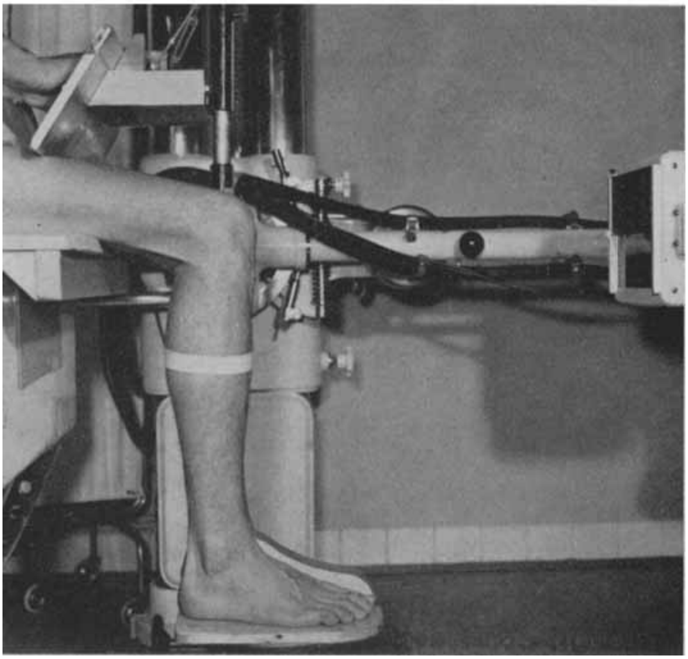
A

Fig. 18. The patient in position for examination. For details: see text. A. General view. The lead-impregnated curtain not in photograph. B. The roentgen tube in the lower position for photographing the ventral part of the condyle section. C. The roentgen tube in the upper position for photographing the dorsal part of the condyle section.

B



C



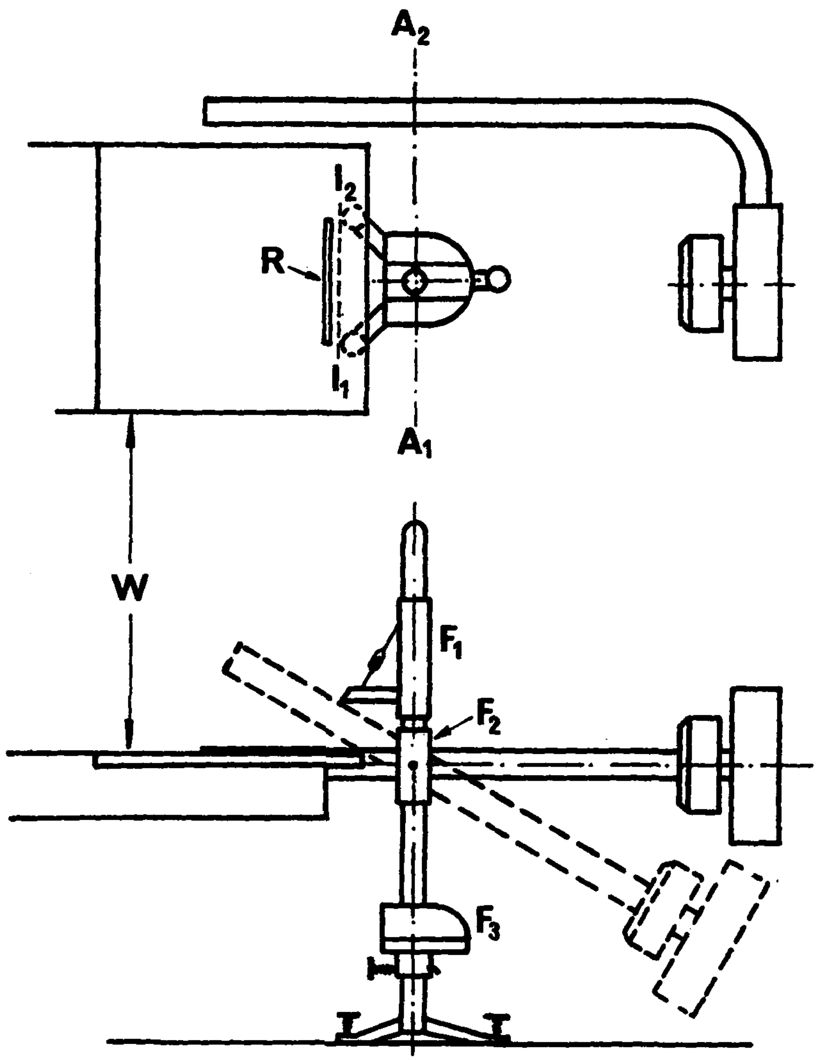


Fig. 19. Schematic drawing of the investigation arrangements seen from above and from the side. The top picture does not include the upper casette support, F_1, with the steel wire S_1—S_2.

A_1—A_2 = Pendulum axis of the Danatom; also = the axis through "the joint markers" (see text).

I_1—I_2 = Inferior steel wire to indicate the horizontal line on the dorsal x-ray picture.

W = Wooden plate secured to the roentgen table

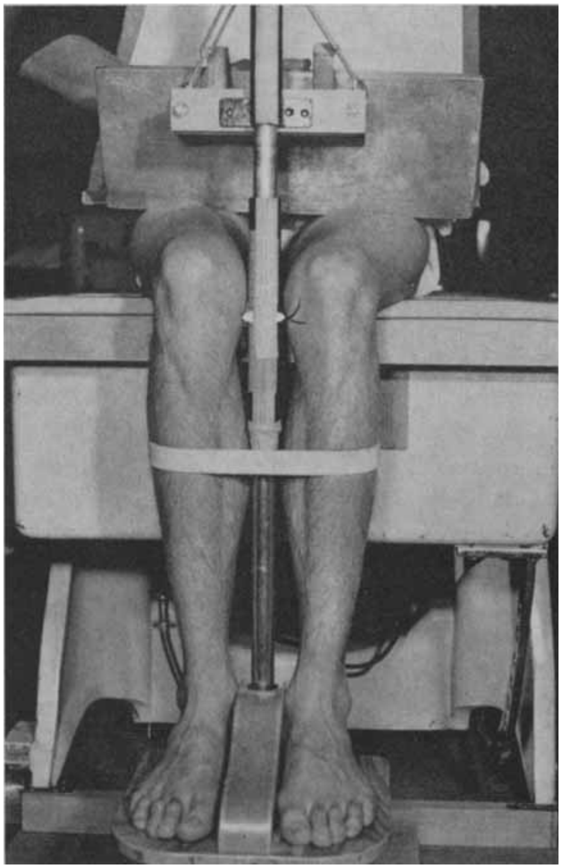
R = Slit in the wooden plate for roentgen film enclosed in an envelope.

F_1 = Upper casette support (with S_1—S_2, superior steel wire not in picture).

F_2 = Knee support with "joint markers" (see text).

F_3 = Footplate—can be raised or lowered.

Fig. 20. I. Photograph of investigation arrangements seen from the roentgen tube.



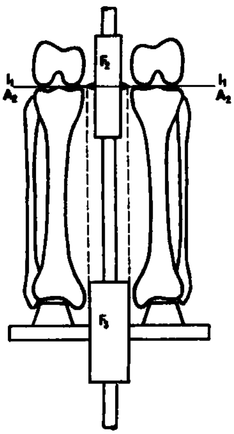


Fig. 20. II. Schematic drawing of the above. For symbols, see Fig. 19.

On the floor below the foot end of the table, in the extension of the mid-line, is set a firm stand with a vertical steel pillar, whose centre is 25,5 cm[1] from the slit with the steel wire. This pillar carries three adjustable supports, on above the other (F_3, F_2, F_1, Fig. 18—20) intended to support feet, knees, and ventral cassette.

The lowest support (F_3) consists of a plate upon which the patient at the examination places his feet, one on each side of a dividing barrier, through a hole in which runs the steel pillar. The plate can be raised or lowered by means of a cog wheel and can be locked in position.

[1] This figure was found empirically: different distances were tested, but with this distance, I almost always got appraisable pictures of both the ventral and the dorsal condyle section.

The middle support (F_2) is intended for the knees. On each side, a metal point protrudes, "the joint markers". These "joint markers" are a full cm long and about 1 cm wide at the base, and are intended to rest against the vertex of the medial joint line on each knee (see Fig. 20).

The axis A_1—A_2 through these joint markers is the central factor at the examination and serves to relate the two pictures. The whole stand and its middle support (F_2) is so placed and adjusted that A_1—A_2 is *partly* parallel with the steel wire I_1—I_2 and level with it, and will therefore coincide with I_1—I_2 on the lower dorsal picture taken with horizontal beam direction, and *partly* identical with the pendelum axis of the Danatom. The central beam from the roentgen tube goes through this axis, irrespective of the position of the tube.

The distance between the points of the joint markers is equal to the thickness of the dividing barrier of the footplate, i.e. 5 cm (see Fig. 20).

The distance between the axis A_1—A_2 and the steel wire I_1—I_2 is 25.5 cm.

The uppermost support (F_1) carries a wooden block, which holds the cassette. The front (facing the patient) is inclined 30° forwards-upwards in relation to the vertical plane (see Fig. 17). Inlaid in the lower edge of the front is a steel wire S_1—S_2 (*S*uperior). With screws and a built in water-level, the cassette support can be so placed that the steel wire S_1—S_2 is horizontal and 20.4 cm (see Fig. 23: I and p. 71) above the horizontal plane through the steel wire I_1—I_2 and 25.5 cm from the axis A_1—A_2 (see Fig. 23).[2] This steel wire S_1—S_2 thus produces a horizontal line on each picture of the ventral condyle section.

A water-level and an indicator light in the roentgen tube enable us to check that the stand pillar, with the three supports, is vertical and stands in the extension of the mid-line of the table. The roentgen tube is then swung down to its lower position 30° below the horizontal plane and secured. The whole of the lower half of the roentgen beam is screened off by a lead-covered brass plate, which glides on two runners in front of the diaphragm, being set in its lower position (see Fig. 18).

The enveloped film is set into the slit in the lamella so that its top edge is level with the surface of the lamella. The patient is placed, appropriately unclothed, on the lamella with one leg on each side of

[2] From an investigation technical standpoint, the height above the horizontal plane could be chosen within quite wide limits, e.g. between 19 and 22 cm. The height 20.4 cm was chosen because this figure simplifies the calculations of LC and MC (see p. 71).

the stand and the feet on the footplate. The medial malleoli are held close to the dividing barrier on the footplate. The medial joint line in the knee joint is palpated, and by the patient's moving forwards or backwards on the lamella and by regulating the height of the footplate, an attempt is made to get the two joint markers on the middle support to rest against the vertex of the medial joint line of each knee. When the position is satisfactory, an elastic band is stretched round the patient's calves, which helps him without any undue muscular effort to retain this position throughout the examination.

A 15×40 cm cassette is placed lengthwise across the patient's thighs, inclined against the above-described cassette holder; it thus lies 30° to the vertical plane. At the examination, the patient is told to press the cassette *lightly* against the soft parts of the thighs. He is told the essentials of the examination and that *two* pictures are to be taken, that the tube will be moved between the takings, but that he must keep still and lightly press the cassette against the soft parts and not try to help in any other manner. One checks by palpation that the patient's heels are planted firmly upon the footplate; the patient must confirm this, and also that he sits comfortably and is not tensed. With an indicator light, it is checked that the knee contours stand out against the upper cassette. The patient is not allowed to press the cassette so hard into the soft parts that it changes the angle of inclination. The upper film is then exposed, which thus pictures *the ventral area of both knees.*

Then, as quickly as possible, adjustments are made for exposing the lower film:

1. By swinging up the tube to horizontal beam direction (thus, the central beam through the axis A_1—A_2 of the joint markers and through the steel wire I_1—I_2 on the underside of the lamella).
2. By raising the lead-covered brass plate, which is automatically lodged in the upper position so that the *upper* half of the roentgen beam is screened off (see Fig. 18).

After that, the lower film is exposed and pictures *the dorsal condyle area of both knees.*

During the entire procedure, the patient sits quiet without, however, holding his breath, and he need not be troubled by cassette changes etc. When the method was finally shaped and had come into use, it took, with very small variations, an average of 10 seconds from beginning the first exposure to concluding the second. Having in mind the rela-

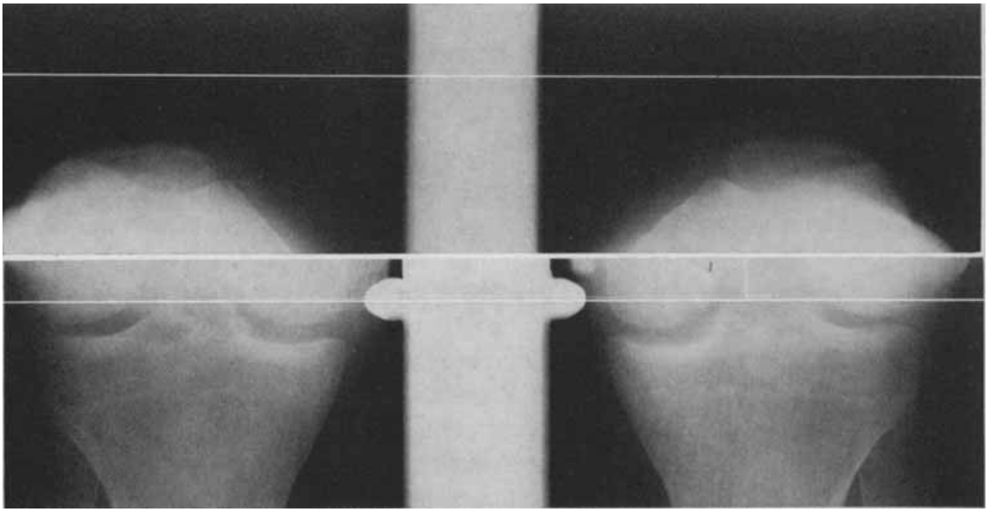


Fig. 21. A. The two x-ray pictures: the upper = the ventral section of *both* knees; the lower = the dorsal section of *both* knees.

tively comfortable conditions for the patient, I believe that no change in position have occurred during this short interval and the pictures can for my purpose be regarded as having been taken simultaneously.

In this way, two practically simultaneous pictures are obtained of *both* knees, one picture of the ventral area of the condyle sections of the knees, and the other, the dorsal. On the two pictures, a horizontal line is projected (the steel wires I_1—I_2 and S_1—S_2). Fig. 21.

In this position, the longitudinal axis of the femur forms an angle of about 9° to the horizontal plane (maximum 11°, minimum 5°) according to what I have found on x-ray side-view pictures taken of 20 males and females with varying flesh and musculature. The x-ray beam then forms an angle of about 25° with the longitudinal axis of the femur, i.e. about the same as Knutsson's method.

With the chosen measurements and placings, one thus obtains appraisable pictures in most cases at the first exposure. On the ventral upper picture, the ventral contour of the condyles always lies below the projection of the steel wire S_1—S_2, usually 3—5 cm below it, whereas on the lower dorsal picture, the condyles usually lie immediately below the projection of the steel wire I_1—I_2. In very short and fat or muscular patients, there is the risk of the upper cassette's being raised so high

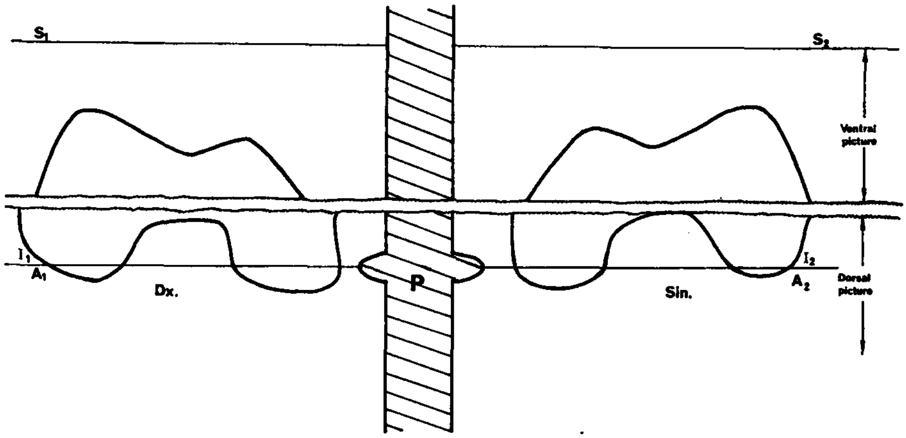


Fig. 21. B. Schematic drawing of the same things.

S_1—S_2 = Superior steel wire, horizontal line on the ventral picture.
I_1—I_2 = Inferior steel wire, horizontal on the dorsal picture.
A_1—A_2 = Pendulum axis of the Danatom; also = the axis through the two "joint markers".
P = Metal stand with the two "joint markers".

by the soft parts that the ventral condyle area will not, at the first attempt, be included in the picture. However, by raising the footplate a few cm (though not enough to risk "losing" the condyles in the dorsal picture, which are also re-taken in the new position) and at the same time asking the patient to press down the cassette a little more into the soft parts of the thighs than at the previous exposure, acceptable pictures are almost always obtained. Of the pictures of about 500 subjects that I have x-rayed in this final position, only two failed.

Measurements and calculations on the roentgenograms

On the two x-ray pictures obtained in the described manner, certain measurements and calculations were made.

I. *The upper, ventral picture* (Fig. 22)

The horizontal line S_1—S_2 (*S*uperior) which always lies above the ventral contour of the condyles is parallel displaced down towards the sulcus, and thus three points are obtained: the highest point of the

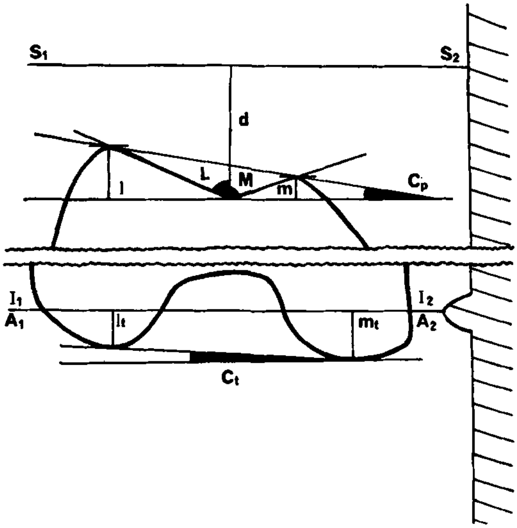


Fig. 22. Drawing (one knee only) that shows the distances and angles which have been measured. (x-ray pictures show both knees.) See text for symbols.

lateral condyle, the highest point of the medial condyle, and the lowest point in the sulcus. *Through,* as well as *to,* the last-mentioned point, four lines are drawn: a horizontal line, a vertical line, and a line to each highest point on the lateral and the medial condyle. Finally, the points on the lateral and the medial condyle are connected by a line called *the ventral or the patellar condyle line, which forms an angle C_p (patellar) to the horizontal line through the sulcus bottom.* Because the lateral condyle usually is higher than the medial, this angle is open laterally. In those isolated cases where the medial condyle is higher, we get instead a medially open angle, which is thus given a minus sign.

The height of the lateral condyle above the horizontal line through the sulcus bottom is called *the lateral condyle height and is indicated by l.*

The height of the medial condyle above the same horizontal line is called *the medial condyle height and is indicated by m.*

The perpendicular distance between S_1—S_2 and the bottom of the sulcus is indicated by *d.*

The angle between the vertical line and the line from the sulcus bottom to the top of the lateral condyle is called *"the lateral sulcus angle" and is indicated by L.*

The angle between the vertical line and the line from the sulcus bottom to the top of the medial condyle is called *"the medial sulcus angle" and is indicated by M.*

L + M (the angle between the lines from the sulcus bottom to the tops of the lateral and medial condyle) is called *"the sulcus angle"*.

II. *The lower, dorsal picture* (Fig. 22)

The horizontal indicator line I_1—I_2 is parallel displaced until it touches the posterior area of one condyle and that of the other. Thus we have two points, which represent the most dorsally situated parts of the condyles. These two points are connected by a line, *the dorsal or the tibial condyle line. This forms an angle, C_t, with that horizontal line which touches the most dorsally lying condyle.* This angle is usually open laterally (as a sign that the medial condyle "dips" deeper than the lateral condyle) and is given a plus sign. The investigation method ensures that this posterior area lies close to the indicator line I_1—I_2. The distances between this line and the two points that represent the most dorsally lying section of each ondyle are *indicated by l_t and m_t* (tibially), respectively, and are given a plus sign if they lie below I_1—I_2 and a minus sign if they lie above this line.

III. *Calculations common to both pictures*

The extension of the condyles ventro-dorsally.

A cassette is placed upon the x-ray table and leaned against the upper cassette support without any patient sitting on the table (Fig. 23: I). The roentgen tube is in the lower position for taking a ventral, upper picture. The central beam goes through A in Fig. 23: I. According to earlier definitions (Fig. 21):

A_1—A_2 = the axis through the joint markers = the pendelum axis of the Danatom.

I_1—I_2 = the inferior indicator line.

S_1—S_2 = the superior indicator line.

The projection of A_1—A_2 on the upper cassette in Fig. 23: I is called B_1—B_2.

A, B, I, and S = points in a common sagittal plane on the lines A_1—A_2, B_1—B_2, I_1—I_2, and S_1—S_2.

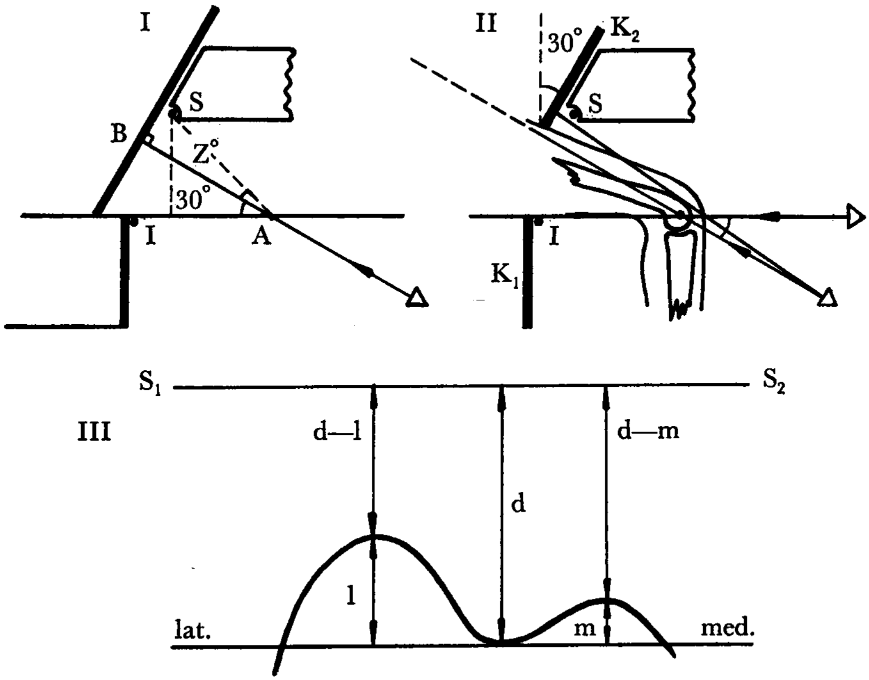


Fig. 23. Drawing to show the roentgen beam and how LC and MC were calculated. See text.

I. Roentgen beam without test subject. The cntral beam through A strikes the upper casette in B.

II. Roentgen beam with test subject. The upper casette is raised and is no longer within the central beam.

III. Calculation of LC and MC. See text.

According to the experimental conditions, the distance S—A is 255 mm and the distance between S and the distance I—A is 204 mm.

From Fig. 23: I we get: $\sin(30+Z) = \frac{204}{255}$

$Z = 23°.1$

$\sin 23.1 = \frac{B\text{—}S}{255}$ B—S = 100 mm.

Thus, we know that the projection of the axis A_1—A_2 is always 100 mm below the line S_1—S_2, even though this projection is omitted from the picture.

When a patient sits on the table, the cassette will be raised so much by the soft parts of the thighs as to put it out of range of the central beam through A_1—A_2 and we get no projection B_1—B_2 of the joint markers (Fig. 23: II). The picture of the ventral contours of the condyles always lies below S_1—S_2, and by measuring the distance between the sulcus bottom and S_1—S_2 (d on Fig. 23: III) on the picture, we can, because we know that B—S is 100 mm, calculate the distance between the sulcus bottom and B_1—B_2. This is 100—d. The distance between the top of the lateral condyle and B_1—B_2 is 100—d+l, and the corresponding distance from the medial condyle is 100—d+m. Fig. 23: III.

The investigation method was so arranged that the joint markers would mark the medial joint line and the points on the condyles that are most dorsal in this position. Table 2 shows that between 3 and 9 mm of the condyles lie below the joint markers, somewhat more for the medial condyle than for the lateral. It shows also that these figures are about the same whether it concerns the condyles of the normal material or those of patients with dislocations of the patella.

Mainly uniform and similar sized parts of the posterior condyle area lie below A_1—A_2. I therefore make an approximation by adding the distance l_t to that part of the lateral condyle which, on the ventral picture, lies above A_1—A_2 and which was calculated by the formula $100-d+l$. The distance thus obtained I let express the ventro-dorsal extension of the condyle, i.e. its "depth".

The same calculation is made for the medial condyle.

The calculated distance $100-d+l+l_t$ is called LC and is an approximate expression for the extension of the lateral condyle ventro-dorsally; and the distance $100-d+m+m_t$ is called MC and is an approximate expression for the extension of the medial condyle ventro-dorsally. The size of the approximation is to some extent unknown, and LC and MC must be appraised with the utmost care.

Roentgen technical information

All patients were investigated with a Danatom type A with standard measure.

The length of the arm of the pendulum from focus to pendular axis is 87 cm. Focus 1.2×1.2. For the ventral, upper picture, a cassette with a reinforcement screen is used. For the dorsal, lower picture, whereon the condyles are projected very close to the edge of the film, envelope packed non-screen film is used. Here the film reaches to the edge of the envelope, whereas on an ordinary cassette, about 1 cm of the edge is lost, and this may sometimes exclude the condyles from the picture.

The upper picture is exposed with 80 mAs at 80 kV, the lower, with 125 mAs at 100 kV.

In order to reduce the radiation as much as possible, the following precautions were observed:

1. The surface of the wooden lamella was covered with 3 mm thick lead-impregnated rubber.
2. In front of the opening of the tube, a lead-covered brass plate was set. This screened off the lower half of the beam when the upper picture was taken, and *vice versa*. Fig. 18.
3. The shutters were adjusted carefully.
4. A lead-impregnated curtain hung in front of the patient and rested upon his thighs. Fig. 20.

The dosage loading of gonads and thorax was tested at the Radiophysic Institution by BD—11 chambers with a sensitivity area 10—300 mR: the dosage received was negligible.

Errors at the roentgenography

There are some sources of error at this roentgenography.

The adjustment of the height and the angle of the tube is relatively coarse, and a displacement of some mm up or down as well as a difference of a few degrees at different examinations could not be avoided. The indicator light, however, has facilitated the symmetric uniform adjustment.

The largest source of error can supposedly be caused by the subjects' not taking precisely the same position in the apparatus.

I have tried to reduce this source of error by undertaking all examinations personally. I have helped the patients to place themselves correctly, have palpated the medial joint line, and have ensured that normal routine was followed.

With the indicated technique, I have tried to examine all the patients with the femur in the same position every time. I have found it practically impossible to set the femur in the correct position and to fix it *directly* there. By fixing the lower leg with the medial tibial condyle immediately above the medial malleolus and by having the knee flexed about 90°, I have tried to fix the femur *indirectly* in the same position at each examination of the patient. These two structures (medial malleolus and medial tibial condyle) are easily palpable even in rather adipose persons.

The femur, however, can with this flexion at almost right-angles in the knee joint, rotate a few degrees on its longitudinal axis even with fixed lower leg: if one firmly fixes the legs in this position and asks the patient to try to move the feet directly laterally, the patient will tense the inwards rotators of the femur and a gap of a few degrees will result laterally in the knee joint; *vice versa*, if one asks him to press the feet together, he will tense the outwards rotators and a gap will result medially (Brattström 1962). In the relaxed position of the patient at the examination, one can ignore this forced movement and consider that the femur in this respect occupies *the same position every time the same patient is examined.*

Different patients can, in this position, have the femur in different rotation positions owing partly to individual differences in the incline of the articular surface of the tibia in relation to the vertical line through the tibia, and partly to the different development of the dorsal area of the femur condyles (see Fig. 24).

The medial joint line is usually easy to palpate approximately, but it is more difficult always to place the medial joint line and the vertex exactly against the joint markers, and variations occur. The joint line sometimes would sit somewhat above or, more frequently, somewhat below the joint markers, which did not always come against the vertex, but somewhat before or behind it. Also the angle that the longitudinal

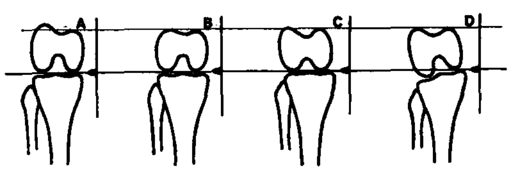


Fig. 24. Different possibilities for obtaining reduced height of the lateral sulcus wall (called l in this work) in knee flexed at approximate right-angles. See also Fig. 26, p. 106. A. Normal. B. The ventro-dorsal extension of the lateral condyle is less because the ventral part of it is low. Femoral dysplasia. C. The dorsal part of the lateral condyle is low; therefore, the femur stands outwards rotated. Illusory dysplasia. D. The articulated surface of the tibia stands obliquely; therefore, the femur stands outwards rotated. Illusory dysplasia.

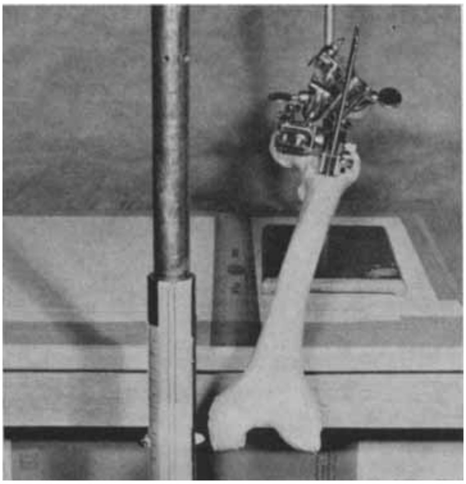


Fig. 25. Preparation from the osteologic collection mounted for investigation of method errors. See text.

axis of the femur formed to the table could vary somewhat: on average, I found 9° (5°—11°, see p. 66).

In order to determine the extent that reasonable variations in these respects (i.e. the different body constitution of the patients and their various positions at the examination) played a role, the following experiments were carried out.

I x-ray examined first three femora from the osteologic collection. They were fixed firmly on a stand in the investigation position approximating that occupied by the femur in the patient. Graded changes in the position of the preparation could be achieved (see Fig. 25).

The usual measurements were made on the roentgenograms.

1. The femur was mounted with the joint markers against the calculated joint line vertex and the shaft forming 10° to the table. The stand with the preparations was moved 1, 2, and 3 cm backwards and ventral pictures were taken in each position. Thereafter the stand was replaced in its initial position and then moved 1, 2, and 3 cm forwards, i.e. towards the roentgen tube. The condyle section was thus moved a total distance of 6 cm, whereas the cassette and the tube remained constantly in the same place. No dorsal picture was taken. On the ventral picture, the usual measurements were made. The results for all three bones lie within the margin of error(see Table 1).

The variation distance, 6 cm, is considerably greater than the one we need to take into account in practice.

2. The femur was mounted with the distal end about 2 cm lower than the position aimed at when examining the patient. The marker was thus about 2 cm ventrally to "the joint line", whereas the collum end was found at normal height above the table. From this initial position, the distal end was raised $^1/_2$ cm at a time until the point was about 1 cm dorsally to the joint line (with the collum end constantly retained in position). A roentgenogram was taken in each position.

The results for all three bones lie within the margin of error (see Table 1).

3. The distal femur end was kept fixed in position, but the collum end was raised so that the femur shaft from the initial position with an angle of 5° to the table via 8°, 11°, and 14 ° was finally x-rayed at an angle of 16° to the table. The results for all three bones lie within the margin of error.

4. The femur was mounted in the position aimed at when examining the patient, and a ventral picture was taken. Then the collum end was moved 3 cm laterally and 3 cm medially, and pictures were taken in these extreme positions, which thus lay 6 cm apart. The distal femur end remained undisturbed. The investigation is intended to show the extent to which the pelvis width plays a role at the patient examination.

No difference could be measured.

One can get an idea about the effect that the different rotation position of the femur can have upon the measured values by the following experiments.

5. A ventral x-ray picture can be turned round a sagittal axis through the sulcus bottom. This corresponds to a rotation change of the femur. It appeared that a turn of 2° gave a result in the measurements. If, for example, such an "artificial" outwards rotation of 2° was made, it resulted in a decrease of l, an increase of m, and a decrease of C_p. L increases and M decreases and the sum L+M is unchanged at "rotations" that were kept within ± 5°.

In order to determine to what extent *small* rotation movements played a role for the measured results, the following experiment was made.

6. Twenty patients were x-ray examined in the usual manner, placed upon the examination table with their feet on the footplate. A 3 mm thick piece of cardboard was then put between the medial malleolus

TABLE 1

The number of deviating measured results obtained at two different measurements of the same picture (col. 1 and 2) and at the measurement of two different pictures of the same knee (col. 3)

For column 1: 1 week between the measurements; column 2: the assistants were unaware of each other's results; column 3: a minimum of 1 week between the two x-ray examinations and the measurements.

In no instance were the deviations more than 1 unit (degree or mm) and negative and positive deviations occurred to the same extent.

Col.	1	2	3
	100 knees, x-rayed once, measured twice by the author	100 knees, x-rayed once, measured once by each of 2 assistants	100[1] knees, x-rayed twice, each measured once by the author
l	19	28	30
m	14	7	18
C_p	24	25	40
C_t	14	17	28
L+M	33	39	30

[1] 50 knees were x-rayed and measured, the figures then doubled.

and the right side of the dividing wall on the footplate, and a 6 mm thick piece in the same place on the left side, and new x-ray pictures were taken. The feet were thus separated, and this resulted in an inwards rotation of the femora. All pictures were measured by me three times with a minimum interval of one week between each measurement, and the mean was recorded. With a distance between the medial tibia condyle and the medial malleolus of 35—40 cm, the change of rotation is less than 1°.

It appeared that already a change of rotation of the femur of this magnitude resulted in changes in the measured results. Placing the cardboard pieces gave, as mentioned, an inwards rotation of the femur, and we could expect an increase of l, decrease of m, increase of C_p and C_t, decrease of L, and increase of M.

On the right side where the 3 mm piece was placed, no tendency was noticed in the figures, but on the left side, an increase of l in 6 of the 20 patients and a decrease of m in 3 patients were measured. C_p and C_t had increased equally in 6 patients. L had increased in 5 patients, and M decreased, so that L+M was unchanged.

7. In order further to illustrate the source of error that can lie in the patients' being differently positioned at the examinations, I made the following experiments: 50 knees were photographed twice; an interval of at least 24 hours intervened between the exposures. Then ordinary measurements were made and the difference between the first x-ray and the second was recorded. The results appear in Table 1. In no instance was there recorded a difference greater than one unit. The table shows that the number of differences are, as expected, somewhat greater at this examination than those noted when I measured twice on the same picture.

Errors in measuring the roentgenograms and in calculations

Both the normal material and the patient material were measured three times: once each by two assistants, who were the same throughout the investigation, and once by me. None of us knew the results of the others' measurements. In no case was there any difference larger than one unit (mm or degree) between the three measurements, and at least two measurements agreed. This "majority result" was considered valid. The measurements were given in whole mm or degrees. A report of the difference between the measurements by the two assistants of 100 right knees in the normal male material is given in Table 1, as well as the differences obtained between two measurements made by me on the same pictures at an interval of one month. With increased experience, differences in the results of our measurements of the same pictures occurred less often.

The difficulty was to say precisely where the point of intersection on the parallel horizontal line occurred on the softly rounded contours.

Furthermore, we measure the *bone* contour and do not positively know how the cartilage helps to form the sulcus.

The given distances were measured on the pictures in mm, but it must be observed that 1 mm on the picture does not correspond to 1 mm on the bone.[3] This has no importance for my discussion of the results.

Because the magnitude is about the same, I have preferred to retain the designation mm instead of introducing a special unit for these measurements.

[3] The picture enlargement is about 1.3/1 at the distances used.

Those approximations made at the calculations of LC and MC are reported on p. 71.

What do these measurements signify?

The measured distances and angles together give an idea of the shape of the intercondylar groove and of the anatomical structure of the distal femur end.

l and m indicate how high above the horizontal line through the sulcus bottom the lateral condyle, as well as the medial, reaches, when the lower leg of the patient is held vertically and the x-rays form an angle of approximately 20°—25° to the femur shaft. C_p gives an idea of the difference in this height between the lateral and the medial condyle. C_t gives an idea of the rotation and the torsion conditions of the distal femur end.

L, M, and L+M give an idea of how steeply the walls of the sulcus rise, and together with l and m give a picture of the shape of the intercondylar groove.

LC and MC give an approximate idea of the extension dorso-ventrally of the lateral condyle, as well as the medial, significant enough to allow comparisons between patients and normals investigated by the same method.

L and M were, during the calculations, treated partly by themselves and partly together (L+M). *The last expression, L+M, gave the best charateristic of the sulcus form and was, moreover, independent of the rotation and the torsion conditions within reasonable limits.*

C. *Summary*

The usual roentgen methods for examining the intercondylar groove are not suitable for measuring exactly the groove and possible changes in its shape. The present author has devised a method whereby the distal femur end and the groove are x-ray examined under standardized conditions.

On the x-ray pictures certain distances and angles were measured in order to get expressions of the shape of the intercondylar groove. See "Definitions . . ."

CHAPTER VI

Normal material

A. *Composition*

The normal material at the x-ray examination is composed of 100 females and 100 males, all of whom I myself examined. The female group consisted of staff at the Orthopedic clinic and patients treated there for complaints not involving the lower extremities. The male group consisted also of staff at the Orthopedic clinic (porters and staff in the bandage workshop) and patients with complaints not involving the lower extremities and also about 40 university students. The average age of the female material is 30·2 years (18—48 years) and of the male 31·0 years (19—52 years). All the investigated persons denied any knee troubles, apart from milder traumatic episodes. No family anamnesis has been recorded. They gave their age and height, and when they were placed upon the examination table, I established that the legs were symmetrical and that no atrophies existed. These persons had to undergo no detailed clinical examination. Only the two special pictures of the distal femur end were taken. The pictures were measured three times: by me and by two assistants (once each) in the earlier described manner (see Chap. V).

The average age of the normal material was somewhat lower than that of the patient material:

	Females	Males
Normal material	30.2	31.0
Patient material	34.6	32.2

In order to get an idea whether this age difference plays any role, I have taken those females in the normal material whose age exceeded 30 years, a total of 40, the average being 38·9 years, and treated their measurement results independently. They did not differ from the other normal material.

The average height of the female normal material was 166·6 cm; the male, 177·2 cm. In order to get an idea whether the body length had any influence upon the measurement results, I treated in a separate group the 28 male normal cases that exceeded 180 cm. It showed no tendency to differ from the other normal material.

B. *Results of measurements*

The results of the measurements of the normal material are shown in Table 2 and 3.

1. *The posterior condyle plane is not horizontal.* This is shown in Table 2 and 3.

When anthropologists measure the torsion of the femur, they put the leg on a horizontal surface with the posterior sides of the two condyles as supports, and then relate all angles to this posterior condyle plane (Martin 1914). Clinically, when one wishes to measure the femur's so-called anteversion angle, which is an expression for this torsion, this is done roentgenologically (see p. 20). Most of the methods used in Scandinavia are based on the principle that the patient is allowed to lie on an examination table with the lower legs hanging over the edge of the table, the central beam directed vertically. By rotating the femur inwards, it is seen on the fluoroscopic screen or in serial films when the femoral neck is projected to its maximum length on the screen or the film, i.e. when the longitudinal axis of the femoral neck is horizontal. The lower leg, hanging over the edge of the table, serves as an indicator:

TABLE 2

Mean values of the distances m_t and l_t, and m_t—l_t (see Fig. 22) of 100 normal females and 100 normal males

	♀		♂	
	dx	sin	dx	sin
m_t	5.75	5.29	9.92	9.32
l_t	2.86	3.90	6.22	7.50
m_t-l_t	2.89	1.39	3.70	1.82

the number of degrees it deviates from the vertical is taken as a measure of the degree of anteversion.

This examination method is based on the assumption that the posterior plane of the condyles in the position in question is horizontal.

It proved, however, that in the normal material the dorsal condyle line, i.e. the line through the most dorsally lying points on the respective condyles, was not usually horizontal. With that horizontal line, which is a tangent to the most dorsally lying condyle, it forms an angle, C_t, which is usually open laterally as a sign of the medial condyle's lying lower than the lateral in the actual examination position. Fig. 22. This position on the part of the femur and the tibia is the same as the roentgenologists use at anteversion measurements.

This appears also from the measured distances l_t and m_t on the figure, where m_t is nearly always larger, and the difference m_t—l_t thus is positive (see Table 2 and Fig. 22).

The figures in Table 2 have not been arranged statistically because the rotation position of the distal femur end is expressed better and more direct by the angle C_t in Table 3 than by the difference m_t—l_t.

The figures in Table 2 were reported partly in order to give the reader an idea of the size order of the measured distances and thus also an idea of the extent of the fault made when we, with the aid of l_t and m_t calculate approximately LC and MC (see p. 71), and partly to give a preliminary orientation of the rotation position of the femur end.

Already here is also seen the difference between right and left side: this will be discussed more closely later.

In Table 3 there appears a detailed report of the findings at the measurements of the normal material.

2. *Right and left side are not symmetrical.* As appears in the table, there occurs a statistically significant difference between right and left side: the height of the lateral condyle (l) is less on the left side, whereas the height of the medial condyle (m) is greater. There has thus partly occurred a levelling between the condyles.

Therefore, it follows that the ratio l/m is also less, and the difference l-m is less on the left side.

The angles also are changed. C_p, the ventral condyle angle, is smaller on the left side, and the medial sulcus angle (M) is also smaller, whereas the lateral sulcus angle (L) increases to about the same extent, so that L+M, the total sulcus angle, is in the main unchanged.

TABLE 3

Results of measurements on x-ray pictures of the normal material, mean values
For symbols, see Fig. 22 and for LC and MC, see p. 71

	100 normal females dx	sin	Diff. dx–sin	100 normal males dx	sin	Diff. dx–sin	Diff. female/male
l	10.08±0.19	9.11±0.17	0.97±0.26***	11.60±0.18	10.66±0.20	0.94±0.27***	−1.52±0.26*** −1.55±0.26***
m	5.59±0.16	5.87±0.15	−0.28±0.22	6.40±0.16	7.33±0.18	−0.93±0.24***	−0.81±0.23*** −1.46±0.23***
l/m	1.98±0.08	1.64±0.05	0.34±0.09***	1.95±0.07	1.55±0.05	0.40±0.09***	0.03±0.11 0.09±0.07
l–m	4.49±0.25	3.24±0.19	1.25±0.34***	5.19±0.24	3.33±0.27	1.87±0.36***	−0.70±0.35* −0.09±0.33
C_p	6.10±0.30	4.36±0.26	1.74±0.40***	5.95±0.26	3.83±0.30	2.12±0.40***	0.15±0.40 0.53±0.40

C_t	2.63±0.22	1.42±0.22	1.21±0.31***	3.09±0.21	1.78±0.21	1.31±0.30***	−0.46±0.30 −0.36±0.30
L	69.39±0.38	70.77±0.38	−1.38±0.54*	69.31±0.35	70.68±0.35	−1.37±0.50**	0.08±0.52 0.09±0.52
M	72.40±0.43	71.59±0.42	0.81±0.60	73.47±0.43	71.24±0.40	2.23±0.59***	−1.07±0.61 0.35±0.58
L+M	141.79±0.60	142.36±0.61	−0.57±0.86	142.78±0.51	141.90±0.54	0.88±0.74	−0.99±0.79 0.46±0.82
LC	65.29±0.79	65.93±0.88	−0.64±1.18	71.98±0.74	72.22±0.77	−0.24±1.07	−6.69±1.08*** −6.29±1.17***
MC	63.66±0.77	64.08±0.83	−0.42±1.13	70.49±0.72	70.71±0.73	−0.22±1.03	−6.83±1.06*** −6.63±1.10***
LC−MC	1.60±0.21	1.85±0.27	−0.25±0.34	1.49±0.26	1.51±0.32	−0.02±0.04	0.11±0.33 0.34±0.42

These now described changes can have two explanations: either that l really has reduced and m increased with consequences also for the angles (Fig. 11 B, p. 48) or that the left femur stands somewhat more outwards rotated in the hip or the distal femur end somewhat more outwards torqued on the left side compared with the right (see Fig. 11 C).

The dorsal condyle angle, C_t, gives information regarding this. If there is torsion or rotation change, this angle will reduce according to the figure and possibly become negative, i.e. open medially. If, on the other hand, it concerns a real reduction of l and an increase of m, it will remain unchanged. In Table 3, it can be seen that the average for C_t is less on the left side as a sign of the torsion or the rotation being changed.

L+M, which within reasonable limits are independent of rotation—torsion, show no significant difference between right and left.

The same tendency with difference on the right and the left side, and about the same degree of statistical significance is found in the female material, as well as in the male (see Table 3).

For the normal material, the ratio l/m has also been calculated (see Table 3), and it shows that on the right side, the medial condyle is about half as high as the lateral condyle in both male and female; on the left side, the medial is about two-thirds as high as the lateral condyle.

LC and MC have faults too great to be able to give positive information about the relatively small differences dealt with here.

Thus, there exists in both female and male a statistically significant difference between right and left side. This difference seems to be due to an increased outwards rotation or torsion on the left side. This difference on the right and the left side, I have not seen described earlier. On a usual axial X-ray picture, which thus depicts only the anterior part of the condyle portion, this asymmetry can be rather pronounced. Here one cannot, see p. 57, decide the reason for this levelling of the two condyle heights in the same way as when one x-ray photographs both the anterior and the posterior condyle portions at the same time. Those authors who have found among their patients that left-sided dislocations are somewhat more common have mentioned nothing about this asymmetry on the x-ray picture.

Difference between the right and the left side of the body is not unusual. Martin states in his Lehrbuch der Anthropologie how usual it is to find a difference in the length of the arms: only 18 per cent of German soldiers had both arms the same length, in 82 per cent the length differed. In 75 of this 82 per cent, the right arm was longer; in the remaining 7, the left was longer. Martin sees this as the result of the right hand being trained and developed more. The legs, too, are often asymmetrical, but here, according to Martin, the left leg is usually the longer. Schreiner (1935), Sauser (1938), and Vogler (1962) find asymmetry in the femur on the right and the left side. Allen (1926) describes a more "advanced ossification" in the metacarpal bones, usually in the right hand of the right-handed. Pryor (1936), Schmid & Halden (1949), and Scheller (1960), however, find so insignificant a difference of ossification in children on the right and the left side (shoulders, hips, and knee joints) that it can be explained by a few persons with pathologic, subclinical changes being recorded in their large "normal material".

The difference found in the present investigation between right and left side must be taken into account when comparing the results of measurements of knee joints in different groups, and the same side must always be used for comparison.

3. *Dissimilarities between male and female.* Male and female show differences between them which, however, concern mainly the measured lengths: l, m, LC, and MC. l and m are statistically significantly higher in male, LC and MC are also, but for these latter, considerable reservation are valid, as earlier mentioned. The angles C_p, C_t, L, and M are mainly alike or show statistically very uncertain differences between male and female.

Thus, in the main, the distal femur end has the same form in female and male, but is somewhat more delicate in the female.

4. *For other results,* see Table 3. Normal values for l, m, C_p, L, and L+M are found also in col. 1 and 2 in "Definitions, Abbreviations . . ."

C. *Summary*

By my methods, 100 female and 100 male, without subjective difficulties and with apparently normal configuration regarding legs and knec joints, were examined roentgenologically.

Differences so pronounced exist between the right and the left side, as can be seen on the x-ray pictures of both male and female, that the two sides must be treated independently, and comparison between the patient material and the normal material must always be made on the same side. This difference seems to be due to changed torsion or rotation conditions.

Normally, differences also exist between male and female, the distal femur end in the female being more delicate than in the male. They are, in the main, similar and occupy the same skeletal position regarding rotation and torsion.

Age and body length do not appear to influence the given measure values.

For the results, see Table 3.

CHAPTER VII

The patient material. General description

A. *Composition of the material*

The intention with this investigation was to collect a patient material so large that certain roentgenological measurements could be made, arranged statistically, and compared with a normal material investigated under the same conditions. I have *not* aimed at any clinical follow-up series.

The material consists of patients who had been treated for recurrent dislocation of the patella in the orthopedic clinics in Lund, Malmö, Hälsingborg, and Kristianstad; at the Orthopedic Hospital in Copenhagen, and at KASG (Köpenhamns Amts Sygehus in Gentofte) during the years 1945 to 1961.

Swedish patients: All patients who had attended hospital as inpatients in Lund, Malmö, and Hälsingborg were recalled for examination, as well as the two male patients who had been inpatients at the Orthopedic clinic in Kristianstad since the clinic started about ten years ago. In order to get the *male* group large enough, I tried to get as many as possible by writing repeatedly to those I had not heard from after the first summons. I also included in the investigation two male outpatients who attended the Orthopedic clinic in Lund during the time of the investigation, both of whom were obvious operation cases. The female patients were usually recalled only once after the first summons. THE SEX PROPORTION IN MY MATERIAL IS THUS ARTIFICIAL. All patients from the Hälsingborg clinic are included in the clinical follow-up series published by Jerre & Knutsson (1958). Some of the patients from Lund are included in Ståhl's work concerning fractures at dislocation of the patella (1950).

The Swedish patient material thus included 53 female and 27 male, whom I examined both clinically and roentgenologically in 1962, using the methods described in Chapter V. Two female and two male patients were examined in the Roentgen-diagnostic clinic of the Karolinska Sjukhus; the others in the Orthopedic clinic and the Roentgen-diagnostic clinic II in Lund.

Danish patients: The patient material from Copenhagen differs somewhat from the Swedish. I based my investigations on Thestrup Andersen's material, see p. 13. In order to equate the age of this material to that of the Swedish, I took patients chiefly from the years 1945—51. Thus I examined ten female and nine male. To these I was able to add two female and three male treated by Thestrup Andersen after 1955 at KASG (Köpenhamns Amts Sygehus in Gentofte), and 16 female and 11 male, who since 1951 (after Thestrup Andersen had finished collecting his patient material) had been treated for recurrent dislocation of the patella in the Orthopedic Hospital in Copenhagen. Thus the Danish material contained 10+2+16=28 females and 9+3+11=23 males.

All patients in the Danish material, I personally examined clinically and roentgenologically (special pictures) in autumn 1962 in the x-ray department of the Orthopedic Hospital in Copenhagen.

The composition of the material appears in Table 4.

The Swedish patients, except for the two males already reported, have all been treated as *inpatients* in the respective clinics, and can be regarded as homogeneous material because the inpatient indications in the clinics, which have throughout had the same principals, have been largely uniform. The Danish material contains both *inpatients and outpatients.* Because the hospitalization and operation indications, accord-

TABLE 4

Number of patients, sex, and treatment clinic

	Lund	Malmö	Hälsingborg	Kristianstad	Copenhagen	Total
♀	38	12	3	—	28	81
♂	16	2	7	2	23	50
♀ + ♂	54	14	10	2	51	131

The sex proportion is artificial (see p. 87). The above figures are not representative of the number of patellar dislocations that have during 1945—60 been treated in the respective clinics.

ing to what I have found in records and from discussions with Danish colleagues, are largely the same as for the Swedish clinics, it is reasonable to assume that the Danish material includes some relatively mild cases. However, all of them fill my requirements according to the definition of recurrent dislocation of the patella. An expression of this is the operation frequency: in the Swedish material, only 18 out of 104 dislocated knees are not operated upon (=17 %) whereas in the Danish material, no less than 41 out of 75 dislocated knees have been left unoperated (=55 %).

The entire material thus contains 81 females and 50 males, and once again it must be pointed out that when collecting material I have made special efforts to expand the male material; therefore, the sex proportion in my total material is artificial.

The right knee in a female patient and one in a male patient has been partly excluded in the discussions. Because of severe deformans troubles, the female, who had a double-sided dislocation, had the right patella removed in 1955 and the left in 1957. Osteo-arthrotical changes so advanced existed on the right side that it was impossible to carry out any measurements on the x-ray picture with any degree of accuracy. This right knee is excluded from all discussions based upon measurements on the x-ray picture, but is found in those instances where the clinical information is the essential. The male patient had a severe rest-condition after polio in the right knee and dislocation of the patella in the left knee. His right knee has not been included in the x-ray measurements. It was atrophic and deformed, whereas the left seemed to be without any noticeable fault. His polio-damaged right knee is excluded from all tables and discussions, whereas the left is included in calculations based upon measurements on x-ray pictures, but not in those instances where clinical information and findings are a basis for ananlyzing the condition right—left.

B. *Different classifications of the patient material in the continued analysis*

The starting point for my investigation is the femoral dysplasia and its possible connection with the clinical picture. The following clinical factors have been analyzed regarding this connection and have been a basis for classifying or attempts at classifying the patient material into different groups.

A. Right—left—bilateral dislocation and the non-dislocation knee (Chapter VIII).
B. Age at onset, operation, and follow-up (Chapter IX).
C. Family occurrence of the condition (Chapter X).
D. Trauma (Chapter XI).
E. Patella alta (Chapter XII).
F. Dislocation frequency (Chapter XIII).
G. Prognosis (Chapter XIV).

The question of what importance the valgus position in the knee has for dislocation of the patella has been the object of several discussions, which have become completely dominated by the skeletal valgus position. However, as has been shown (see p. 30, ff.) it is the angle (called by me the Q-angle) occurring in the extensor mechanism that is important. Changes in this Q-angle can be due to, among other things, skeletal changes, changes of the origin and insertion of the muscles and of the ligaments, and some neuro-muscular damage with the balance in the quadriceps upset as a consequence. The question of, on one hand, the relation between the valgus position in the knee and the Q-angle, and on the other, the dislocation of the patella is considerably more complicated than what has so far been generally imagined. However, in my opinion, a more close analysis of these conditions lies beyond the scope of my investigation.

C. *Summary*

131 patients with recurrent dislocation of the patella (81 female and 50 male) have been collected from the orthopedic clinics in Southern Sweden and Copenhagen (Denmark) and examined roentgenologically and clinically.

At the further analysis of the femoral dysplasia different classifications of the patient material are used as basis, and the different principles of these classifications are reported.

CHAPTER VIII

Right-left-bilateral dislocations. The non-dislocating knee

A. *General classification according to the symptoms in each knee*

The patients were classified into unilaterally dislocating and bilaterally dislocating groups.

Unilateral dislocations

Right side or left—which has the greater tendency to dislocate? A low lateral condyle has been mentioned by many as one of the most usual causes of recurrent dislocation of the patella.

Some authors have also shown that among *unilateral* dislocations a certain predominance exists for the *left side*. Thus, Marion & Barcat (1950) report 54 per cent of about 300 unilateral dislocations on the left side; Thestrup Andersen (1955), 53 per cent of 201; Sjövall (1943), 69 per cent of 26; and, finally, Böhi (1957), 62 per cent of 30. The reported difference is, in every material considered independently, small or uncertain. However, as those authors (who with larger material reported unilateral dislocations as right or left side) *all* find a left side dominance, it gives the figures an increased importance.

In my *normal* material, a significant difference was shown between right and left side: the height of the lateral condyle above the sulcus bottom (l) was lower on the left side, whereas the medial height (m) was higher on the left side. The changes in the angles argue that this change was due to the left distal femur end standing rotated or torqued outwards, i.e. illusory dysplasia of the femur.

This assymetry could possibly explain the left-side dominance in recurrent dislocations of the patella that is pointed out by some authors. In order to investigate these conditions, I have classified the patient material into: 1. right-side dislocating, 2. left-side dislocating, and 3. bilateral dislocating, and have further analyzed these three groups. The classification is shown in Table 5.

TABLE 5

The patients classified according to luxating side
(One polio patient excluded from the material—see text)

	Number of patients			Number of luxating knees	
	Unilateral		Bilat.		
	dx	sin		dx	sin
♀	27	23	31	58	54
♂	17	15	17	34	32
♀ + ♂	44	38	48	92	86

The proportion given earlier of approximately one-third right, one-third left, and one-third bilateral dislocating agrees rather well. No predominance occurs for the left side among the unilaterally dislocating patients.

The non-dislocating knee. Rather pronounced troubles often occur in the unilaterally dislocating patients in the form of feelings of instability in the non-dislocating knee: a feeling that "it is about to collapse", "it feels as the other knee did before it went out of joint", and similar comments. These knees are here referred to as *unstable knees.*

Some patients are, subjectively, completely trouble-free in the non-dislocating knee. These are called *sound* knees. If the knee joints are classified according to these principles, the material appears as seen in Table 6.

The table shows that in 82 patients with unilateral dislocations no less than 30 (37 %) have troubles from the non-dislocating knee (9 right, 21 left).

Bilateral dislocations

In bilaterally dislocating patients, one can as a rule distinguish a dominant side, i.e. that which has usually dislocated more often and given more trouble. This side usually dislocated first. If the bilaterally dislocating patients are classified with regard to the dominant side and the onset side, the material appears as shown in Table 7.

One finds that in bilateral dislocations the left side dominates usually

TABLE 6

Total knee joints in the patient material (luxating or non-luxating) classified into the groups "luxating", "unstable", and "sound"
One male polio patient excluded. The sex proportion in the material is artificial

	Knees of patients luxating unilaterally									Knees of pat. luxating bilaterally			Total number of knees		
	Luxating			Unstable			"Sound"								
	dx	sin	total	dx	sin	total	dx	sin	total	dx	sin	total	dx	sin	total
♀	27	23	50	4	16	20	19	11	30	31	31	62	81	81	162
♂	17	15	32	5	5	10	10	12	22	17	17	34	49	49	98
♀ + ♂	44	38	82	9	21	30	29	23	52	48	48	96	130	130	260

nearly twice as often as the right; and more than twice as often it dislocates first.

These differences between right and left side are statistical probable (*).

TABLE 7

Dominant side and side of onset in 48 bilaterally luxating patients
The meaning of "dx=sin" is that both sides have been equally troublesome and began at about the same time

	48 patients luxating bilaterally					
	Dominant side			Side of onset		
	dx	sin	dx–sin	dx	sin	dx–sin
♀	9	15	7	4	10	17
♂	3	7	7	4	7	6
♀ + ♂	12	22	14	8	17	23

B. *Results of the measurments on x-ray pictures of right, left, and bilaterally dislocating patients*

The results of the measurements appear in Table 8 (common to female and male); 9, 10, 11, and 12 (female), and 13, 14, 15, and 16 (male).

Female and male: no change of rotation-torsion

In Table 8, the values of the dorsal condyle angle C_t are reported. No significant difference occurs in the dorsal condyle angle between normal material and different patients groups.

The posterior condyle plane (see p. 20) is, in the position that my patients assume, not horizontal. The femur is rotated inwards a few degrees (between 1.25 and 3.10 degrees). This concerns female as well as male, the normal material as well as patients with dislocation of the patella, and right as well as left side.

In the patient material a similar difference between right and left is seen as in the normal material: on the right side, C_t is throughout greater as a sign that the right femur stands more inwards rotated or inwards torqued than the left.

The rotation and torsion conditions are thus mainly the same for the normal material and the patient material, and *in case some differences have been indicated in the formation of the sulcus in patients with recurrent dislocation of patella, this is not due to changed torsion or rotation*, as maintained by several authors (Dreesmann 1908, Hübscher 1909, Lückerat 1919, Hohlbaum 1921, and Strube 1934).

Female

Column 5, Table 9, which concerns females with *unilateral right-side dislocations* shows that the mean value for l (i.e. the height of the lateral condyle above the sulcus bottom) is 2.15 ± 0.55 mm less than in the normal material, this difference is highy significant (***).

m is 1.85 ± 0.42 mm less (***), whereas C_p shows no significant change. Both L and L+M are larger in the dislocating knees: these differences are statistically highly significant (***).

These measurements show that the height of the condyles above the sulcus bottom is reduced in the dislocating knees. This results in an increase of the sulcus angle L+M. The reduction of the condyle height

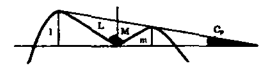
TABLE 8

Mean values for the dorsal condyle angle, C_t, in the normal material compared with different groups in the patient material, females and males

Col.		1	2		3 (1–2)	4		5 (1–4)	6		7 (1–6)	8		9 (1–8)
		Normal material	All knees in patient material	No	Diff. normal — all knees	All luxating knees	No	Diff. normal — luxating knees	Unstable knees	No	Diff. normal — unstable knees	"Sound" knees	No	Diff. normal — "sound" knees
♀	dx	2.63±0.22	2.76±0.26	80	−0.13±0.34	2.75±0.30	57	−0.12±0.37	2.50	4		2.84±0.55	19	−0.21±0.59
	sin	1.42±0.22	2.00±0.31	81	−0.58±0.38	2.25±0.36	54	−0.83±0.43	1.25±0.76	16	0.17±0.79	1.91±0.62	11	−0.50±0.66
♂	dx	3.09±0.21	2.88±0.32	49	0.21±0.38	3.03±0.41	34	0.06±0.46	1.40	5		3.10±0.53	10	−0.01±0.57
	sin	1.78±0.21	1.80±0.28	50	−0.02±0.35	1.97±0.38	33	−0.19±0.43	2.20	5		1.17±0.37	12	0.61±0.43

TABLE 9

Measured results of unilaterally luxating females
Comparison with the normal material. Mean values



Col.	1	2	3	4	5 (1–3)	6 (2–4)	7	8	9 (1–7)	10 (2–8)
	100 normal females		Unilat. (right) luxation		Diff. normal-unilat. (right) luxation		Unilat. (left) luxation		Diff. normal-unilat. (left) luxation	
	dx	sin	dx (27)	sin (27)	dx	sin	dx (23)	sin (23)	dx	sin
l	10.08±0.19	9.11±0.17	7.93±0.52	7.85±0.39	2.15±0.55***	1.26±0.43**	7.57±0.53	5.78±0.67	2.51±0.56***	3.33±0.69***
m	5.59±0.16	5.87±0.15	3.74±0.39	4.59±0.44	1.85±0.42***	1.28±0.46**	4.04±0.56	3.96±0.58	1.55±0.58**[1]	1.91±0.60***[1]
C_p	6.10±0.30	4.36±0.26	5.74±0.88	4.33±0.79	0.36±0.93	0.03±0.83	4.74±0.72	2.74±1.17	1.36±0.77	1.62±1.20
L	69.39±0.38	70.77±0.38	75.44±0.93	74.89±0.73	−6.05±1.01***	−4.12±0.82***	75.04±1.01	77.65±1.21	−5.65±1.08***	−6.88±1.27***
L+M	141.79±0.60	142.36±0.61	152.52±1.67	148.63±1.54	−10.73±1.77***	−6.27±1.66***	150.17±2.30	155.22±2.14	−8.38±2.38***[1]	−12.86±2.23***

[1] t-test lowers the significance by one star.

occurs uniformly, i.e. affects the lateral condyle and the medial proportionately, as is apparent from the fact that C_p is in the main unchanged.

Column 6 in the same table shows that also the *left (the non-dislocating)* knee, in these 27 females with only right-side dislocations, displays statistically significant changes of the same type as the right, except that they are somewhat less pronounced: l and m are less than normal, C_p is without significant difference, and L and L+M have increased.

The corresponding values in the females who showed *dislocations in only the left knee*, 23, are found in Table 9, col. 9 and 10. This shows that the knees have the same changes as those just described in the right-side dislocation (smaller l and m, larger L and M), and this refers to dislocating (left) knees (col. 10) as well as non-dislocating (right) knees (col. 9).

The group non-dislocating knee (see Table 6) can be classified into *unstable* knees and *sound knees*; "sound knees" means knee joints which to the patients have, subjectively, been completely trouble-free, and in which there has never been any feeling of instability.

The measured values of these "sound" knees in 30 females (19 right side, 11 left) were analyzed and compared with those of the normal material. The results can be seen in Table 10.

Statistically significant differences in all reported magnitudes are found on the right side (col. 5), except for m and C_p where the change is probable and not significant, respectively. A check of the significance by the t-test gives the same significance for all values. This means that l, as well as m, is less than normal in the completely trouble-free right knee in these left-side dislocating patients; l seems to have reduced proportionally somewhat more than m. The lateral sulcus angle L and the total sulcus angle L+M have increased.

On the left side, there are only 11 completely trouble-free knees in right-side dislocating patients. Here the changes are less pronounced, and the group is smaller. The tendency is the same (col. 6, Table 10) as for the 19 "sound" right knees; however, it is only when is concerns L and L+M that the difference becomes statistically probable (*). The t-test gives the same result.

In Table 11 are found the *comparison values partly for the bilaterally dislocating knees (col. 5/6), partly for all dislocating right knees* (uni-

TABLE 10

Comparison of the measured results for normal material, on one hand, and "sound" (subjectively trouble-free) knees in unilaterally luxating females, on the other
Mean values

Col.	1	2	3	4	5 (1–3)	6 (2–4)
	100 normal females		"Sound" knees in unilat. luxating females		Diff. normal — "Sound" females	
	dx	sin	dx (19)	sin (11)	dx	sin
l	10.08±0.19	9.11±0.17	7.68±0.62	8.18±0.59	2.40±0.65***	0.93±0.61
m	5.59±0.16	5.87±0.15	4.16±0.67	5.00±0.62	1.43±0.69*	0.87±0.64
Cp	6.10±0.30	4.36±0.26	4.84±0,84	4.27±1.23	1.26±0.89	0.09±1.26
L	69.39±0.38	70.77±0.38	74.79±1.19	73.82±1.33	−5.40±1.25***	−3.05±1.38*
L+M	141.79±0.60	142.36±0.61	149.21±2.69	146.73±1.96	−7.42±2.76**	−4.37±2.05*

lateral right dislocations plus right knees in the bilateral dislocations—col. 9), *and partly for all dislocating left knees* (unilateral left dislocations plus left knees in bilateral dislocations—col. 10).

The bilateral dislocations (col. 5/6) show highly significant changes: l is fully 3.5 mm less, m nearly 2.5 mm less in the dislocating knees than in the normal material; L and L+M have increased strongly. The changes are of the same type and magnitude in both sides.

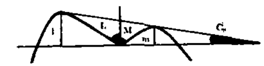
In column 3, Table 12, I have compared column 3, Table 9 (right side in unilateral right dislocations) with column 3, Table 11 (right side in bilateral dislocation) and find that the latter show more pronounced dysplastic changes, but the difference is statistically uncertain.

The same tendency is found (col. 6, Table 12) if a corresponding comparison is made for the left side (left side in unilateral left dislocation compared with left side in bilateral dislocation).

In column 4, Table 12, I have compared the left, non-dislocating knee in unilateral right dislocating females (col. 4, Table 9) with the left

TABLE 11

Measured results of females luxating bilaterally and bilaterally/unilaterally
Comparison with the normal material. Mean values



Col.	1	2	3	4	5 (1–3)	6 (2–4)	7	8	9 (1–7)	10 (2–8)
	100 normal females		Bilat. luxations		Diff. normal — bilat. luxations		All luxating knees (unilat. or bilat.)		Diff. normal — all luxating knees	
	dx	sin	dx (30)	sin (31)	dx	sin	dx (57)	sin (54)	dx	sin
l	10.08±0.19	9.11±0.17	6.47±0.66	5.39±0.45	3.61±0.68***	3.72±0.48***	7.16±0.43	5.56±0.38	2.92±0.47***	3.55±0.42***
m	5.59±0.16	5.87±0.15	3.33±0.35	3.42±0.32	2.26±0.38***	2.45±0.35***	3.53±0.26	3.65±0.31	2.06±0.30***	2.22±0.34***
p	6.10±0.30	4.36±0.26	4.40±0.88	2.81±0.65	1.70±0.93	1.55±0.70*	5.04±0.62	2.78±0.62	1.06±0.69	1.58±0.67*
L	69.39±0.38	70.77±0.38	77.47±1.22	79.23±0.98	−8.08±1.28***	−8.46±1.05***	76.51±0.78	78.56±0.76	−7.12±0.87***	−7.79±0.85***
L+M	141.79±0.60	142.36±0.61	153.33±2.14	155.97±1.64	−11.54±2.22***	−13.61±1.75***	152.95±1.37	155.65±1.30	−11.16±1.50***	−13.29±1.44***

TABLE 12

Comparison of measured results (mean values) of unilaterally luxating females, on one hand, and bilaterally luxating, on the other

Col.	3	4	5	6
	Diff. between unilateral (right) luxation and bilateral		Diff. between unilateral (left) luxation and bilateral	
	dx	sin	dx	sin
l	1.46±0.84	2.46±0.60***	1.10±0.85	0.39±0.81
m	0.41±0.52	1.17±0.54*	0.71±0.66	0.54±0.66
C_p	1.34±1.24	1.52±1.02	0.34±1.14	−0.07±1.34
L	−2.03±1.53	−4.34±1.22***	−2.43±1.58	−1.58±1.56
L+M	−0.81±2.71	−7.34±2.25**	−3.16±3.14	−0.75±2.70

knee in bilaterally dislocating (col. 4, Table 11). We see that despite the left (non-dislocating) knee's having pronounced dysplastic changes, it differs significantly from the left knee in bilaterally dislocating patients; the latter having even more pronounced dysplasia.

A corresponding investigation (col. 5, Table 12) for the right non-dislocating knee in unilateral left dislocating females (col. 7, Table 9) compared with the right knee in bilaterally dislocating (col. 3, Table 11) shows the same tendency, but the differences are non-significant.

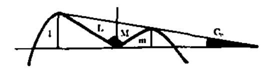
Male

Tables 13, 14, 15, and 16 show the measured results for the *male patients*. The male-patient material is not so large as the female; therefore, mean errors are somewhat larger.

In column 5, Table 13 (i.e. right knee in *unilateral right dislocating patients* compared with the normal material) the same changes are observed as in the corresponding female group: l and m have reduced

TABLE 13

Measured results of unilaterally luxating males
Comparison with the normal material. Mean values



Col.	1	2	3	4	5 (1–3)	6 (2–4)	7	8	9 (1–7)	10 (2–8)
	100 normal males		Unilat. (*right*) luxation		Diff.normal-unilat. (right) luxation		Unilat. (left) luxation		Diff. normal-unilat. (left) luxation	
	dx	sin	dx (17)	sin (17)	dx	sin	dx (15)	sin (16)	dx	sin
l	11.60±0.18	10.66±0.20	6.94±0.60	8.06±0.68	4.66±0.63***	2.60±0.71***[1]	8.93±0.57	8.00±0.61	2.67±0.60***	2.66±0.64***[1]
m	6.40±0.16	7.33±0.18	4.24±0.53	5.18±0.50	2.16±0.55***[1]	2.15±0.53***[1]	4.93±0.40	4.38±0.29	1.47±0.43***[1]	2.95±0.34***
C_p	5.95±0.26	3.83±0.30	3.35±0.90	3.29±0.75	2.60±0.94**[1]	0.54±0.81	5.00±0.68	4.19±0.87	0.95±0.73	−0.36±0.92
L	69.31±0.35	70.68±0.35	77.18±1.06	75.88±1.22	−7.87±1.12***	−5.20±1.27***[1]	73.80±1.08	75.31±1.34	−4.49±1.14***[1]	−4.63±1.39***[1]
L+M	142.78±0.51	141.90±0.54	154.24±2.07	149.94±2.16	−11.46±2.13***	−8.04±2.23***[1]	149.33±1.65	151.06±1.50	−6.55±1.73***[1]	−9.16±1.59***

[1] t-test lowers the significance by one star.

highly significantly (***), L and L+M have increased. The decrease in the male patients of C_p (statistically significant) as appears in Table 13 was, however, only hinted at in the female material.

The *non-dislocating knee* is in the males the seat of dysplastic changes (col. 6, Table 13), highly significant, but not so fully pronounced as on the dislocating side.

It is seen in columns 9 and 10, Table 13, that the same condition as already described for the unilaterally right dislocating patients also refers to the *unilaterally left dislocating patients*, i.e. both the dislocating and the non-dislocating knee are seats of dysplastic changes.

As in the female patient material the *"sound" male knees*, i.e. those non-dislocating knees that are, subjectively, completely trouble-free, have been assembled, and the measured values have been compared with the normal material. This concerns 10 "sound" right knees in left dislocating patients and 12 "sound" left knees in right dislocating patients. The results appear in Table 14.

TABLE 14

Comparison of the measured results for normal material, on one hand, and "sound" (subjectively trouble-free) knees in unilaterally luxating males, on the other
Mean values

Col.	1	2	3	4	5 (1–3)	6 (2–4)
	100 normal males		"Sound" knees in unilat. luxating males		Diff. normal — "sound" males	
	dx	sin	dx (10)	sin (12)	dx	sin
l	11.60±0.18	10.66±0.20	9.00±0.68	8.08±0.87	2.60±0.70***[1]	2.58±0.89**
m	6.40±0.16	7.33±0.18	4.70±0.50	5.25±0.53	1.70±0.53***[1]	2.07±0.56***[1]
Cp	5.95±0.26	3.83±0.30	5.30±0.78	3.25±0.97	0.65±0.82	0.58±1.01
L	69.31±0.35	70.68±0.35	74.00±1.38	75.33±2.13	−5.69±1.50***[1]	−4.65±2.16*
L+M	142.78±0.51	141.90±0.54	149.80±2.36	149.25±2.92	−7.02±2.41**	−7.35±2.97**

[1] t-test lowers the significance by one star.

On the right side (col. 5) a clear difference exists: l, m, and L show a highly significant difference (***) and also L+M (**) whereas C_p shows no significant difference. t-test reduced the three-star significance to two-star, but has no effect upon the two star.

Also on the left side where there are 12 "sound" knees in right-side dislocating males, the "sound" side is the seat of dysplastic changes (col. 6).

Columns 5 and 6, Table 15, show that the dysplastic changes in the *bilaterally dislocating male patients* are statistically significant.

In Table 16 the measured values of the unilaterally dislocating males are compared with the corresponding values of the bilaterally dislocating. Between the dislocating knees in the two groups (col. 3 and 6, Table 16) no significant differences exist, and the tendency is not uniform. As in the female patients, the non-dislocating knee is somewhat less dysplastic than the corresponding dislocating knee (col. 4/5, Table 16) but the differences are non-significant.

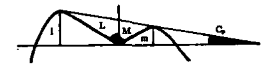
TABLE 16

Comparison of measured results (mean values) of unilaterally luxating males, on one hand, and bilaterally luxating, on the other

Col.	3	4	5	6
	Diff. between unilat. (right) luxation and bilateral		Diff. between unilat. (left) luxation and bilateral	
	dx	sin	dx	sin
l	−0.94±1.12	1.06±1.10	1.05±1.11	1.00±1.05
m	−0.70±0.95	−0.11±0.81	−0.01±0.89	−0.91±0.70
C_p	−0.36±1.25	0.82±1.35	1.29±1.10	1.72±1.42
L	1.30±2.07	−1.65±2.02	−2.08±2.08	−2.22±2.10
L+M	3.65±4.38	−1.35±3.63	−1.26±4.20	−0.23±3.29

TABLE 15

Measured results of males luxating bilaterally and bilaterally/unilaterally
Comparison with the normal material. Mean values



Col.	1	2	3	4	5 (1–3)	6 (2–4)	7	8	9 (1–7)	10 (2–8)
	100 normal males		Bilat. luxations		Diff. normal — bilat. luxations		All luxating knees (unilat. or bilat.)		Diff. normal — all luxating knees	
	dx	sin	dx (17)	sin (17)	dx	sin	dx (34)	sin (33)	dx	sin
l	11.60±0.18	10.66±0.20	7.88±0.95	7.00±0.86	3.72±0.97***	3.66±0.88***	7.41±0.56	7.49±0.53	4.19±0.59***	3.17±0.57***
m	6.40±0.16	7.33±0.18	4.94±0.79	5.29±0.64	1.46±0.81*	2.04±0.67**	4.59±0.47	4.85±0.36	1.81±0.50***	2.48±0.40***
Cp	5.95±0.26	3.83±0.30	3.71±0.87	2.47±1.12	2.24±0.91*	1.36±1.16	3.53±0.62	3.30±0.72	2.42±0.67***	0.53±0.78
L	69.31±0.35	70.68±0.35	75.88±1.78	77.53±1.61	−6.57±1.81***	−6.85±1.65***	76.53±1.03	76.46±1.05	−7.22±1.09***	−5.78±1.11***
L+M	142.78±0.51	141.90±0.54	150.59±3.86	151.29±2.92	−7.81±3.89*	−9.39±2.97***[1]	152.41±2.18	151.18±1.65	−9.63±2.24***	−9.28±1.74***

[1] t-test lowers the significance by one star.

For all groups of dislocating knees, it has thus been demonstrated that the height of the lateral condyle above the sulcus (l) is lower than normal, and that the height of the medial condyle (m) is also lower. As a consequence of this, the angles L and L+M are larger. The anterior condyle angle, C_p, is throughout somewhat lower in dislocated knees, but the reduction is in every group statistically uncertain, except regarding "all dislocations in the right knee" in males (unilateral+bilateral) where the difference between the normal material and the patient material is 2.42 ± 0.67 (***) (col. 9, Table 15).

The femoral dysplasia of these *dislocating knees* is real. But also the *non-dislocating knees* show pronounced dysplastic changes. Dysplasia is a predisposing factor, usually to be found bilaterally. It is not secondary to the dislocation and from the insurance point of view this fact is of importance.

All changes reported now can be due to the lateral condyle and the medial really having become smaller; that the ventro-dorsal extension has reduced. When, in the literature, relevant problems are discussed, expressions like "maldeveloped", "aplastic", "dysplastic", "worn down", "pressure necrosis", "obstruction deformity", and so on, are used about the lateral condyle, all expressions suggesting that there might be a real decrease in the extension of the condyle.

Those measurements reported so far in Chapter VIII are related to the sulcus bottom. Probably most other authors have, more or less consciously, done the same in their estimations of the height of the lateral condyle on axial pictures, although this is not usually mentioned in the text.

However, theoretically the same changes can be thought to appear if the bottom of the sulcus is raised. Naturally, a combination of real decrease in the extension of the condyle and raising the bottom of the sulcus can also explain the changes. Fig. 26.

In order to get an idea of how this happens, tomography of the distal femur end taken laterally might be of value. Also lateral pictures, whereon one can with certainty decide which is the lateral condyle and which the medial, provide some information if normal material is available for comparison.

I have attempted by calculating the distances LC and MC (see Chapter V, p. 71) to get some idea of these problems. These distances are

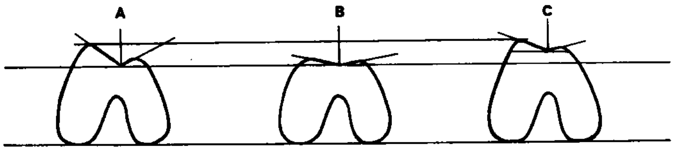


Fig. 26. This shows how the same changes in l, m, C_p, L, and L+M can arise, either by an actual lowering of the height of the condyles above the sulcus bottom (B) or by raising the sulclus bottom (C). A = normal conditions.

approximate, and the approximation is partly of uncertain magnitude; therefore, they ought to be appraised with the greatest care.

Table 17 shows LC and MC partly in the normal material, partly for all dislocating right knees (unilateral+bilateral), and partly for all dislocating left knees (unilateral+bilateral) in females. Table 18 shows the same thing in males.

Column 5 and 6 in the respective tables show that the mean for both LC and MC is significantly (**) or highly significantly (***) greater in the dislocated knees; this refers to both males and females. (Exception: On the right side, the difference between the normal material and the dislocated knees concerning LC is in males statistically probable (*)).

LC and MC are approximate expressions and must be appraised most carefully. Because the differences are of the just-reported magnitude, I, however, consider it justified to say that my investigations argue against the idea that the lowering in the height of the condyles above the bottom

TABLE 17

The extension of lateral and medial condyle ventro-dorsally expressed by LC and MC (see p. 71) in normal and in luxating knees
Mean values females. LC=lateral condyle, MC=medial condyle

Col.	1	2	3	4	5(1–3)	6(2–4)
	100 normal females		All luxating knees of respective sides		Diff. normal — luxating knees	
	dx	sin	dx (57)	sin (54)	dx	sin
LC	65.26±0.79	65.93±0.88	73.79±2.16	73 02±1.68	−8.53±2.30***	− 7.09±1.89***
MC	63.66±0.77	64.08±0.83	73.18±2.08	74.20±1.77	−9.52±2.22***	−10.12±1.96***

TABLE 18

Same as Table 17
Mean values for males

Col.	1	2	3	4	5(1–3)	6(2–4)
	100 normal males		All luxating knees of respective sides		Diff. normal — luxating knees	
	dx	sin	dx (34)	sin (33)	dx	sin
LC	71.98±0.74		77.59±2.52		−5.61±2.63*	
		72.22±0.77		78.21±2.19		−5.99±2.32**
MC	70.49±0.72		78.32±2.50		−7.83±2.60**	
		70.71±0.73		78.06±2.31		−7.35±2.42**

of the sulcus, which can be established in patients with recurrent dislocation of the patella, has been brought about by a real reduction of the ventro-dorsal extension of the condyles, and also argue that this levelling between the contours is brought about by the raising of the sulcus bottom.

C. *Summary*

About one-third of the 130 patients had bilateral dislocations; one-third had right side; one-third had left side. Of 82 patients with unilateral dislocations, 30 (37 %) had troubles with the non-dislocating knee in the form of feelings of instability. In the bilaterally dislocating patients, the left side is dominant (shows more symptoms) more often (12 right, 22 left, 14 both) and is usually also the side where the trouble starts (8 right, 17 left, 23 both).

In the actual x-ray investigation position, the distal femur end occupies mainly the same rotation or torsion position in patient material as in normal material. The same tendency of the right femur to increased inwards rotation or torsion as seen in the normal material is also seen in the patient material. In the dislocating knees of the *female* patients both the lateral and the medial condyle have reduced in height above the bottom of the sulcus (l and m have reduced on the dislocating side), L and L+M increased, whereas C_p shows no statistical change.

The dysplastic changes of the dislocating knee are more pronounced if the patient dislocates bilaterally than if he does so unilaterally, but the difference is statistically non-significant.

The non-dislocating knee in the unilaterally dislocating shows significant dysplastic changes, and even if only the completely trouble-free knee joints are taken into account, these, too, show significant dysplastic changes.

In most instances, similar changes are seen in the *male* patient material, but because this is smaller, the statistical significance becomes less.

The possibility is discussed that these changes are not due to an actual reduction of the extension of the condyles in ventro-dorsal direction, but to a relative raising of the sulcus bottom.

CHAPTER IX

Age at onset, operation, and follow-up investigation (With special reference to the difference between the right and the left side)

A. *General clinical appraisal*

Age of onset

The mean age of the patients at the first dislocation in the respective knee in different groups is reported in Table 19.

The table shows, among other things:

1. The mean age of the first dislocation in unilaterally dislocating patients is 16.4 years for females and 16.3 for males; in the bilaterally dislocating, the first dislocation occurs at age 13.3 and 16.4 years, respectively.

2. The onset of the condition in the patient, irrespective of whether it later becomes bilateral, occurs in females at age 15.2 years and in males at age 16.3.

This is a somewhat higher age of onset than is usually indicated. Thus, Marion & Barcat, without separating females and males, make a classi-

TABLE 19

Mean age at first luxation in respective knee in all patients

		Unilateral luxation			Bilateral luxation				Age at onset. All patients
		dx	sin	dx+sin	1st knee	2nd knee	dx	sin	
♀	No.	27	23	50	31	31	31	31	81
	Mean age	16.8	15.9	16.4	13.3	18.0	16.9	14.4	15.2
	Range	10–38	9–24	9–38	6–22	8–50	6–50	8–35	6–50
♂	No.	17	16	33	17	17	17	17	50
	Mean age	16.3	16.3	16.3	16.4	19.5	17.8	18.1	16.3
	Range	10–21	5–26	5–26	1–29	1–40	1–34	1–40	1–40

fication according to the age of onset with two peaks corresponding to age 5 years and 15 years. Thestrup Andersen finds the mean age for females to be 14.2 years and for males, 17.6 (10 females and 9 males are the same in the material of Thestrup Andersen as in that of mine).

3. In bilateral dislocations, the onset age in females for the left knee is lower than for the right knee: 14.4 and 16.9, respectively. This difference is statistically suggestive but uncertain (2.5 ± 1.7 years).

Age at operation

Table 20 shows the age at operation for the different patient categories, and also that the operation age of the males is throughout somewhat lower than that of the females.

Of greater interest is the interval between the onset and the operation. Table 21 shows, among other things, that the interval between age at onset and operation is about 9 years in females, compared to about 6 years in males. The explanation of this difference, using the evidence from my material, can only be conjectural.

Thestrup Andersen in his material has found the same tendency, even though, instead, he reports the interval between the first dislocation and the first visit to the doctor. He finds that females wait on average 8.3 years before they visit the doctor, and males 5.6 years. He proffers no explanation for this difference between the sexes.

Table 21 shows also that both males and females seem to go a longer time with the condition in the left knee than in the right.

TABLE 20

Mean age of patient at time of operation in resp. knee

		Unilateral luxations			Bilateral lux. Bilateral op.		Bilat. lux. & unilat. op.
		dx	sin	dx+sin	1st knee	2nd knee	
♀	No.	20	17	37	13	13	13
	Mean age	23.3	25.6	24.4	21.4	25.4	22.2
♂	No.	15	12	27	7	7	4
	Mean age	20.5	23.0	21.6	21.1	23.4	27.8

TABLE 21

Interval between onset and operation in resp. knee
Mean values

		Unilateral luxations			Bilateral lux. Bilateral op.		Bilat. lux. & unilat. op.
		dx	sin	dx+sin	1st knee	2nd knee	
	No.	20	17	37	13	13	13
♀	Mean values	7.6	10.1	8.8	8.6	9.9	9.7
	Range	0–20	0–28	0–28	0–33	0–33	0–31
	No.	15	12	27	7	7	4
♂	Mean values	4.1	6.9	5.3	5.5	6.7	7.8
	Range	0–10	0–32	0–32	0–20	0–24	0–23

Age at follow-up investigation

Table 22 shows the age at the follow-up investigation in all patients. Apart from a remarkable difference, hard to explain, between the age of unilateral left dislocations in females and in males (35.2 and 28.8 years, respectively) no greater differences are found. The mean age of the female patients was, at the follow-up investigation, 34.6 years and of males 32.2 years.

TABLE 22

Mean age at follow-up investigation
All patients

		Unilateral luxations		Bilat. lux.	Total patients
		dx	sin		
	No.	27	23	31	81
♀	Mean age	32.9	35.2	35.5	34.6
	Range	15–34	19–60	15–74	15–74
	No.	17	16	17	50
♂	Mean age	34.0	28.8	33.6	32.2
	Range	14–50	18–60	23–60	14–60

TABLE 23

Interval between operations in resp. knee and follow-up investigation
Mean values

		Unilateral luxations			Bilat. lux.
		dx	sin	dx+sin	dx+sin
♀	No.	20	17	37	39
	Mean values	8.9	5.9	7.5	10.5
	Range	1–20	1–16	1–20	0–29
♂	No.	15	12	27	18
	Mean values	11.7	7.3	9.8	8.7
	Range	1–21	0–24	0–24	3–14

Observation period

Table 23 shows the time between operation and follow-up investigation, the so-called observation period, for all operated patients. For females this averages 9 years; for males, 9.3 years.

Only patients with an observation period of more than two years have been included in the report (see Chapter XIV) concerning the relation between the treatment results and the femoral dysplasia.

B. *Measurements on the x-ray pictures*

Onset before and after age 16 (17) years

It is reasonable to expect that patients with pronounced dysplasia have an earlier age of onset of dislocation of the patella than those with less pronounced dysplasia.

I have divided the female patient material into two groups: onset of the condition before and after age 16 years; and the male correspondingly, but in the latter I have set the limit at age 17 years in order to get the groups more commensurate. In bilaterally dislocating patients, the age of onset in the first knee has been the determining factor. The patient material is distributed according to the following:

	Females	Males
Onset before age 16 (17)	54	27
Onset after age 16 (17)	27	23

TABLE 24

Comparison of measured results for all knees (luxating or non-luxating) in female patients where the condition began after and before age 16 years
Mean values

Col.	3	4	5	6	7 (3–5)	8 (4–6)
	All knees of patients where condition began after age 16		All knees of patients where condition began before age 16		Diff. "after age 16" — "before age 16"	
	dx (27)	sin (27)	dx (53)	sin (54)	dx	sin
l	8.33±0.38	7.41±0.49	6.74±0.47	5.78±0.39	1.59±0.60**	1.63±0.63**
m	4.41±0.39	5.07±0.42	3.30±0.30	3.41±0.34	1.11±0.49*	1.66±0.54**
C_p	5.37±0.64	3.37±> 0.26	4.74±0.68	3.26±> 0.26	0.63±0.93	0.11±> 0.39
L	73.93±0.68	75.26±0.92	77.19±0.85	78.37±0.71	−3.26±1.09**	−3.11±1.16**
L+M	148.78±1.37	149.40±1.41	153.87±1.59	155.26±1.34	−5.09±2.10**	−5.86±1.94**

The measured results are reported in Table 24 (females) and in Table 25 (males), and the difference between "late-onset" patients and "early-onset" patients is calculated.

In the females, significant or probable differences are seen (col. 7/8, Table 24) on the right side as well as on the left: l and m are greater in "late onset" patients than in "early onset" patients, L and L+M are less.

In the males, all values go in the same direction as in females, but here the differences are non-significant (col. 7/8, Table 25).

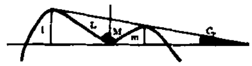
C. *Summary*

In the patient material reported here, the recurrent dislocation of the patella has its onset in females at age 15.2 years, in males at 16.3 years.

TABLE 25

Comparison of measured results for all knees (luxating or non-luxating) in male patients where the condition began after and before age 17 years

Mean values



Col.	3	4	5	6	7 (3–5)	8 (4–6)
	All knees of patients where condition began after age 17		All knees of patients where condition began before age 17		Diff. "after age 17" — "before age 17"	
	dx (23)	sin (23)	dx (26)	sin (27)	dx	sin
l	8.57±0.47	7.91±0.44	7.27±0.68	7.48±0.66	1.30±0.83	0.43±0.79
m	4.91±0.46	5.17±0.41	4.50±0.50	4.78±0.41	0.41±0.68	0.39±0.58
C_p	4.48±0.69	3.26±> 0.30	3.54±0.68	3.33±> 0.30	0.94±0.97	−0.07±> 0.45
L	74.39±0.82	76.26±> 0.38	76.85±1.30	76.26±0.38	−2.46±1.54	0
L+M	150.13±1.92	149.87±1.21	152.65±2.80	151.52±2.20	−2.52±3.40	−1.65±2.51

The interval between onset and operation is longer for females than for males.

The interval between onset and operation is longer for the left knee than for the right. This applies to both females and males.

The mean age at the follow-up investigation was 34.6 years (females) and 32.2 years (males).

Patients in whom the condition has an early onset—for females before age 16 years, for males before age 17 years—showed on the x-ray picture more pronounced dysplastic changes than those whose onset occurred after the age mentioned. The difference is significant in females and non-significant in males.

CHAPTER X

Family occurrence

As mentioned in Chapter III, several authors have stated that recurrent dislocation of the patella often exists in or has been found among the patient's relatives.

Bauer & Göttig (1936) have assembled from the literature 18 genealogical trees of families with dislocation of the patella, where in some instances they have been able to trace the condition for five generations. They consider the predisposition to dislocation of the patella to be dominantly hereditary, with a stronger penetrance factor in the female side, because of, among other things, the physiologically greater genu valgum.

Also in the genetic text-book of Touraine (1955) and Just (1940) the predisposition is considered to be dominantly hereditary. Bauer & Göttig are of the opinion that extremely few instances of recurrent dislocation of the patella are clearly traumatically conditioned, by far the most are congenital, which, in turn, is due to inherited tendencies. Bauer & Göttig establish the following criteria for the diagnosis congenital dislocation of the patella: 1) low onset age; 2) bilateral dislocation; 3) no or only slight initial trauma; 4) family occurrence of the condition; 5) x-ray changes in the knee joint (genu valgum, low lateral condyle, small and thick patella); 6) other congenital joint or bone changes occurring at the same time, such as dislocation of the hip, deformity of the foot, dislocation of the radius, dislocation of the shoulder, and above all, a general hypermobility in all joints. The dislocation of the patella is, according to these authors, often only the most dramatic manifestation of a general malady of the joints.

Marion & Barcat (1950) find dislocations in relatives of seven per cent of their patients, without having specially investigated this detail; Thestrup Andersen, who has directed attention to this matter, finds such an occurrence in 20 to 25 per cent among parents, siblings, or children. Thestrup Andersen thinks along the same lines as Bauer & Göttig and has in ten per cent of his approximately 300 patients found other congenital deformities (flatfoot, clubfoot, contractions, general laxness in the joints, etc.). He believes that a thorough investigation of patients with recurrent dislocation of the patella might disclose several non-symptom producing deformities.

Carter & Sweetnam (1960) have asked 111 patients with recurrent dislocation of patella wether they had relatives with joint troubles. This enquiry revealed 10 relatives suffering from patella dislocations.

All my patients have been asked whether they know of any occurrence of "the kneecap jumping out of joint" among their close relatives (children, siblings, cousins, nephews, nieces, parents, grandparents, aunts, uncles). Several patients have replied that relatives within that bracket have suffered from that condition. In cases of doubt, where the patient has not been absolutely certain, I have written and asked the relative concerned or studied the records.

TABLE 26

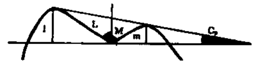
Comparison between all knees (luxating or non-luxating) in patients without and with positive family anamnesis

Mean values for females

Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Patients with luxation (unilat. or bilat.) without pos. family anamnesis		Patients with luxation (unilat. or bilat.) with pos. family anamnesis		Diff. "without pos." —"with pos." family anamnesis	
	dx (59)	sin (59)	dx (21)	sin (22)	dx	sin
l	7.36±>0.19	6.51±0.35	7.05±0.74	5.82±0.62	0.31±>0.74	0.69±0.71
m	3.88±0.50	4.12±0.31	3.09±0.35	3.55±0.42	0.79±0.61	0.57±0.52
C_p	4.83±>0.30	3.42±>0.26	5.29±1.06	2.95±1.10	−0.46±>1.06	0.47±>1.10
L	75.76±>0.38	76.88±0.70	77.00±1.24	78.55±1.04	−1.24±>1.24	−1.67±1.25
L+M	151.14±0.97	152.22±1.32	155.00±1.74	156.23±1.48	−3.86±1.98	−4.01±1.98 *

TABLE 27

Same as Table 26
Mean values for males



Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Patients with luxation (unilat. or bilat.) without pos. family anamnesis		Patients with luxation (unilat. or bilat.) with pos. family anamnesis		Diff. "without pos." — "with pos." family anamnesis	
	dx (39 st)	sin (40 st)	dx (10 st)	sin (10 st)	dx	sin
l	7.72±0.49	7.43±0.49	8.50±0.75	8.70±0.60	− 0.78±0.90	− 1.27±0.78
m	4.87±0.39	5.05±0.32	4.00±0.58	4.60±0.64	0.87±0.70	0.45±0.72
C_p	3.54±0.54	2.90±0.63	5.70±0.68	4.90±0.67	− 2.16±0.87 *	− 2.00±0.92*
L	75.85±> 0.35	76.50±0.93	75.10±1.48	75.30±0.55	0.75±> 1.48	1.20±1.08
L+M	151.31±> 0.51	150.78±> 0.54	152.10±3.21	150.70±> 0.54	− 0.79±> 3.21	0.08±> 0.81

In this way, 22 females and 10 males proved to have a family occurrence of the condition (24 %). (None of these 32 patients are included in Thestrup Andersen's material.)

These 22 females and 10 males with positive family anamnesis have been more closely examined with regard to Bauer & Göttig's criteria.

Bilateral dislocations occurred in 11 of the 32 patients with family occurrence of the condition. This is the usual proportion, i.e. about one-third of the entire material.

The *age of onset* is for females 13.6 years and for males 16.5, compared with 15.2 and 16.3, respectively, for all patients. This lower age of onset for females with family occurrence of the condition is statistically uncertain.

Concerning *trauma*, the reader is referred to Chapter XI.

The *dysplastic changes* are shown in Table 26 (females) and 27 (males). It appears from columns 7 and 8 in Table 26 that l and m are smaller and L and L+M are larger in females with positive family anamnesis, but the differences are statistically uncertain. Only for L+M on the left side is the limit "probable significant (*)" reached, but t-test gives lower value and no significance.

For the male patients (Table 27) the tendency is rather irregular, and the small material (10) makes it too hazardous to draw any conclusions.

Summary

Of my 131 patients, 32 (24 % — 22 females and 10 males) reported that a close relative had suffered recurrent dislocation of the patella. The 22 female patients with positive family anamnesis showed somewhat more pronounced dysplasia than the other patients, but this difference is statistically uncertain.

In the small group of male patients (10) tendencies are uncertain, and the smallness of the material permits no conclusions.

CHAPTER XI
Trauma

Trauma as an etiologic element has earlier played a big role in the discussions of recurrent dislocation of the patella. The classification into congenital and acquired dislocations is one of the most generally accepted, and in the latter group, the so-called traumatic dislocations have been dominant. However, in recent years, one has become increasingly aware of the difficulty in maintaining the borders between these two groups. This is partly due to the difficulty in defining the concepts congenital and traumatic in precisely this condition, and partly due in most instances to a *combination* of congenital factors and trauma giving rise to the dislocation. Nikolai (1960) has indicated the difficulties these determinations give rise to from the point of view of insurance.

In the material presented here, no so-called traumatic single dislocations are included, which Thestrup Andersen, for instance, finds in 13 of his 315 patients. He finds a further 59 "acquired" dislocations, six being permanent (status after polio, large cicatrizations after extensive operations, or trauma on soft parts) and three bilateral dislocations. These three patients had, concerning both knees, stated as cause violent direct assault at the initial dislocation, and Thestrup Andersen found no dysplastic changes on the x-ray pictures. Of the remaining 47 unilateral dislocations, four were judged to be caused by recurrent hydrops, whereas no less than 43 were considered to be caused by direct or indirect violence. In 14 of these, Thestrup Andersen finds slight dysplastic changes on the x-ray pictures, but points out the difficulties in determining these, because one moves on the border between the normal and the pathologic.

In my patient material, I have tried to focus interest upon those who have suffered a clear and unmistakable, violent action against the knee. I have not been able to introduce more than 5 females and 13 males (as expected, more males than females).

Of these patients, 1 female and 3 males dislocated bilaterally. None of these bilaterally dislocating patients have reported a trauma to *both* knees. If one, therefore, excludes these patients, 4 females and 10 males remain. Of the 4 thus excluded, 3 had, moreover, a family anamnesis.

The measured results for these 14 patients are reported in Table 28 A and B. It is remarkable that nine of the ten males have unilateral right dislocations (Is the right leg more exposed to trauma?).

As far as can be judged from the small material, dysplastic values exist. Thus, the sulcus angle (L+M) is throughout more than 150°, the mean for the 14 patients is more than 154°, i.e. about 12° higher than the mean of the normal material. Similar values occurred in the normal material, but were rare.

My normal material consists of 400 knees (female and male, right and left). As demonstrated earlier, the sulcus angle L+M is about the same, irrespective of sex and side. Of these 400 knees, only 20 (5 %) had a sulcus angle, L+M, more than 150°, and 9, an angle more than 154°.

If one excludes the patients who have family occurrence of dislocation of the patella, two females and eight males (10 patients) remain.

If one, moreover, excludes the patients who subjectively have clear instability in the non-dislocating knee, one female and six males remain. They have *a unilateral dislocation of the patella, are completely trouble free in the other knee, have no family occurrence of dislocation of the patella, and have a clearly defined trauma in the anamnesis.* (Patient No. PK 101, PM 203, 204, 208, 302, 304, and 307.)

The measured results on the x-ray pictures of these seven patients are reported individually in Table 29.

It shows there that the female patient (unilateral left dislocation) has an almost normal height of the lateral condyle, l, a very high medial condyle, m, which gives her a negative condyle angle, C_p, of —3° on the dislocating side. She has, moreover, a small sulcus angle, L+M, mainly owing to the medial sulcus angle being so small. All these changes can be referred back to the high medial condyle. Right and left side are mainly alike.

All males, six, showed low or negative C_p and/or a large sulcus angle, L+M, and/or a low lateral condyle, l. *The changes affected both the dislocating and the sound side.*

The fact that the changes are bilateral argues strongly that the dysplasia is not secondary, but existed before the dislocation and together with the trauma led to the dislocation.

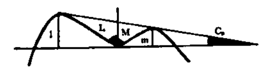
TABLE 28 A

Measured results of unilaterally luxating patients with a clear trauma in the anamnesis. Females
Mean values for col. 1, 2, and 4

Col.	1	2	3	4
	100 normal females		Unilat. luxation with trauma	
	dx	sin	dx (1)	sin (3)
l	10.08±0.19		8	
		9.11±0.17		2.67
m	5.59±0.16		3	
		5.87±0.15		7.33
C_p	6.10±0.30		5	
		4.36±0.26		−5.0
L	69.39±0.38		78	
		70.77±0.38		80.33
L+M	141.79±0.60		156	
		142.36±0.61		152.67

TABLE 28 B

Same as Table 28 A. Males
Mean values for col. 1, 2, and 3

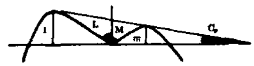


Col.	1	2	3	4
	100 normal males		Unilat. luxation with trauma	
	dx	sin	dx (9)	sin (1)
l	11.60±0.18		6.22	
		10.66±0.20		8
m	6.40±0.16		4.33	
		7.33±0.18		5
C_p	5.95±0.26		2.33	
		3.83±0.30		4
L	69.31±0.35		78.67	
		70.68±0.35		75
L+M	142.78±0.51		155.11	
		141.90±0.54		150

TABLE 29

Measured results of **unilaterally** ***luxating patients*** **with** ***trauma and*** **without** ***family anamnesis, and*** **without** ***troubles in the non-luxating knee***

One female (PK 101) with left-sided luxation and six male with right-sided luxation



Pat. No.	l dx	l sin	m dx	m sin	C_p dx	C_p sin	C_t dx	C_t sin	L dx	L sin	M dx	M sin	L+M dx	L+M sin
PK 101	9		9		0		1		76		62		138	
(♀)		8		10		−3		0		73		61		134
PM 203	8		3		6		1		77		83		160	
		9		4		6		2		73		80		153
204	5		6		−2		0		79		75		154	
		7		5		2		2		78		76		154
208	2		2		0		3		86		82		168	
		4		4		0		−2		84		75		159
302	8		5		5		−1		73		76		149	
		8		5		3		0		76		76		152
304	5		5		0		1		79		76		155	
		3		5		−3		1		85		72		157
307	6		8		−3		−2		78		64		142	
		12		6		8		5		69		65		134

Of the seven patients who clinically filled the demand for a clearly traumatic dislocation, thus only one (the female) did not show dysplastic changes on the x-ray picture. She had, on the contrary, a very strongly developed medial condyle, whereas the lateral was apparently normal.

Summary

If, in order to diagnose traumatic dislocation, one requires an obvious, direct trauma; unilateral dislocation with no troubles in the other knee; with no family anamnesis, only one female and six males fill the conditions. All males had unilateral right dislocations with dysplastic changes in *both* knee joints. This bilateral dysplasia argues strongly that the dysplasia is not secondary, but existed before the dislocation and *together with the trauma* led to the dislocation.

CHAPTER XII

Patella alta

High standing patella or patella alta has by several authors been made responsible for recurrent dislocation of the patella. The patella in these patients sits cranially to the sulcus and lacks bone support at the side when the knee is extended or lightly flexed. The patella has therefore been considered "more vulnerable" and to dislocate more easily.

If we consider patella alta to be *one* cause of dislocation and femoral dysplasia to be *another*, it would be reasonable to expect that if we had a pronounced patella alta, the femoral dysplasia would be less pronounced, it being, so to speak, not necessary for the dislocation.

If, on the other hand, we consider the dysplasia secondary to the dislocations, either in the form of rubbing down or some other process, the dysplasia ought to be quite as pronounced in the patella-alta patients as in the non-patella-alta patients.

In order to illustrate these conditions, I intended to divide my patient material into two groups, patella alta and non-patella alta, and to investigate whether there was any difference in the formation of the distal femur end in these two groups.

However, it proved difficult to get strict criteria for the diagnosis patella alta. Most textbooks on roentgenologic diagnostics mention nothing about the condition or how it is diagnosed (*inter alios*, Schinz *et al.* 1952, Brailsford 1953, and Köhler & Zimmer 1956). The normally used method is that described by Blumensaat (1938), (see p. 35). It has been used by, *inter alios*, Wiberg (1941), Fürmeier & Breit (1952), and Thestrup Andersen (1955). It is quick and convenient and for practical purposes gives an idea of the position of the patella vertically. However, I have been unable to find published any normal material investigated by this method. I found when measuring the angle between Blumensaat's line and the femur shaft (u, Fig. 8, p. 36) in about 200 male knees that this angle could vary in different individuals between 60° and 27°.

This must influence the determination of the position of the patella vertically and make the method inexact.

Blumensaat's method presumes, moreover, a picture taken laterally with the knee at 30° flexion. In my patient material, I could get such pre-operative pictures of only about 25 patients. In most pictures taken laterally, the knee was considerably more flexed. To take fresh pictures laterally at the follow-up investigation, with the knee flexed 30°, would not have produced much information because most patients were operated and the patella pulled medially-*distally*.

Because a strict method of determining patella alta does not at present exist, and the available x-ray material did not permit with any degree of satisfaction an arrangement by the normally used method (Blumensaat's), I was compelled to relinquish the attempt to illustrate the question regarding the relation between patella alta and the femoral dysplasia.

Summary

The available x-ray material did not permit an analysis of the relation between patella alta and femoral dysplasia. The normally used method of determining patella alta (Blumensaat's) is inexact.

CHAPTER XIII

Dislocation frequency

With the guidance of the anamnestic information concerning the dislocation frequency, the knee joints were classified into three groups:

1. Joints with *few* dislocations—a total of 2 to 4 dislocations.
2. Joints with *several* dislocations (the patient having had several, but in the main not more than he can recall)—usually 5 to 10 dislocations.
3. Joints with *many* dislocations (the patient has lost count: "it occurs once a week" and similar).

There is no distinct border between these groups.

There is no reason why *one* knee of a patient should not belong to one group and the *other* knee to another group.

Classified according to these principles, the material appears as shown in Table 30.

Comparison of the measured results of these three groups produced very uncertain results, conflicting partly because some of the subgroups were so small (7, 8, and 9 in the smallest). (See Table 30.)

In order to get larger groups, I combined the groups "several" and "many" into one group and compared its values with corresponding values of "few".

More pronounced dysplasia ought reasonably to produce more frequent dislocations. The results are shown in Table 31 for females and 32 for males. No statistically significant difference is seen (col. 7/8) but with two exceptions, all values (l, m, L, and L+M) for both females and males and for both right and left side go in the expected direction, i.e. the dysplasia is more pronounced in patients with frequent dislocations. The exceptions are m for female on the right side and L for males on the left side, but neither of these two "unexpected" differences is greater than fully half of its own mean error.

TABLE 30

Classification of the luxating knee joints according to the number of luxations in resp. knee

	Few[1] lux. in knee		Several[2] lux. in knee		Many[3] lux. in knee		Total No. of knees	
	dx	sin	dx	sin	dx	sin	dx	sin
♀	14		30		13		57	
		17		25		12		54
♂	13		13		8		34	
		17		9		7		33
♀ + ♂	27		43		21		91 + 87	
		34		34		19		= 178

[1]=2—4 luxations. [2]=5—10 luxations. [3]=>10 luxations
(Approximate figures)

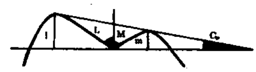
TABLE 31

Comparison of the measured results for luxating knees with "few" luxations, on one hand, and "several" or "many", on the other.
Mean values for females

Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Luxating knees with "few" occurrences		Luxating knees with "several" or "many" occurrences		Diff. "few"—"several" or "many" occurrences	
	dx (14)	sin (17)	dx (43)	sin (37)	dx	sin
l	7.71±0.66		6.98±0.52		0.73±0.84	
		6.53±0.67		5.38±0.48		1.15±0.82
m	3.29±0.52		3.60±0.29		−0.31±0.60	
		3.76±0.41		3.59±0.40		0.17±0.57
C_p	6.36±1.40		4.60±0.45		1.76±1.47	
		4.00±1.28		2.22±0.65		1.78±1.44
L	75.93±1.02		76.70±0.99		−0.77±1.42	
		77.00±1.30		79.27±0.91		−2.27±1.59
L+M	152.71±2.11		153.02±1.66		−0.31±2.69	
		153.76±1.55		156.51±1.71		−2.75±2.31

TABLE 32

Same as Table 31
Mean values for males



Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Luxating knees with "few" occurrences		Luxating knees with "several" or "many" occurrences		Diff. "few"—"several" or "many" occurrences	
	dx (13)	sin (17)	dx (21)	sin (16)	dx	sin
l	8.46±0.66	7.71±0.56	6.76±0.74	7.25±0.89	1.70±0.99	0.46±1.05
m	4.85±0.73	5.24±0.54	4.43±0.60	4.44±0.45	0.42±0.95	0.80±0.70
C_p	4.39±0.85	3.00±0.91	3.00±0.81	3.62±1.09	1.39±1.17	−0.62±1.42
L	75.00±1.04	76.59±0.97	77.48±1.47	76.00±1.89	−2.48±1.80	0.59±2.12
L+M	150.85±3.21	149.82±1.78	153.38±2.84	152.63±2.72	−2.53±4.29	−2.81±3.26

Summary

No connection between the degree of femoral dysplasia and dislocation frequency appears in the material reported here.

CHAPTER XIV

Femoral dysplasia and prognosis of the function of the femoro-patellar joint

A. *Classification*

As earlier mentioned, I have not sought to pursue a clinical follow-up series, because, for one thing, parts of my patient material were already published by Thestrup Andersen (1955) and Jerre & Knutsson (1958).

Several authors (*inter al.* Felländer 1949, Marion & Barcat 1950, and Thestrup Andersen 1955) have stated that at recurrent dislocation of the patella the prognosis for the femoro-patellar joint is worse if roentgenologic investigation discloses pronounced dysplastic changes there. I therefore wanted to investigate the possible role played by any dysplastic changes I could measure on the x-ray pictures, for the prognosis.

The knee joints have been classified—mainly according to the subjective troubles in the *femoro-patellar joint* of the patients that were disclosed at the follow-up series—into three groups:

1. Good result: The patient is completely or almost trouble free in the knee joint: no dislocations and no feelings of instability; is able to take part in sports and dancing; no disability at work.
2. Fair result: The patient has troubles in the form of feelings of instability, locking of the knee joint, pain at exertion, and hydrops. He restricts himself regarding work, sport, and dancing because of the knee.
3. Poor result: Besides pronounced troubles according to the criteria of the "fair" group, the patient still has dislocations.

Post-operative complications such as thrombosis, peroneus paresis, and similar have not influenced the classification, because it was the function and the prognosis of the femoro-patellar joint that interested me. The result has been appraised as poor (referring to the femoro-patellar joint) if one or more surgical attempts have failed and patellectomy has become necessary, even though the function of the knee joint is good at the follow-up examination.

In order for a knee joint to qualify for this appraisal, I have, as far as *operated* knee joints are concerned, required an observation period of at least two years after the operation, and regarding *the non-operated*, a period of at least five years between the onset of the condition in the knee and the follow-up examination. If I choose a shorter period than five years, there is the risk of several *relatively fresh* dislocations, which could soon need operations and thus, perhaps, be transferred from the group "poor result" (with dislocations) to either of the groups "good" or "fair". How long the observation period should be can be a matter of opinion. Bearing in mind that males on average wait fully five years and females fully eight years after the onset of the condition before going to operation (see Table 21) a longer period than that chosen by me (five years) might be thought more suitable. These figures, however, are coloured by the fact that earlier there was more restriction in determining operation indications (the investigation included patients treated from and including 1945); nowadays the time between the onset of the condition and the operation is shorter.

The average time between the onset of the condition in the knees and the follow-up investigation is thus for *the unoperated* females 21.2 years and for the males 19.3 years.

The observation period for *the operated* knee joints (with a minimum observation period of at least two years) is for females 10.2 years and for males 9.7 years.

The classification of the patient material based upon these details is shown in Tables 33, 34, and 35.

Table 33 shows that on average two-thirds of the number of dis-

TABLE 33

Number of luxating knees and number of operated knees considered at the appraisal of the function of the femoro-patellar joint at the follow-up investigation
Operated knees, >2 years observation time; unoperated, >5 years period sickness

	♀			♂			♀+♂
	dx	sin	dx+sin	dx	sin	dx+sin	
Operated	37	32	69	21	17	38	107
Non-operated	17	17	34	8	10	18	52
Total	54	49	103	29	27	56	159

locating knee joints were operated on, whereas one-third had a conservative therapy, such as elastic bandage, physical treatment, and in isolated instances orthopedic bandage treatment. In some instances, no treatment was applied. In the choice of surgical or conservative treatment, there is no difference between right and left side, or between female and male.

Table 34 shows the function of the femoro-patellar joint in dislocated knees at the follow-up investigation. Of 159 dislocating knees, operated or non-operated, 87 have become good, which is a better result than usual (see Chapt. III). However, as mentioned earlier, I have considered only the function of the femoro-patellar joint; therefore, a comparison with other materials must be made with extreme caution.

Table 34 shows also that 14 knee joints, after having dislocated at least twice, have become completely symptom free and have not given the patient concerned any feeling of instability. Of these, three were patients with bilateral dislocations, and in addition to the successful operation in one knee, they become well also in the non-operated knee. The explanation might be that an unloading of the non-operated knee had occurred when the patient became stable in the operated knee.

TABLE 34

The condition in luxating knee at follow-up investigation. The same observation time and period of sickness as in Table 33
For criteria of groups "good", "fair", and "poor", see text

	♀						♂						♀+♂		
	dx			sin			dx			sin			dx+sin		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Operated	21	9	7	22	5	5	15	5	1	15	1	1	73	20	14
Non-operated	4	5	8	6	5	6	2	1	5	2	2	6	14	13	25
Total	25	14	15	28	10	11	17	6	6	17	3	7	87	33	39

TABLE 35

The same as Table 34, but the material is classified according to right-left side

	♀+♂					
	dx			sin		
	Good	Fair	Poor	Good	Fair	Poor
Operated	36	14	8	37	6	6
Non-operated	6	6	13	8	7	12
Total	42	20	21	45	13	18

Table 35 shows the distribution of the material into right and left dislocations. No difference regarding operation frequency and prognosis is seen.

B. *Measurements*

The measured results of 87 knee joints referred to the group "good" (73 operated and 14 non-operated) on one hand were compared with 33 of the group "fair" (20 operated and 13 non-operated) plus 39 of the group "poor" (14 operated and 25 non-operated) on the other hand and are reported in Table 36 (females) and Table 37 (males).

Concerning the *females*, it can be seen that on the right side (col. 7, Table 36) no significant difference exists between these two groups.

On the left side (col. 8, Table 36), l and L differ statistically probably (*), the dysplastic changes being less pronounced among the "good results". (On the right side, these magnitudes go in the same direction, but do not go over the significance limit.)

Concerning males, we find a statistically significant difference on the right side (col. 7, Table 37) where, for example, l is on average 3.09 ± 0.83 (***) mm higher in patients of the group "good result" and also L (**) and C_p (*) are significantly less dysplastic in this group. On

TABLE 36

Comparison of measured results for luxating knees, which at re-examination were classified as "good", on one hand, and "fair" or "poor", on the other (see text)
Mean values for females

Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Luxating knees classified at re-examination as "good"		Luxating knees classified at re-examination as "fair" or "poor"		Diff. "good" — "fair" or "poor"	
	dx (25)	sin (28)	dx (28)	sin (21)	dx	sin
l	7.60±> 0.19	6.39±0.44	7.39±> 0.19	4.76±0.59	0.21±> 0.30	1.63±0.74 *
m	3.32±0.34	3.68±0.45	3.96±0.38	3.91±0.45	−0.64±0.51	−0.23±0.64
C_p	6.00±1.05	3.86±0.77	4.71±0.63	1.43±0.98	1.29±1.23	2.43±1.25
L	75.80±> 0.38	76.79±0.85	76.07±> 0.38	79.86±1.09	−0.27±> 0.57	−3.07±1.38 *
L+M	152.52±> 0.60	153.75±1.79	151.64±> 0.60	156.67±1.72	0.88±> 0.90	−2.92±2.48

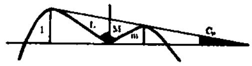
the left side (col. 8, Table 37) no significant difference exists; with the exception of C_p the magnitudes go in the same direction as on the right side, but do not reach the significance limits.

C. *Summary*

Those knee joints in which dislocation of the patella laterally has occurred at least twice have, at the follow-up investigation, been classified into three groups (good, fair, and poor result) primarily according to the subjective troubles in the *femoro-patellar joint* of the patient. For operated knee joints to be appraised in this prognosis investigation, an observation period of more than two years (average for 107 operated knee joints about 10 years) was required. For non-operated knee joints, an illness period of more than five years was required (average for 52 knee joints about 20 years).

TABLE 37

Same as Table 36
Mean values for males



Col.	3	4	5	6	7 (3–5)	8 (4–6)
	Luxating knees classified at re-examination as "good"		Luxating knees classified at re-examination as "fair" or "poor"		Diff. "good" — "fair" or "poor"	
	dx (17)	sin (17)	dx (12)	sin (10)	dx	sin
l	9.00±0.54		5.91±0.63		3.09±0.83***	
		8.00±0.49		7.30±0.88		0.70±1.01
m	4.82±>0.16		4.83±>0.16		−0.01±>0.24	
		5.30±0.53		4.70±0.61		0.60±0.81
C_p	4.88±0.72		1.75±1.12		3.13±1.33*	
		3.25±>0.30		3.50±>0.30		−0.25±>0.45
L	73.88±0.98		78.42±1.27		−4.54±1.60**	
		75.59±0.89		76.30±1.84		−0.71±2.04
L+M	149.41±2.17		152.16±2.85		−2.75±3.58	
		149.18±1.62		151.30±2.32		−2.12±2.83

The classification of the patient material is shown in Table 33.

Of 159 dislocating knees, 87 (=55 per cent) have obtained a good function in the femoro-patellar joint; 14 (=9 per cent) of them without operation.

The measurement on the x-ray pictures showed statistically probable differences on the left side for females and significant differences on the right side for males, and uncertain differences on the right side for females and on the left side for males: the group classified "good result" was in some respects less dysplastic than the combined group "fair+poor result".

Conclusions and summary

A. *X-ray examination of the distal femur end*

At recurrent dislocation of the patella, so-called axial pictures are usually taken of the patella. Because dislocation occurs as a rule when the patella is in the cranial part of the inter-condylar groove, one should try to get a picture of this area and not of the caudal parts of the groove. The projection recommended by Knutsson fills this requirement. Small changes in the rotation of the femur and the position of the cassette, however, have consequences for the picture of the formation of the femur condyles; therefore, these details should if possible be standardized. The modification of Knutsson's method (described by Fürmeier) of keeping the patient's knee joints and foot joints together and x-raying both knee joints at the same time, increases the possibility of symmetric position and is recommended as a clinical routine method.

In order to investigate the femoral dysplasia, the present author has worked out a method of examining roentgenologically the distal femur end in standardized conditions, and has thereby made it possible to get objective, measurable expressions for changes in the shape of the intercondylar groove. With this method, two almost simultaneous pictures are obtained, one of the *ventral* area of the femur condyle section on *both* knees, and the other of the *dorsal* area. The ventral picture has the same angle between the roentgen rays and the femur shaft as Knutsson—Fürmeier have indicated. On both pictures, a horizontal line is projected.

On the *ventral* x-ray picture, certain magnitudes were measured: a) the height of the lateral and the medial condyle above the sulcus bottom, b) the angles between the vertical line from the sulcus bottom and lines from the sulcus bottom to the highest point of each condyle, and c) finally the angle between a line through these two highest points and the horizontal line through the sulcus bottom (see Fig. 22).

These magnitudes give an idea of the formation of the osseous parts of the *ventral* condyle section.

On the *dorsal* picture, the following have been measured: a) the distance between the projected horizontal line and the most dorsally lying point on each condyle; b) the angle between a line through these two points and that horizontal line which touches the most dorsally lying condyle.

These magnitudes give an idea of the torsion-rotation conditions, and a possibility of estimating approximately the ventro-dorsal extension of the condyles.

At the appraisal of the femoral dysplasia on pictures taken according to Knutsson—Fürmeier, it is better to start from the sulcus angle L+M (see Fig. 22), because this angle gives a more definite idea of the femoral dysplasia than does the usual estimation of the height of the lateral condyle above a horizontal line through the sulcus bottom. L+M is independent of photographic enlargement and (within reasonable limits) of the rotation-torsion of the femur.

B. *Normal material*

The author personally investigated 100 females and 100 males with subjectively healthy knees, using the method referred to above. The measured results are reported in Table 3, p. 82.

The total sulcus angle L+M shows the following values:

	dx	sin
Females	141.79 ± 0.60	142.36 ± 0.61
Males	142.78 ± 0.51	141.90 ± 0.54

A statistically significant difference is usually found between the right and the left side because the distal femur end on the left side stands outwards rotated or outwards torqued in relation to the right side.

The female distal femur end is more gracile than the male, but is primarily of the same form.

C. *Patient material*

131 patients from the south of Sweden and from Copenhagen (81 females and 50 males) with recurrent dislocation of the patella (at least two dislocations) were investigated clinically and roentgenologically by

the author personally, and the same magnitudes as in the normal material were measured. The patients were grouped according to certain clinical and anamnestic criteria, and the means of the measured magnitudes of each group were calculated and compared with the means of the normal material and other patient groups.

The following appears from the investigation of the patient material:

1. *Rotation-torsion:* Common to all groups, no statistically significant difference in rotation or torsion is found between the normal material and the patient material (Table 8). In patients with recurrent dislocation of patella, the changes recorded in the ventral parts of the condyle section are thus real and are not due to changed position in the distal femur end, as has been maintained by several authors.

2. *Right-left:* The asymmetry established in the normal material between the right side and the left is also found in the measured results in the patient material, because the left distal femur end stands more outwards rotated or outwards torqued than the right.

48 patients had bilateral dislocations, 44 had unilateral right, and 38 had unilateral left (82 unilateral dislocations). In the 48 bilaterally dislocating patients, the onset of the condition occurred in the left knee twice as often as in the right, and the left knee being that which twice as often gave most symptoms.

3. *The dislocating knee:* Measurement on the x-ray pictures showed pronounced femoral dysplasia in the dislocating knee joints, because the height of the lateral condyle, as well as the medial, above the sulcus bottom is less in dislocating knees, and the sulcus angle L+M has increased. This dysplasia in the dislocating knee is more pronounced if the dislocation is bilateral than if it is unilateral, but the difference is statistically non-significant.

4. *The non-dislocating knee:* Of the 82 unilaterally dislocating patients, 30 (37 %) had subjective troubles in the form of feelings of instability in the non-dislocating knee—only 52 were completely trouble free.

In these unilaterally dislocating patients, the *non-dislocating knee* also shows statistically significant differences, compared with the normal material, in the form of lowered condyle heights and increased sulcus angle. This difference is also seen if the values are calculated for solely the 52 unilaterally dislocating patients who were completely trouble free in the non-dislocating knee.

The predisposition of the condition is thus bilateral to a considerably larger extent than the clinical manifestation would lead one to believe. This also argues strongly against the suggestion that the low lateral condyle or the increased sulcus angle is secondary and the consequence of the dislocation.

5. *The height of the sulcus bottom:* The possibility that these dysplastic changes are due to a relative raising of the sulcus bottom, rather than to a substantial decrease of the ventro-dorsal extension of the condyles, is discussed. Certain measured findings argue for this possibility.

6. *The age factor:* The female patients have their first dislocation on average at age 15.2 years; the male, at age 16.3 years. Patients whose condition had an earlier onset (females less than 16 years, males less than 17 years) have a more pronounced femoral dysplasia than those whose onset came after the mentioned age.

7. *Family occurrence:* Twenty-two females and ten males (32 patients =24 %) stated that some close relative had suffered recurrent dislocation of the patella. The 22 females with positive family anamnesis showed somewhat more pronounced dysplasia than did the other patients, but the difference is statistically non-significant.

The male group is too small for any conclusions to be drawn.

No significant difference between patients with and those without positive family anamnesis could thus be demonstrated.

8. *Trauma:* Five females and 13 males (18 patients) reported a strong and direct assault on the knee as reason for the first dislocation. Of these, only one female and six males were unilateral dislocating and with no troubles in the other knee, and without family anamnesis. All six males had dysplastic changes in *both* knee joints. Only the female patient showed no signs of dysplasia. This bilateral dysplasia in the males argues for the dysplasia not being secondary, but existing before the dislocation and, together with the trauma, leading to dislocation.

9. *Dislocation frequency:* No definite relation between the degree of femoral dysplasia and dislocation frequency emerged.

10. *Prognosis:* The conservatively treated knee joints that showed dislocation for more than five years and the surgically treated knee joints that had an observation period of at least two years were appraised with regard to the condition in the femoro-patellar joint.

Of 159 dislocated knees appraised in this manner, 87 were referred to the group "good", of whom 14 were without operation. On the x-ray pictures, the group "good" showed less pronounced dysplasia than did the combined group "fair" and "poor", but the differences were only partly significant.

Acknowledgements

My grateful thanks are due to Professor Gunnar Wiberg, who made this investigation possible by generously placing the resources of the Clinic at my disposal, for discussions and invaluable criticism during the progress of the work.

To Laborator O. Norman, head of the Roentgen-Diagnostic Clinic II, Lund, for constructive criticism, and for generous help by placing the technical resources of his Clinic at my disposal.

To head physician P. Thestrup Andersen, Copenhagen, whose willingness to assist and enthusiasm for the investigation were invaluable and stimulating.

To Professor C.-H. Hjortsjö, Lund, for kind interest and advice in planning the investigation.

To head psysician Ingemar Bergstrand, Boden, for his interest, good advice, and fruitful discussions.

To head physician R. Schalimtzek—and through him to the Directors and staff of the Ortopedisk Hospital in Copenhagen—for the kind assistance I was given in Copenhagen.

To Professor A. Bertelsen (Copenhagen) and head physicians M. Brunk (Kristianstad), E. Hjalmar Larsen (Copenhagen), S. v. Rosen (Malmö) and K. Stenport (Hälsingborg) for putting their patient material at my disposal.

Economic support was provided by the Medical Faculty of the University of Lund, by the Järnhardts Stiftelse, and by the Österlunds Stiftelse.

References

ALBEE, F. H.: The bone graft wedge in the treatment of habit. disloc. of pat. Med. Rec. 1915, 88: 257—259.

ALDIBERT, A.: Des lux. habit. de la rotule chez l'enfant. Rev. mens. malad. de l'enfance 1894, 12: 607—619 and 653—669.

ALLEN, B.: An x-ray study of development of ossification centers of skeletal system. Radiology 1926, 7: 398—409.

ALTSCHUL: Technik der axialen Patellaraufnahmen. Fortschr. Röntgenstr. 1923—24, 31: 781—782.

ANDERSEN, D.; BAUMGARTL, F. & GREMMEL, H.: Die Röntgendiagnostik des Femoropatellargelenkes und ihre klin. Bedeutung. Der Radiolog. 1961, 1: 216—222.

APPEL, K.: Zur Lehre von den cong. Pat.lux. Münch. med. Wschr. 1895, 42: 581—583 and 604—606.

BADE, P.: Die habit. Lux. der Pat. Z. orthop. Chir. 1903, XI: 3: 451—488.

— Die Behandlung der habit. Kniescheibenverrenkung. Zbl. Chir. 1934, 61: 1121.

BARDENHEUER: Über Kapselverengerung bei Gelenkaffektionen. Zbl. Chir. 1900, 27: II: 1027.

BAUER, K. H. & GÖTTIG, I.: Der Nachweis einer Systemerkrankung bei örtlichen körperlichen Missbildungen. Z. menschl. Vererb.- u. Konstit-lehre 1936, 19: 8—31.

BERNAYS, A.: Die Entwicklungsgeschichte des Kniegelenkes des Menschen. Morph. Jb. 1878, 4: 403—445.

BILLING, L.: Roentgen examination of proximal femur end in children and adolescents. Acta Radiol. (Stockh.) 1954, Suppl. 110.

BLANCO, P.: Rec. disloc. of pat. End results following surgical treatment. N.Y. St. J. Med. 1949, 49: 169—170.

BLENCKE, A.: Ein Beitrag zur sogen. „cong. Verrenkung der Kniescheibe nach oben". Z. orthop. Chir. 1902, 10: 523—545.

BLUMENSAAT, C.: Die entzündlichen Erkrankungen der Kniescheibe u. Die Tumoren der Kniescheibe. Ergebn. Chir. Orthop. 1936, 29: 310—371.

— Die Lageabweichungen und Verrenkungen der Kniescheibe. Ergebn. Chir. Orthop. 1938, 31: 149—223.

BOGEN, H.: Über familiäre Luxation und Kleinheit der Pat. Z. orthop. Chir. 1906, 16: 359—419.

BOON-ITT, S. B.: The normal position of pat. Amer. J. Roentgenol. 1930, 24: 389—394.

BRAILSFORD, J. F.: The Radiology of Bones and Joints. J. & A. Churchill, London 1953.

BRATTSTRÖM, H.: Pat. shape and degenerative changes in femoro-patellar joint. Acta orthop. scand. 1960, 29: 153.
— Two sources of error in measurement of anteversion angle of femur. Acta orthop. scand. 1962, 32: 252—256.
BRISARD, P.: Tactique op. dans le traitement des lux. cong. et recidiv. de la rotule. Acta orthop. belg. 1950, 16: 452—456.
BROOKE, R.: The treatment of fractured pat. by excision. Brit. J. Surg. 1936—37, 24: 733—747.
BÖCKER, W.: Eine neue Methode der Behandlung der habit. Pat.lux. Z. orthop. Chir. 1904, 13: 307—314.
BÖHI, P.: Über habit. Pat.lux. Diss. Basel 1957.
BÖHLER, L.: Ein Fall von doppelseitiger habit. Pat.lux. Z. orthop. Chir. 1918, 38: 303—310 and 623—628.
BÖHM, M.: Das menschliche Bein. Herman Gocht (red.): Deutsche Orthopädie. 1935, 9.
CAMPBELL, W. C.: Operative Orthopaedics. C. V. Mosby Company, St. Louis, 1956.
CARTER, C. & SWEETNAM, R.: Rec. disloc. of pat. and of the shoulder. J. Bone Jt. Surg. 1960, 42 B: 721—727.
CAVE, E. F. & ROWE, C. R.: The Patella. Its importance in derangement of the knee. J. Bone Jt. Surg. 1950, 32 A: 542—553.
CERWENKA, W.: Die Behandlung der habit. Pat.lux. Zbl. Chir. 1962, 87: 2: 1833—1838.
CLARK, K. C.: Positioning in Radiography. Heinemann, London 1962.
LE COEUR, P.: Etudes de mecanique anatomique normale, pathologique et thérapeutique appliquées a la lux. de la rotule. Bull. et Mémoires de la Soc. des Chir. de Paris 1956, 46: 261—272.
COLE, W. H. & WILLIAMSON, G. A.: Chronic rec. disloc. of pat. J.A.M.A. 1934, 102: 357—360.
CONN, H. R.: A new method of op. reduction for cong. lux. of pat. J. Bone Jt. Surg. 1925, 23: 370—383.
COTTA, H.: Zur Therapie der habit. Pat.lux. Arch. Orthop. Unfall-Chir. 1959, 51: 265—271.
DAUNEGGER, C.: Versuche und Studien über die Lux. der Pat. Diss. Zürich 1880.
DEBRUNNER, H.: Über einige Probleme der Pathogenese und Therapie der sogenannten habit. Pat.lux. Wiederherstellungschir. u. Traum. 1957, IV: 109—125.
— Das Kniegelenk (in Hohmann et al.: Handbuch der Orthopädie). Thieme, Stuttgart 1961.
DE PALMA, A. F.: Diseases of the Knee. Lippincott, Philadelphia 1954.
DE PALMA, A. F. & FLYNN, J. J.: Joint changes following experimental partial and total patellectomy. J. Bone Jt. Surg. 1958, 40 A—1: 395—413.
DICKSON, J. A.: Rec. disloc. of pat. Surg. Clin. N. Amer. 1936, 16: 997—1000.
DRACHMANN, A. G.: Tilfælde af medfødt Mangel af musc. quadriceps femoris. Nord. med. Ark. 1872, 4 nr. 6: 7—8.
DREESMANN: Angeborene Hüftverrenkung. Dtsch. Z. Chir. 1908, 94: 275—296.
DREHMANN, G.: Zur operation der habit. Verrenkung der Kniescheibe. Berl. klin. Wschr. 1921, 58: 406—407.
DREW, D.: Disloc. of pat. Proc. roy. Soc. Med. 1908, 1: 11.
DUCHENNE, G. B.: Physiologie des mouvements. Baillière et Fils, Paris 1867.

DIXON, W. J. & MASSEY, F. J.: Introduction to Statistical Analysis. McGraw-Hill Book Company, I.N.C. New York 1951.

ESTOR, E. & H.: La lux. récidiv. de la rotule. Rev. Orthop. 1933, 20: 330—335.

EWALD, P.: Über cong. Lux. ... der Patella ... Arch. klin. Chir. 1906, 78: 824—844.

FELLÄNDER, M.: The late results of op. treatment of rec. disloc. of pat. Acta orthop. scand. 1949, 18: 157—167.

FÉVRE, M.: Procédé parsonnel pour le traitement des lux. graves de la rotule. Mém. Acad. chir. 1950, 76: 976—977.

FÉVRE, M. & DUPUIS, P.: Traitement de la lux. cong. irréductible de la rotule. J. Chir. (Paris) 1934, 44: 833—851.

FICK, R.: Handbuch der Anat. des Menschen (v. Bardeleben, Edit) Jena 1911.

FIEBACH, M.: Über kong. Pat.lux. Bruns' Beitr. klin. Chir. 1911, 76: 283—296.

FILES, G. W.: Medical Radiographic Technic. Ch. Thomas, Springfield, Ill. 1959.

FINSTERER, H.: Zur Kenntnis der Lux. der Pat. Bruns' Beitr. klin. Chir. 1909, 62: 453—495.

FRANCILLON, J.: Résultat thérapeutique éloigné d'une lux. récidiv. de la rotule. Lyon chir. 1950, 45: 117—118.

FREEHAFER, A.: A Study of the function of pat. Clin. Orthop. 1962, 25: 162—167.

FRIBERG, S.: Über Totalexstirpationen der Pat. Acta chir. scand. 1941, 85: 361—388.

FRIEDLAND, M.: Zur Therapie der lateralen Pat.lux. Arch. orthop. Unfall-Chir. 1925, 23: 353—358.

FRIEDLÄNDER, W.: Die habit. Lux. der Pat. Arch. klin. Chir. 1901, 63: 243—276.

FRIES, G.: Kritisches zum Torsionsproblem der unteren Extremitäten bei der kong. und habit. Kniescheibenlux. Z. Orthop. 1962, 96 (Beilageheft): 197—199.

FRÜND, R.: Hinweis zur Roentgendiagnostik der habit. pat.lux. Z. Orthop. 1958, 90: 191—194.

FÜRMAIER, A.: Beitrag Zur Mechanik der Pat. und des Gesamtkniegelenkes. Arch. orthop. Unfall-Chir. 1953, 46: 78—90.

— Die Technik der Röntgenuntersuchung des Kniegelenks. (In: Hohmann et al: Handbuch der Orthopädie.) G. Thieme, Stuttgart 1961.

FÜRMAIER, A. & BREIT, A.: Über die Röntgenologie des Femoro-Patellargelenkes. Arch. orthop. Unfall-Chir. 1952, 45: 126—138.

GALENOS, C.: Cit. Karl.

GALLIE, W. E.: Dislocations (The Shattuck lecture). New Engl. J. Med. 1935, 213: 91—98.

GALLIE, W. E. & LE MESURIER, B.: Habit. disloc. of pat. J. Bone Jt. Surg. 1924, 22: 575—581.

GALLOWAY, J. D. B. & MACEY, H. B.: Bilateral rec. disloc. of pat. Proc. Mayo Clin. 1937, 12: 783—784.

GARNIER, C.: Disc. Rev. Orthop. 1950, 36: 444—447.

GOCHT, H.: Die überpflanzung der Kniebeugemuskeln auf den Kniestreckapparat. Arch. orthop. Unfall-Chir. 1918—19, 16: 533—548.

GOLDTHWAIT, J. E.: Permanent disloc. of pat. Ann. Surg. 1899, 29: 62—68.

— Slipping or rec. disloc. of pat. Boston med. surg. J. 1904, 150: 169—174.

GRASER, E.: Behandlung der Lux. pat. inveterata durch Osteotomie am Femur mit Drehung der Epiphyse. Verh. dtsch. Ges. Chir. 1904, 33: II: 457—466.

GRASHEY, R.: Typische Rtg.-bilder von normalen Menschen. Lehmanns med. Atlanten 1928, 5: 211.

GUERIN, J.: Deux exemples de lux. ... Gaz. Hôp. (Paris) 1842, 4: 372—373.

HALL, M. C.: Radiographic examination of the lateral femoral condyle in relation to the etiology of rec. disloc. of pat. Clin. Orthop. 1962, 24: 161—163.

HARMON, P. H.: Intra-articular osteochondral fractures as a cause for internal derangement of the knee in adolescents. J. Bone Jt. Surg. 1945, 27: 703—705.

HARMS, J.: Die röntgenologische Darstellung der Pat. und ihres Gleitlagers. Röntgen- u. Lab. Prax. 1953, 6: 236—237.

HARRISON, M. H. M.: The results of a realignment op. for rec. disloc. of pat. J. Bone Jt. Surg. 1955, 37 B: 559—567.

HAUSER, E. D. W.: Total tendon transplant for slipping pat. Surg. Gynec. Obstet. 1938, 66: 199—213.

HAXTON, H.: Patellar index in mammals. J. Anat. (Lond.) 1944, 78: 106—107.

— The function of pat. and the effects of its excision. Surg. Gynec. Obstet. 1945, 80: 389—395.

HELLUM, C.: Luxatio patellae habitualis. T. norske Lægeforen. 1962, 82: 1: 687—689.

HERZOG, K.: Methode zur op. Behandlung der gewohnheitsmässigen Kniescheibenverrenkung. Zbl. Chir. 1947, 72: 2: 1008—1012.

HEUSNER, L.: Über die Dauerresult. der Sehnenüberpflanzung. Verh. dtsch. Ges. Chir. 1902, 31: 142.

HEYWOOD, A. W. B.: Rec. disloc. of pat. J. Bone Jt. Surg. 1961, 43 B: 508—517.

HILDEBRAND: Zur op. Behandlung der habit. Kniescheibenlux. Arch. klin. Chir. 1902, 66: 366—372.

HJORTSJÖ, C. H.: Rörelseapparaten. Gleerup, Lund 1959.

HOFFMEISTER, W.: Die Op. der habit. Lux. der Pat. Zbl. Chir. 1928, 55: 65—67.

HOHLBAUM, J.: Über die Aetiologie der Pat.-Lux. Bruns' Beitr. klin. Chir. 1921, 121: 1—53.

HORWITZ, M. T.: Rec. disloc. of the pat. J. Bone Jt. Surg. 1937, 19: 1027—1036.

HOUKOM, S. S.: Rec. disloc. of pat. Arch. Surg. (Chicago) 1942, 44: 1026.

HÜBSCHER, C.: Über Op. bei habit. Lux. der Kniescheibe. Z. orthop. Chir. 1909, 24: 1—22.

ISERMEYER, H.: Über pathologische Lux. der Pat. nach aussen. Arch. klin. Chir. 1867, 8: 1—23.

JANSEN, M.: Genu impressum und Patella alta. Z. orthop. Chir. 1930, 52: 314—331.

JANZ, G.: Zur op. Behandlung der Pat.lux. Arch. klin. Chir. 1930, 156: 463—473.

JAROSCHY, W.: Die diagnostische Verwertbarheit axialer Patellaraufnahmen. Fortschr. Röntgenstr. 1923—24, 31: 781—782.

— Über pathologische Befunde an der Kniescheibe bei habit. Pat.lux. und anderen Erkrankungen. Bruns' Beitr. klin. Chir. 1924, 131: 626—641.

JEFFREYS, T. E.: Rec. disloc. of pat. due to abnormal attachment of iliotibial tract. J. Bone Jt. Surg. 1963, 45 B: 740—743.

JERRE, T. & KNUTSSON, B.: Late results of transplantation of the tibial tubercle in rec. disloc. of pat. Acta orthop. scand. 1958, 27: 141—152.

JOHNSON, W. H. & KENNEDY, J. A.: Radiographic Anatomy of the Human Skeleton. Livingstone, Edinburgh and London 1961.

JUST, G.: Handbuch der Erbbiologie des Menschen. Springer, Berlin 1940.

KAPEL, O.: Die op. Behandlung der habit. und permanenten Lux. Pat. im besonder nach Krogius und Goldthwait. Acta chir. scand. 1936, 77: 201—228 and 296—305.

KARL, F.: Die habit. Lux. der Kniescheibe. Arch. klin. Chir. 1921, 118: 667—677.

KARLHOLM, S.: Late results of Krogiusplasty. Acta orthop. scand. 1961, 30: 124—128.

KAZZANDER, J.: Über die Entwickelung des Kniegelenkes. Arch. Anat. u. Physiol. 1894, 161—176.

KIESSELBACH, A.: Anatomische Bemerkungen zur Verlagerung der Ansatzstelle des Ligamentum patellae bei Pat.lux. Z. Orthop. 1956, 87: 240—250.

KIRMISSION, E.: Cit. Thestrup Andersen, 1898.

KNUTSSON, F.: Über die Röntgenologie des Femoropatellargelenks sowie eine gute Projektion für das Kniegelenk. Acta radiol. (Stockh.) 1941, 22: 371—376.

KOPSCH, F.: Rauber & Kopsch: Lehrbuch und Atlas der Anatomie des Menschen. Band I. Georg Thieme, Leipzig 1940.

KROGIUS, A.: Zur op. Behandlung der habit. Lux. der Kniescheibe. Zbl. Chir. 1904, 31: 254—257.

KRÖMER, K.: Die Form der Pat. bei der habit. Kniescheibenverrenkung. Chirurg. 1937, 9: 88—89.

KÖHLER, A. & ZIMMER, E. A.: Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde des Skelettes. G. Thieme, Stuttgart 1956.

LACHERETZ, M.: Le traitement chirurgical de la lux. récidiv. et habit. de la rotule. Rev. Orthop. 1951, 37: 31—40.

LANCE, P.: Disc. Rev. Orthop. 1950, 36: 437.

LANGE, M.: Orthopädisch-Chirurgische Operationslehre. J. F. Bergmann, München 1962.

LANZ, O.: Sehnenplastik bei habit. Lux. der Pat. Korresp. Bl. f. schweiz. Ärz. 1904, 34: 270—272.

v. LANTZ, T. & WACHSMUTH, W.: Praktische Anatomi. Erster Band/Vierter Teil: Bein und Statik. Springer, Berlin—Heidelberg 1938.

LEVITIN, J. & COLLOFF, B.: Roentgen Interpretation of Fractures and Dislocations. Charles C. Thomas, Springfield, Ill. USA 1956.

LEWIN, P.: The Knee. Lea & Febiger, Philadelphia 1952.

LUXEMBOURG, H.: Zur Behandlung der habit. Pat.lux. Med. Klin. 1914, 10: I: 1013—1014.

LÜCKERATH, F.: Die habit. Lux. der Kniescheibe. Dtsch. Z. Chir. 1919, 149: 236—264.

MAC AUSLAND, W. R. & SARGENT, A. F.: Rec. disloc. of pat. Surg. Gynec. Obstet. 1922, 35: 35—41.

MC CARROLL, H. R. & SCHWARTZMANN, J. R.: Lateral disloc. of pat. J. Bone Jt. Surg. 1945, 27: 446—452.

MC FARLAND, B.: Excision of pat. for rec. disloc. J. Bone Jt. Surg. 1948, 30 B: 158—159.

MC KEEVER, D.: Transplantation of the tibial tubercle. J. Bone Jt. Surg. 1951, 33 A: 478—479.

— Rec. disloc. of the pat. Clin. Orthop. 1954, 3: 55—60.

MACEY, H. B.: Disc. See Galloway & Macey.

MACNAB, I.: Rec. disloc. of pat. J. Bone Jt. Surg. 1952, 34 A: 957—967.

MALGAIGNE, J. F.: Mémoire sur le déterminations des diverses especes de lux. de la rotule, leurs signes et leur traitement. Gaz. méd. Paris 1836, 433—438, 465—471, 565—569, 673—678.

MALKIN, S. A. S.: Disloc. of pat. Brit. med. J. 1932, II: 91—94.

MARION, J. & BARCAT, J.: Les lux. de la rotule. Rev. Orthop. 1950, 36: 181—241

MARTIN, R.: Lehrbuch der Antropologie, Fischer, Jena 1914.

MARZIANI, R.: Sulla lussazione della rotula e sul suo trattomento operativo. (Ref. in Zentr. Org. ges. Chir.) Arch. Orthop. (Milano) 1930, 46: 797—924.

MASSERONI, A.: Considerazioni sulla patogenesi e terapia della lussazione laterale congenita della rotula. Arch. Orthop. (Milano) 1952, 65: 255—262.

MERKEL, F.: Zur Funktion der Vasti. Arch. orthop. Unfall-Chir. 1925, 23: 203—207.

MERLE D'AUBIGNÉ, M.: Sublux. externe de la rotule dans l'arthrose du genou. Rev. Orthop. 1959, 45: 437—453.

v. MEYER, H.: Der Mechanismus der Kniescheibe. Arch. Anat. Entwickl.gesch. (Anat. Abt.) 1880, 4: 280—296.

— Versuche und Studien über die Lux. der Pat. Arch. klin. Chir. 1883, 28: 256—277.

MEYER, A.: Über Pat.lux. nach innen. Arch. orthop. Unfall-Chir. 1929, 21: 512—524.

MOORE, H. B.: A case of heriditary rec. disloc. of pat. J. Bone Jt. Surg. 1930, 12: 654—655.

MOREIRA, F. E.: Lux. habit. de la rotule. Rev. Orthop. 1939, 26: 202—214.

MORWA, R.: Contribution au traitement des lux. traumatiques récidiv. de la rotule en dehors. Rev. Orthop. 1934, 21: 153—163.

MUMFORD, E. B.: Cong. disloc. of pat. J. Bone Jt. Surg. 1947, 29: 1083—1086.

MURPHY, J.: Cit. Mac Ausland & Sargent, 1914.

NICOD, L. & NIKOLAKAKOS, G.: La lux. spontanée de la rotule. Schweiz. med. Wschr. 1963, 93: 314—315.

NICOLL, E. A.: Principles of exercise therapy. Brit. med. J. 1943, I: 747—750.

NIKOLAI, N.: Die traumatische Kniescheibenverrenkung und ihre Folge. Mschr. Unfallheilk. 1960, 63: 215—224.

OBER, F. R.: Slipping pat. or rec. disloc. of pat. J. Bone Jt. Surg. 1935, 17: 774—779.

PAYR, E.: Das „Patellarspiel" und seine Bedeutung für die Pathologie des Kniegelenks. Chirurg 1928, 1: 7—14 and 66—76.

— Über die Behandlung der gewohnheitmässigen oder „rückfälligen" Verrenkung der Kniescheibe. Zbl. Chir. 1934, 61: II: 1554—1559.

PELTESOHN, S.: Das Verhalten der Kniescheibe bei der Little'schen Krankheit. Diss., Leipzig 1901.

PITZEN, P.: Über Ursache und op. Behandlung der habit. Pat.lux. München. med. Wschr. 1938, 85: 1577—1578.

POLLARD, B.: Old disloc. of pat. reduced by intraarticular op. Lancet 1891, 1: 988.

POUYANNE, L.: Lux. récidiv. de la rotule traitée par l'op. de Krogius. Rev. Orthop. 1945, 31: 233.

PRUVOT, G.: Lux. spontanées habit. de la rotule. Rev. Orthop. 1950, 36: 51—53 and 454—455.

PRYOR, J. W.: Bilateral symmetry as seen in ossification. Amer. J. Anat. 1936, 58: 87—102.

RAVELLI, A.: Zum Röntgenbild des menschlichen Kniegelenkes. Fortschr. Röntgenstr. 1949, 71: 614—619.

RICHERAND, A.: Cit. Isermeyer, 1802.
RITVO, M.: Bone and Joint X-ray Diagnosis. Henry Kimpton, London 1955.
ROBERTSON, G.: A method of treatment for habit. disloc. of pat. Surg. Gynec. Obstet. 1912, 14: 378—379.
ROHLEDERER, O.: Ätiologie und Symptomalogie der Praelux. Pat. Zbl. Chir. 1951, 76: I: 103—115.
— Die Torsionsverhältnisse des Kniegelenks. Z. Orthop. 1962, 96 (Beilageheft): 192—197.
ROLANDER, S.: Patellarluxationens behandling. Nord. Med. 1961, 66: 1634.
ROUX: Lux. habit. de la rotule. Traitement op. Rev. Chir. (Paris) 1888, 8: 682—689.
ROVIRA, M. & BARRIOS, A. D.: Contribucion al Esterdo de la Luxacion Cong. de la Rotula. Chir. del Aparato Locomotor. 1951, 8: 169—179.
RÜTT, A.: Zur Therapie der sog. habit. Pat.lux. Arch. orthop. Unfall-Chir. 1959, 51: 376—385.
— Die Torsion des distalen Femurendes und ihre röntgenologische Erfassung. Z. Orthop. 1962, 96 (Beilageheft): 149—154.
SAEGESSER, M.: Spezielle Chirurg. Therapie. Huber, Bern 1949.
SAUSER, G.: Die Ötztaler. Ber. Naturwiss.-mediz. Verein. Innsbruck. 1938, 45—46: 246—258.
SAMSON, J. E.: Le traitement de la lux. habit. de la rotule par la greffe osseuse. Rev. Orthop. 1928, 15: 334—339.
SCHANZ, A.: Zur Behandl. der habit. Pat.lux. Z. orthop. Chir. 1900, 7: 531—533.
— Die habit. Lux. der Kniescheibe. München. med. Wschr. 1910, 57: 2554.
SCHELLER, S.: Roentgenographic studies on epiphyseal growth and ossification in the knee. Acta Radiol. (Stockh.) 1960, Suppl. 195.
SCHINZ, H. R. et al: Lehrbuch der Röntgendiagnostik. G. Thieme, Stuttgart 1952.
SCHLOFFER: Lux. der Pat. nach aussen. Wien. klin. Wschr. 1906, 519.
SCHMID, F. & HALDEN, L.: Die postfetale Differenzierung und Grössenentwicklung der Extremitätenknochenkerne. Fortschr. Röntgenstr. 1949, 71: 975—984.
SCHOU, J.: Lux. cong. pat. Ugeskr. Læg. 1893, 28: 457—462.
SCHREINER, K. F.: Zur Osteologie der Lappen. Institutet for Sammenlign. Kultur. Oslo 1935, 217.
SCHULTHESS, W.: Zur Pathologie und Therapie der spastischen Gliederstarre. Z. orthop. Chir. 1899, 6: 1—13.
SEEDORFF, K.: Habit. disloc. of pat. treated op. ad modum Goldthwait. Acta orthop. scand. 1946, 16: 203—211.
SETTEGAST: Typische Röntgenbilder von normalen Menschen. Lehmanns Med. Atlanten Bd 5, 211.
DE SÉZE, S.; DJIAN, A. & MAUGEIS DE BOURGUESDON, J.: Etude Radiologique cinetique de l'Articulation du Genou. Rev. Rhum. 1951, 18: 149—154.
DA SILVA, M.: Luxações Rotulianas. Gaz. méd. port. 1951, 4: 375—383.
SJÖVALL, H.: Zur Frage der rezidiv. und perman. Kniescheibenverrenkungen. Acta orthop. scand. 1943, 14: 185—217.
SMILLIE, I. S.: Injuries of the Knee Joint. E & S Livingstone Ltd., Edinburgh 1946.
SOLIERO: Lussazione della rotula. Zbl. Chir. 1906, 33: 1172—1173.
SOMMER, R.: Die traumatischen Verrenkungen der Gelenke. Neue Dtsch. Chir. 1928, 41: 396—420.

SOMMER, R.: Die op. Behandlung der gewohnheitsmässige Kniescheibenverrenkung. Bruns' Beitr. klin. Chir. 1934, 159: 223—228.

SORREL, E.: Disc. Mém. Acad. Chir. 1942, 68: 407.

STRACKER, O.: Zur Op. der habit. Pat.lux. Chirurg 1936, 8: 817—819.

— Die Angeborene Hüftlux. Z. Orthop. 1961, 95 (Beilageheft).

STEINDLER, A.: Orthopedic Operations. Charles C. Thomas, Springfield, Ill. 1946.

STREUBEL, C. W.: Über den Mechanismus der Verrenkungen der Kniescheibe. Schmidt's Jb. ges. Med. 1866, 129—130 and 311—317.

STRUBE, H.: Zur op. Behandlung der Pat.lux. Dtsch. Z. Chir. 1934, 243: 412—419.

SWYNGHEDAUW, P. & LAINE, E.: Les malformations de la rotule dans la genése de la lux. habit. ou cong. de la rotule. Rev. Orthop. 1945, 31: 25—35.

STÅHL, F.: Fracture of patella incidental to lateral disloc. Acta orthop. scand. 1950, 20: 50—63.

TAVERNIER, M. L.: Traitements des lux. recidiv. de la rotule. Rev. Orthop. 1950, 36: 447—448.

TEAL, F.: Treatment of disloc. of pat. Clin. Orthop. 1954, 3: 61—65.

TENNEY, B.: Some surgical conditions in the knee-joint. Ann. Surg. 1904, II: 1—34.

— The anatomy and surgery of the internal derangements of the knee-joint. Ann. Surg. 1908, II: 714—728.

THESTRUP ANDERSEN, P.: Luxatio Patellae (in Danish, with an English summary), Diss., Copenhagen 1955.

— Disloc. of pat. and achondroplasia. Acta orthop. scand. 1958, 28: 27—50.

— Treatment of rec. disloc. of pat. by the method of MacCarroll & Schwartzmann. Acta chir. scand. 1959, 117: 252—257.

THOMAS, H. O.: Cit. Sommer, 1892.

TOURAINE, A.: L'Hérédité en Médecine. Masson & Cie, Paris 1955.

TRENDELENBURG, F.: Disc. Zbl. Chir. 1900, 27: 1027.

TREVOR, D.: Surgery of the pat. Ann. roy. Coll. Surg. Engl. 1957, 20: 298—315.

VEDOVA, R. DALLA: Neues op. Verfahren in der Behandlung der habit. Kniescheibenverrenkung. Zbl. Chir. 1909, 36: I: 449—451.

VINDITTI, D. & FORCELLA, G.: Un Nuovo Intervento per il Trattamento della Lussazione Cong. di Rotula. Chir. Organi Mov. 1958, 45: 502—510.

VINDITTI, D.: Le Lussazioni recidivanti di rotula. Minerva Ortop. (Torino) 1954, 515: 151—171.

VOGLER, W.: Untersuchungen über die sagittale Krümmungsform der Femurkondylen am gesunden Kniegelenk. Diss., Kiel 1962.

WAGNER, L. C.: A plastic op. for relief of rec. slippings and disloc. of pat. J. Bone Jt. Surg. 1932, 14: 332—334.

WATSON-JONES, R.: Fractures and Joint Injuries. Livingstone, Edinburgh and London 1955.

WHITELOCKE, A.: The op. treatment of outward disloc. of pat. Brit. J. Surg. 1914, 6—16.

WIBERG, G.: Roentgenographic and anatomic studies on the femoropatellar joint. Acta orthop. scand. 1941, 12: 319—410.

WIEMUTH, V.: Die habit. Verrenkungen der Kniescheibe. Dtsch. Z. Chir. 1901, 61: 127—172.

WILES, P.: Essentials of Orthopaedics. Churchill, London 1951.

WREDE, L.: Beitrag zur Kasuistik und Aetiologie der erblichen angeborenen Kniescheibeverrenkung. Med. Klin. 1911, 7: 1: 19—20.

XOUDIS, A.: Etude clinique et traitement de la lux. cong. de la rotule en dehors. Diss., Paris 1924.

ZANOLI, F.: La lussazione cong. della rotula & Lussazione patol. della rotula. Chir. Organi Mov. 1926, 10: 83—164 & 593—604.

ZURRIA, G.: Lussazione cong. della rotula. Boll. Soc. med. chir. Catania 1934, 2: 163—167.

ÖWRE, A.: Chondromalacia patellae (In English). Diss., Oslo 1936.