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FRACTURE OF THE PATELLA

A Study of 422 Patellar Fractures

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INTRODUCTION

The patella is of importance for the extension of the knee-joint. It increases the force of the quadriceps apparatus by improving the leverage. Furthermore, the patella protects the anterior articular surface of the distal femur against external violence, but may easily be injured owing to its unprotected position.

Fractures of the patella are common and have increased not least owing to traffic accidents.

The first osteosynthesis, on the whole, of a fresh fracture was performed on the patella by Lister, as early as 1877 (Hirsch 1966). Several methods have since been suggested but there is no unanimity as to the surgical procedure most suitable for the various types of fracture. The advantages and disadvantages with different methods of surgery are still subjects of discussion. The results of treatment vary and only a few extensive follow-up studies with a long period of observation have been published.

Therefore, it was considered appropriate to analyse the late results of treated fractures of the patella in an area with a population of about half a million, where it could be expected that a comparatively large number had sustained acute patellar fracture within a limited period of time.

In October 1959, The Department of Bone and Joint Surgery was opened under the guidance of Professor Erik Moberg, M.D., who, during the following twelve years, was distinguished for the elaboration of the principles of surgical treatment of fractures in Göteborg. During 1959 a Radiographic archive was compiled. The skeletal radiographic examinations were guided and elaborated during the following years by Ass. Professor Sven Scheller, M.D. Consequently, there existed a basis on which a series of accurately radiographically examined and adequately treated patients could be collected and followed up.

The purpose of this study was to elucidate the following problems:

1. Which were the modes of injury and what was the effect on the late results?
2. Which types of fracture occurred and what was the effect on the late results?
3. Which methods of treatment were used, and how did the choice of method affect the late results?
4. Did circumstances other than sequelae of the injury affect the late results?
5. Is there now reason to abandon any surgical method or instead introduce one?

CHAPTER I

PATELLA—ANATOMY AND FUNCTION

Anatomy

The extensor apparatus of the knee-joint has been thoroughly studied and its anatomy is well-known, both with respect to the patella and the connected muscles, tendons, and ligaments. This brief survey is based on the following publications: v. Lanz & Wachsmuth (1938), Wiberg (1941), Hirsch (1944), de Palma (1954), Baumgartl (1964), and Smillie (1970).

The patella is a flat, in the frontal section triangularly shaped bone with rounded edges. Its distal part is called the apex, its proximal part is referred to as the basis. The patella is situated in the anterior area of the knee-joint and its cartilage surface facing the distal femur is the facies articularis patellae, which through a vertical ridge is divided into a small medial and a large lateral portion. A closer inspection reveals that the cartilage surface consists of no fewer than seven different facets. At the medial margin there is a narrow strip-shaped facet. The remaining cartilage surface of the patella is divided into two lower, two intermediate and two upper facets, situated in pairs, and separated by the vertical ridge. The basis and sides of the patella give insertions to fibres from the rectus femoris, vastus intermedius, vastus lateralis and vastus medialis. The apex is joined to the tuberosity of the tibia via the patellar ligament. The slightly convex anterior part of the patella is covered with fibres from the quadriceps tendon which proceed into the superficial layer of the patellar ligament. The cartilage surface of the patella articulates with the cartilage surface of the distal femur.

With regard to the various shapes of the patella (Knutsson 1941), Wiberg (1941) distinguishes three types:

In type I, the ridge is situated almost in the centre of the patella thus dividing the articulating surface into two almost equally sized halves, concave in transversal section.

In type II, the ridge is situated more medially which results in the medial portion being considerably smaller than the lateral.

In type III, the medial portion is smaller still and, furthermore, convex.

Baumgartl (1964), moreover, mentions a fourth type with the medial

portion neither concave nor convex but plane and, in addition, the so-called "Jägerhutpatella", where the medial facet is lacking.

The various shapes are believed to be of importance for the weight-bearing of the articular cartilage (Wiberg 1941, Hirsch 1944).

The contact surface between the patella and the distal femur varies with different positions of the knee-joint. In the extended position only the lower facets of the patella articulate with the femur, while increasing flexion brings a larger portion into contact with the femur. At maximal flexion, to a certain extent, the patella sinks in between the femoral condyles with simultaneous lateral displacement. In this position, the upper facets of the patella articulate with the articular surface of the distal femur.

The vascular anatomy of the patella has been studied by Crock (1962) and Scapinelli (1967). The superior, medial, and inferior genicular arteries together form a patellar rete, thus penetrating the entire patella, particularly in the centre and lower pole posterior to the patellar ligament. Scapinelli found 41 cases of ischemic necrosis resulting from a transverse fracture of the patella. In 38 of these cases the proximal fragment was necrotic. The radiographically established density was most pronounced 2–3 months after the trauma and disappeared after six months without leaving any permanent loss of function. (From the point of view of vascular anatomy, he recommends that the proximal portion be removed if transverse fracture demands partial patellectomy.)

The patella is incorporated in the tendon system of the quadriceps muscle which consists of the rectus femoris, vastus intermedius, vastus lateralis, and vastus medialis. Lieb & Perry (1968) differentiated between vastus medialis longus and obliquus, the former longitudinally directed and the latter more transversally. In some instances they are separated by a fascia. The strong quadriceps tendon which inserts into the proximal portion of the patella, includes almost all fibres from the rectus femoris and all from the vastus intermedius. Furthermore, proximal fibres from the vastus lateralis and medialis are included. The tendon consists of a superficial portion which continues across the anterior part of the patella down into the patellar ligament, and a deeper and stronger portion which inserts into the patella.

Passing the patella on its lateral and medial sides a few tendinous fibres from the rectus femoris and many from the vastus lateralis and medialis, respectively, insert directly on the tibia. Mainly these fibres are longitudinally directed and together with deep transverse fibres, originating from the femoral epicondyles and inserting into the patella, they constitute the patellar retinacula. The longitudinal portion of the retinacula (syn. the lateral expansions of the tendinous system of the quadriceps apparatus, abbr. the lateral expansions) serves together with the ilio-tibial tract as the auxiliary extensors of the knee-joint (German=Reservestreckapparat). If the patellar retinacula are

preserved—although the extensor apparatus is injured, for instance, in patellar fracture—it is possible to walk without limping and, in a supine position, lift the leg (v. Lanz & Wachsmuth 1938).

The patella has been called the largest sesamoid bone of the body (Jonasch 1964) developed in order to protect the quadriceps tendon where it slides across the distal femur (Gegenbauer 1876). According to Brooke (1937) and v. Lanz & Wachsmuth (1938) the patella can be removed without causing considerable functional disturbance. Sometimes the patella is missing in the newborn (Wuth 1899). Baumgartl (1964) contradicts the opinion that the patella is a sesamoid bone and refers to embryologic studies by Bernays (1878), de Vriese (1909) and Jarecki (1932). The patellar rudiment can already be observed in the ninth embryonic week, prior to the development of the cavity and the musculature of the knee-joint. Furthermore, the patellar rudiment does not lie inside but under the tendon of the quadriceps muscle. In conformity with de Palma (1954), Baumgartl believes that the patella is not a sesamoid bone, but a specific part of the skeleton which cannot be removed without causing permanent disability.

Function

"The action of the quadriceps in producing extension of the knee-joint is the basic factor in maintaining the erect position in man" (Smillie 1970). Among the various muscles belonging to the quadriceps, he attaches a certain amount of importance to the vastus medialis for the final extension and holds this muscle to be "the key of the knee". According to Smillie it does not begin to act until the last 15 degrees of extension and it is also responsible for the stability of the joint. In conditions which impair the activity of the quadriceps, atrophy of the vastus medialis has been fully visible prior to the onset of atrophy of the other portions, and sometimes a simultaneous deficiency of extension has been present (Smillie).

Other authors have not demonstrated any selective activity of the vastus medialis in the final extension of the knee-joint. Electro-myographic studies by Brewerton (1955), Pocock (1963), Hallén & Lindahl (1967) and Lieb & Perry (1971) show continuous activity in all portions of the quadriceps during movement from a flexed to a maximally extended knee. According to Hallén & Lindahl, there was a reduced EMG-activity following local anaesthesia of the vastus medialis which, however, did not cause any difference in the extension capacity.

Investigations of the extension force of the knee at various positions of flexion show that the force is greatest at degrees between 60 and 75 (extended knee=0°) and decreases both with a large and a small angle of flexion (Clarke

et al. 1950, Lindahl, Movin & Ringqvist 1969). This fact confirms von Schwann's law: The tension of contraction diminishes as the muscle fibres shorten (Haxton 1945).

The pressure transferred from the patella to the femur was calculated by Fürmaier (1953). It is directly dependent on the position of flexion in the knee-joint and the weight of the body. His tables show that when a person weighing 60 kg allows his entire weight to rest on a flexed knee, the pressure between the patella and the femur is 162 kgf at a flexion of 45 degrees, 444 kgf at a flexion of 90 degrees, and 774 kgf at a flexion of 135 degrees. Maquet (1969) performed similar calculations and found even higher pressure between the patella and the femur. If the weight-bearing of a flexed knee equals the entire body-weight of a 60 kg heavy person, the pressure between the patella and the femur, according to his calculations, amounted to 256 kgf at a flexion of 36 degrees, and 420 kgf at a flexion of 47 degrees.

Morrison (1969) performed dynamic studies on walking on stairs and on a sloping ramp. When walking down the ramp, the mean pressure between the femur and the tibia was measured to be 3.83 times the body-weight. The greatest value of muscle force calculated was a tension of 564 pounds in the quadriceps whilst the muscle was lengthening. This force was developed by a subject walking down the ramp.

Frankel & Burstein (1970) calculated the force on the patellar ligament to be 316 kg during the act of kicking a football under maximal acceleration of the lower leg, the body-weight of the subject being approximately 100 kg.

A lacking patella, according to Fürmaier (1953), will increase the pressure between the femur and the tibial plateau. Maquet (1969) calculated a considerable reduction of pressure between the patella and the femur to result, if the tibial insertion of the patellar ligament were to be moved anteriorly. (He recommends this procedure in attempts to treat osteoarthrosis of the patello-femoral joint.)

CHAPTER II

FRACTURES OF THE PATELLA

Occurrence

Fractures of the patella constitute approximately one per cent of all skeletal injuries (Järvinen 1942, 0.5%; Schönbauer 1959, 0.86%; Villiger 1965, 1.6%).

Injuries resulting from traffic accidents increase the number of these fractures (Schönbauer 1959, series 1925–1952, 21.3%, Villiger 1965, series 1958–1963, 51%).

Fractures of the patella occur in all ages. The frequency in children and adolescents under 15–16 years of age is low, however. Diebold (1927) collected 1,200 cases from the literature, 16 (1.34%) of which were younger than 16 years of age. In a series by Järvinen (1942) three of 100 were younger than 15 years of age. Schönbauer (1959) reported five (0.87%) of 578 to be younger than 16 years of age.

Thomson (1942) stated the mean age to be 40 years in his compilation of 554 patients with partial patellectomy. Schönbauer found the mean age to be 42.4 years. Nummi (1971) found the mean age to be 41.9 years, the male age being 38.0 years and the female age 48.5 years.

The male representation in many series is in the majority (Diebold 1927, 89%; Schönbauer 1959, 86%; Seligo 1971, 81%). Järvinen reports a male representation of 66 per cent and Nummi 63.8 per cent.

There is no difference with respect to the localization of side in more comprehensive series. Bilateral fractures are uncommon. Schönbauer reported four bilateral fractures in 541 subjects and Nummi five in 702.

Types of fracture

In the literature on fractures of the patella the following classification is often found:

1. Transverse and oblique fractures.
2. Comminuted and stellate fractures.
3. Other types: longitudinal fractures, apical and basal fractures and fractures in the frontal plane.

ad. 1. Transverse and oblique fractures were found in 77.6 per cent by Schönbauer (1959). Also in many other investigations it was found to be the most common type of fracture (Paschold 1958, 66%; Baumgartl 1964, 51.5%; Seligo 1971, 60%), but the frequency is often based only on hospitalized cases. In Nummi's (1971) mode of classification, transverse fractures occurred in 34.9 per cent. According to Schönbauer, the transverse fractures were situated in the middle third in 32 per cent, in the lower third in 22 per cent, and in the upper third of the patella in 14 per cent. The remaining 32 per cent in his series consisted of apical and basal, extra-articularly situated, transverse fractures. According to Nummi, about half of the transverse fractures were situated in the lower third.

ad. 2. Comminuted and stellate fractures constituted the largest group (37.6%) in Nummi's series (1971), but most authors find this type to be more uncommon (Paschold 1958, 28%; Baumgartl 1964, 27.8%; Seligo 1971, 34%). Schönbauer (1959) only reported 9.2 per cent of this type.

ad. 3. Longitudinal fractures are regarded by some authors as very rare (Teubner & Schreier 1968, Black & Conners 1969). However, Schönbauer (1959) in his series reported 12.5 per cent and Nummi (1971) 27.5 per cent. Fractures in the frontal plane are very uncommon (Baumgartl 1964).

A special type of fracture may occur in acute traumatic dislocation of the patella with avulsion of a thin fragment from the medial border. Sometimes a shearing fracture of the anterior portion of the lateral femoral condyle will result at the reposition. The latter fragment will then be moved by the patella to the medial area of the knee-joint (Scheller & Mårtenson 1970).

Mechanisms

In text-books and comprehensive surveys, a question regularly arising is whether the fracture is caused by direct or indirect violence, or by a combination of both. However, already in 1909 Heineck pointed out that etiological studies cannot be a true guide in the decision of surgical or non-surgical procedures. The position of flexion of the knee-joint at the time of the trauma is important (de Palma 1954). Already at a flexion of 30 degrees there is a tilting of the patella which then has a narrow, transversal support (Teubner & Schreier 1968). With the increased pressure against the femur as the knee becomes further flexed, calculated by Fürmaier (1953) and Maquet (1969), and with the great tensile forces of the quadriceps and the patellar ligament, which Morrison (1969) and Frankel & Burstein (1970) measured or calculated, there is a pre-disposition to fractures, either by direct or indirect violence or by a combination of both.

Indirect violence—according to de Palma (1954)—often causes a transverse fracture. The mechanism in indirect violence he describes thus: The quadriceps muscle is forcibly contracted when the entire body weight is transferred to the leg and the knee is semi-flexed in stumbling, for instance. The patella rides high on the femoral condyles where it is firmly kept in place by the quadriceps tendon and the patellar ligament. A sudden contraction of the quadriceps will cause a transverse fracture of the patella. However, he points out that a transverse fracture can also be caused by direct violence, e.g. by a blow from an object.

Direct violence causes patellar fractures increasingly, not least as a result of the motorism becoming progressively greater (J. Böhler 1961). A common cause is when the patella strikes against the dashboard with great force, which has given rise to the expression: "dashboard fracture". These fractures are of different appearances: comminuted fractures with or without separation between the fragments, transverse fractures with two large fragments or transverse fractures with a split upper or lower pole, depending on the length of the leg and the height of the dashboard (Smillie 1970).

Direct violence is considered to be the most common cause of longitudinal lateral fractures (Madlener & Paas 1930). According to Teubner & Schreier (1968) there will be a greater risk of this type of fracture occurring if the appearance of the patella corresponds to Types II and III as described by Wiberg (1941). A further risk—according to Teubner & Schreier—arises when the knee is flexed, as vastus lateralis will then produce a lateral dislocation of the fragment. The dislocation is usually slight, however (de Palma 1954).

Considerable separation between the fracture parts is more often observed in indirect than direct violence (Watson-Jones 1955) and implies that the longitudinal portion of the patellar retinacula has been injured. Both the medial and the lateral portion will be torn. According to de Palma (1954) the extent of the tears depends upon the severity of the force expended to produce the fracture. Smillie (1970) suggests that the victim braces the quadriceps to meet the impact and, the fracture having occurred, the contracting muscle tears the expansions.

According to J. Böhler (1961) it is more important from the therapeutic point of view to decide whether the lateral expansions are torn than to determine the type of fracture.

Diagnosis

The diagnosis of a patellar fracture, in most cases, involves no difficulties. With a wide separation between the fracture parts, it is often possible to palpate an indentation in the place of the patella. The knee-joint is frequently

expanded by a haematoma. The larger the injury of the lateral expansions, the smaller the swelling of the knee, as a rule, owing to the haemorrhage infiltrating the soft tissues. The patient's inability to lift his leg with his knee extended is a typical sign. With minor ruptures of the lateral expansions it may be possible for the patient to lift his leg with a slight deficiency of extension of the knee, but impossible to keep the knee in this position if the leg is subjected to pressure. When the lateral expansions are severely torn, there is a total loss of active extension. The diagnosis of longitudinal fractures, however, may be difficult. The radiograph is unveiling, provided the examination does not only include frontal and lateral views but also axial projection.

Therapy

Development of Methods

Closed methods were generally used in the therapy of patellar fractures up to the latter part of the last century. For instance, methods employed were: splinting of the leg and elevation of the injured extremity, immobilization in plaster with hyper-extension of the knee-joint and flexion of the hip-joint, or elastic bandages followed by early massage treatment.

Earlier a number of constructions had been used to approximate the fragments without open surgery of the fracture. The most well-known device is Malgaigne's hook. Other semi-open procedures were suggested during the latter part of the last century by, inter alia, v. Volkmann (1868) who united the patellar ligament with the quadriceps tendon by putting a suture subcutaneously into the ligament and the tendon. Kocher (1880) percutaneously inserted a silver thread in a sagittal direction into the joint below and around the patellar fragments and then tightened the wire outside the skin.

On March 5, 1877 Cameron of Glasgow performed the first open operation of a patellar fracture at the advice of Lister, who that year reported satisfactory results of fresh injury, treated surgically. Both of them used a silver thread which was inserted through drilled holes in order to unite the fracture parts. On the European continent the first operation of acute patellar fracture was performed in Germany by Trendelenburg in 1878.

At the German Convention of Surgery in 1905, Thiem outlined the treatment of patellar fractures and explained the principles which were to serve as a guide for the continued procedures. He maintained that patellar fractures with severely reduced or lost active extension of the knee, and with separation between the fracture parts, should be treated by open suturation.

Heineck (1909) published a survey from the literature of 1,100 cases of patellar fracture and recommended the following surgical procedures:

"1 — The fracture must be reduced.

2 — The bony fragments must be maintained in intimate apposition until organic union has been effected.
3 — The continuity of the divided soft tissues must be re-established.
4 — The functional integrity of the knee-joint must be restored".

To begin with attention was drawn to various types of suture material for the osteosynthesis. From catgut, kangaroo tendon, silver thread and aluminium bronze thread there was more and more of a change-over to the use of stainless steel wire.

Several modes of applying the metal wire were recommended. Cerclage, i.e. encircling the patella with metal wire, was first employed by Berger (1892) who, according to Thiem (1905), incorporated this word into the medical vocabulary. Cameron and Lister pierced the fracture parts and gained many followers. Quénu (1898) applied the metal wire via a transversally drilled hole in one fragment and around the other. He called this hemi-cerclage. Payr (1917) and later Magnuson (1936) drilled two longitudinal holes and then inserted the metal wire.

Partial patellectomy, retaining one large fragment into which the tendon is inserted after removing the smaller fragments, was introduced by Thomson (1935). In 1942 he reported the results of 554 fractures, treated by 113 surgeons according to this method which has been advocated by many.

Total patellectomy, because of fracture, was performed as early as the turn of the century. Heineck (1909) came to the conclusion that the patella under normal circumstances is not absolutely necessary for the function of the knee. However, functional impairment resulted after removal of the patella. His ideas were instructive for the treatment right up to 1936 when Blodgett & Fairchild, and in the following year Brooke, presented satisfactory results of total patellectomy in fresh fracture. They recommended total excision as a routine method in fresh fracture of the patella. Many authors have later praised this method of operation. From Scandinavia Romanus (1938) and Friberg (1941) reported good results. Moreover, early criticism was raised against routine employment (Moberg 1944, Haxton 1945).

Present Concepts of Treatment

Non-operative treatment is recommended for non-dislocated fractures with a preserved extensor mechanism (de Palma 1959, J. Böhler 1961, Baumgartl 1964, Smillie 1970). L. Böhler (1957) accepts a separation of 2–3 mm between the fragments. If the joint capsule is expanded owing to a haematoma, puncture of the joint is suggested, either immediately (de Palma, J. Böhler and Smillie) or after a few days if the haematoma persists (Baumgartl). A compression bandage should be applied. Sometimes an additional puncture of the

knee is required (J. Böhler). Not until 2 or 3 days have elapsed is a plaster cast applied from the malleoli to the inguen. When the plaster has dried full weight-bearing is generally permitted (J. Böhler, Baumgartl and Smillie), while de Palma recommends partial weight-bearing with crutches as protecting support. Exercise of the quadriceps with rhythmic contractions and leg-raising is instituted after a day or two. de Palma, J. Böhler and Baumgartl remove the cast after 4–6 weeks, while in certain cases Smillie prolongs the time of immobilization in plaster to eight weeks. Then he recommends a strict programme of exercise of the extensors and the flexors of the knee.

Operative treatment is recommended for dislocated fractures where the extensor function is completely or partly lost. A general agreement exists with respect to non-operative treatment but not with regard to the choice of operative method. There are three principles of treatment:

1 — Restoration of normal anatomy.
2 — Repair of quadriceps apparatus, retaining one large fragment.
3 — Total excision of the patella.

ad 1. Restoration of normal anatomy with osteosynthesis is recommended by most authors in transverse fractures with two large fragments, where restoration of the articular surface involves no difficulty. Fixation with a metal wire is—according to Baumgartl (1964)—the best method.

Cerclage—circumferential wire loop—which was introduced by Berger (1892) but is now known as Denègre Martin's method, is used by many and suggested, inter alia, by Anderson (1971).

Metal wire inserted through longitudinally drilled holes, according to Payr, is also recommended, inter alia, by Anderson.

Hemi-cerclage according to Quénu is suggested by Baumgartl.

Transversally drilled holes are also recommended. L. Böhler (1957) uses metal wire and Watson-Jones (1955) catgut.

Metal wire through cross-drilled holes is applied by J. Böhler (1961).

The AO-group has introduced anterior application of one or two wires, inserted through longitudinally drilled holes, for which the so-called "Zuggurtungsprinzip" is employed (Hachez-Leblanc 1958, Weber 1963, Huggler 1964, Tscherne & Szyszkowitz 1968, Müller, Allgöwer & Willenegger 1970).

Fixation by screw (de Palma 1959, Detmar 1966, Smillie 1970) and by various compression instruments (Forgon 1959, Burny 1969) is also carried out.

Post-operative immobilization in plaster is, according to the AO-group, not necessary for healing of the fracture if the "Zuggurtungsprinzip" has been used. With other methods of osteosynthesis immobilization in plaster is recommended but usually not until 10–14 days have elapsed (J. Böhler 1961, Baumgartl 1964, Smillie 1970). Watson-Jones (1955) and de Palma (1959)

apply a plaster cylinder from the malleoli to the inguen immediately after the operation. Watson-Jones applies the plaster with the knee almost fully extended, while de Palma immobilizes with the knee completely extended. de Palma prescribes contractions of the quadriceps immediately after the operation but no leg-raising until two weeks have elapsed. Weight-bearing is generally permitted two weeks after the operation, but de Palma recommends protected weight-bearing on crutches. The duration of immobilization in plaster varies from 3–5 weeks (J. Böhler) and 5–8 weeks (Smillie). de Palma removes the plaster after six weeks.

ad. 2. Partial patellectomy with repair of the quadriceps apparatus retaining one large fragment is often recommended in transverse fractures, with difficulty in achieving a smooth articular surface. Furthermore, partial patellectomy is recommended in transverse fractures with one large and one small fragment or where a small part (1/3–1/2) is split, and in comminuted fractures where a large fragment can be saved (de Palma 1959, J. Böhler 1961, Ehlert 1963, Weller & Samimi 1967, v. Ruéff & Pelzl 1968, Giebel, Krahl & Sabri 1969, Szyszkowitz & Tscherne 1969, Smillie 1970, Anderson 1971). de Palma recommends the method also in transverse fractures with two large fragments if a wide separation exists. Schönbauer (1959) advises against the method and Baumgartl (1964) only uses it in fractures with small pole fragments where osteosynthesis cannot be performed.

Most authors recommend removal of the lower pole (Thomson 1935, de Palma 1959, Smillie 1970, Anderson 1971), whilst Scapinelli (1967) advises removal of the upper pole, if possible.

To attach the tendon, Thomson (1935) drilled two holes from the proximal anterior part of the remaining patella in distal direction to the posteriorly situated part of the fracture surface, but well anterior to the articulating cartilage. The suture material was passed through one of these holes, interwoven deeply into the substance of the opposing patellar tendon, and looped back through the other hole. Duthie & Hutchinson (1958) warn against adapting the tendon to the anterior part of the fracture surface as tilting of the patella may result. Thomson (1942) and Watson-Jones (1955) suggest immobilization in plaster for 1½–3 weeks, while de Palma (1959) and Anderson (1971) follow the same schedule as after osteosynthesis.

In longitudinal lateral fractures the fragment should be excised to prevent osteoarthrosis developing (de Palma 1954, O'Donoghue 1958, J. Böhler 1961, Scapinelli 1967).

ad. 3. Total excision of the patella is recommended in comminuted fractures, where no large fragment is present and in major traumas where the cartilage

surface of the distal femur is also injured (Watson-Jones 1955, de Palma 1959, Schönbauer 1960, J. Böhler 1961, Tessari 1962, Baumgartl 1964, Castaing *et al.* 1969, Jani, Viernstein & Besirsky 1969, Smillie 1970). O'Donoghue (1958) suggests the use of this method in all types of fracture with the exception of marginal avulsions. Sørensen (1964) can find no reason to adopt the method, and Anderson (1971) under all circumstances wishes to save small fragments proximally and distally. Several authors of text-books (de Palma, Baumgartl, and Smillie) believe that this is never the method of choice.

Friberg (1941), Moberg (1944), and Jonasch (1964) emphasize the importance of removing all skeletal tissues in order to prevent regeneration of bone tissue and calcification in the tendon.

Some authors recommend an end-to-end adaptation of the quadriceps tendon to the patellar ligament (J. Böhler 1961, Smillie 1970), while others suture the tendon with mattress sutures in order to avoid deficiency of active extension (Watson-Jones 1955, de Palma 1959). Various plastic methods have been described (Schopp & Fellhauser 1950, Shorbe & Dobson 1958).

In the post-operative course de Palma (1959) follows the same schedule as for other methods of operation. Smillie (1970) uses Thomas' splint for a fortnight and then a plaster splint in extension. Three weeks after the operation quadriceps exercise is practised, but weight-bearing is, according to him, not resumed until the plaster cast has been removed and the leg can be extended without deficiency of extension. Watson-Jones (1955) discards the plaster cast after three weeks, and active flexion and extension exercises are begun. He permits weight-bearing to be resumed after six weeks.

Patellar prostheses have been designed by McKeever (1955) and Clein & Rostrup (1964) but are not commonly used.

All authors emphasize the importance of identifying the injury to the lateral expansions and carefully restoring their anatomy, irrespective of the operation technique selected to repair the fracture.

Results of treatment

There is a large number of reports on the results of treatment of patellar fractures. Heineck (1909) published a survey from the literature of 1,100 cases and Diebold (1927) introduced the literature on 1,200 cases. Many authors have later published their own series which have been smaller. Often they only discuss one or two methods. More comprehensive series have been reported by Schönbauer (1959), Nummi (1971), and Seligo (1971). Schönbauer's primary series consisted of 545 patients during the period 1925–1952, 296 of whom were followed up on an average of eight years after the injury. Nummi published the results of the treatment of 707 patellar fractures during the years

1961–1967 in 702 patients, 391 of whom were followed up on an average of 4.2 years after the injury. Seligo followed up 174 patients selected from an unknown large primary series ranging from 1950–1965.

Subjective complaints are experienced to a great extent by many patients in several series with a long time of observation. Crenshaw & Wilson (1954) emphasize that a follow-up study exceeding one year is necessary to assess the subjective complaints resulting from the injury. Table 1 shows the percentage of patients in three series who had subjective complaints after operative and non-operative treatment respectively.

Reduced range of mobility is reported both for surgically and non-surgically treated patients. Table 2 shows the percentage of patients taken from three large series with deficiency of extension and/or reduced flexion capacity of the knee-joint.

Ehlert (1963) points out that the recovery of mobility depends on the operation technique, time of immobilization in plaster, physiotherapy, and the motivation of the patient. He believes that a long period of immobilization in

Table 1. Subjective complaints after fracture of the patella in three series with a long period of observation.

Author	Mean time of observation (years)	Operated		Non-operated		Notes
		Number of patients	Subjective complaints	Number of patients	Subjective complaints	
Schönbauer (1959)	8	80	66%	194	24%	closed fractures only
Nummi (1971)	4.2	155	86%	236	52%	
Seligo (1971)	see notes	86	72%	88	51%	fractures from 1950–1965

Table 2. Reduced range of mobility in the knee-joint after patellar fracture (three series).

Author	Number of patients	Extension deficiency	Flexion deficiency > 20°
Schönbauer (1959)	274	1.4%	4%
Nummi (1971)	391	6.5%	12.5%
Seligo (1971)	174	22%	8%

plaster will result in the shrinking of the capsule. Impairment of active extension can be found after total patellectomy if the tendon becomes extended (de Palma 1954). On the other hand, Smillie (1970) warns against impaired flexion if overlapping and shortening of the tendon are performed in total excision of the patella.

Positive drawer sign after patellectomy was found by Friberg (1941) in 20 patients out of 32.

The circumference of the thigh frequently becomes reduced after fracture of the patella. Nummi (1971) reported a difference exceeding 3 cm in 72 patients (18.4%). According to West (1962) atrophy of the quadriceps is more common after total patellectomy than after other methods of treatment, as pointed out by Smillie (1970) and Seligo (1971) also.

Reduced force of extension of the knee-joint is also a common finding after fracture of the patella. According to Nummi (1971) almost half of the patients (45.5%) revealed impaired extension force. Seligo (1971) reported pronounced impairment of force after both non-surgical and surgical treatment of patellar fracture, but mentions that the patients often were unaware of this, a fact pointed out by Schönbauer (1959) as well. Haxton (1945) and O'Donoghue, Tompkins & Hays (1952) reported reduced force of extension after total patellectomy. This, Haxton believes, depends on the reduced length of the levers. Even if, from the theoretical point of view, it is accepted that absence of the patella reduces the force of extension, the practical importance has been subject to lively discussions. Brooke (1937) maintains that the force increases after total excision of the patella. Duthie & Hutchinson (1958) observed that the force increased after total patellectomy as compared with partial. Other authors have found no change in the force of extension after total patellectomy (Castaing *et al.* 1969).

The risk of refracture is, according to Jensenius (1952), very great. In fact, he uses this as an argument against osteosynthesis. In Schönbauer's series refracture occurred in six patients (1.1%) and in Nummi's in seven (1.0%).

Nummi reported 17 (5%) cases of pseudarthrosis. Of these 14 had had a longitudinal fracture. The late results were hardly affected. Schönbauer observed pseudarthrosis to the same extent (17 of 330, 5%).

Enlargement of the patella is, according to Sørensen (1964), an important factor in provoking osteoarthrosis. Thomson (1942) mentions that this enlargement does not develop after partial patellectomy, which, in his opinion, many regard as one of the advantages with this method of operation.

Calcium bodies and bone-resembling tissue in the patellar ligament and the quadriceps tendon are believed to cause inconvenience (Moberg 1944, Jonasch 1964). Seligo (1971) maintains that these so-called regenerates have no effect on the late results.

Osteoarthrosis (syn. degenerative arthritis, arthrosis deformans) in the knee-joint after patellar fracture is believed by many to be a common finding and occurs after both non-surgical and surgical treatment. In a series of 54 patients, Paschold (1958) reported osteoarthrosis in 31 per cent of the non-operatively and in 27 per cent of the operatively treated. Villiger (1965) and Seligo (1971) also found osteoarthrosis in a larger frequency after non-surgical than surgical treatment. Sørensen (1964) who found no difference in frequency of osteo-arthrosis in those operated in comparison to those non-operated, points out that osteoarthrosis occurred in almost half the number of cases (41%) also in the uninjured knee. Nummi (1971) reported osteoarthrosis in 118 (76.1%) of the surgically and 82 (41%) of the non-surgically treated cases, but mentions that his figures are too high as no regard was paid to degenerative arthritis with increasing age.

The development of osteoarthrosis resulting from fractures treated with osteosynthesis is regarded by several authors to be connected with a persisting step in the articular surface following the operation (Moberg 1944, Schönbauer 1955, Dethloff 1956, J. Böhler 1961, Weller & Samimi 1967, Jani, Viernstein & Besirsky 1969, Nummi 1971). Sørensen (1964) could not demonstrate any connection of that kind.

Detmar (1966) reported a lower frequency of osteoarthrosis after partial as compared with total patellectomy, whilst the experience of Duthie & Hutchinson (1958) was the contrary. They believed that the increased frequency of osteoarthrosis in patients with partial patellectomy depended on tilting of the patella.

Development of osteoarthrosis after total patellectomy has been studied on animals. Bruce & Walmsley (1942) found degenerative changes of the facies patellaris femoris in rabbits after patellectomy. Cohn (1944) compared the development of osteoarthrosis after partial and total patellectomy in rabbits and found an increase in osteoarthrosis in those with total excision. The same was shown in experiments on dogs as reported by de Palma & Flynn (1958). Borsalino (1964) found osteoarthrosis in guinea-pigs which were treated with cerclage and partial patellectomy, but there were no degenerative changes after total excision of the patella.

In their clinical series several authors discuss osteoarthrosis after total patellectomy. Schönbauer (1955) found no osteoarthrosis after total excision in comminuted fractures at the follow-up examination eight years later, whereas osteoarthrosis had developed after other methods of treatment for the same type of fracture. The frequency of osteoarthrosis was lower after total excision as compared with other types of operation, as was demonstrated by Crenshaw & Wilson (1954), Dethloff (1956), Senst & Nowak (1968) and Seligo (1971).

Onset and progressive development of osteoarthrosis should not, according to several authors, be connected with various methods of treatment, but instead with the injury (Duthie & Hutchinson 1958, Paschold 1958, Nowak & Senst 1968). J. Böhler (1961) points out that the often concomitant injury of the articular surface of the distal femur is an important osteoarthrosis-provoking factor.

The period of sick-leave is shorter for non-operatively than operatively treated patients and shorter still after closed than open fractures. Schönbauer (1959) reported the mean period of sick-leave by the following figures:

After non-operative treatment for closed fractures 69 days
After non-operative treatment for open fractures 128 »
After operative treatment for closed fractures 137 »
After operative treatment for open fractures 173 »

Nummi (1971) reported that the median period of sick-leave after non-operative treatment was slightly less than two months. After operative treatment the median period of sick-leave was about four months. After partial patellectomy return to work was somewhat earlier than after osteosynthesis. The median period of sick-leave after total patellectomy was about five months in the same series.

The degree of disablement after patellar fracture as estimated by the insurance companies in Finland was reported by Järvinen (1942). After non-operative treatment no lifelong compensation was paid to anyone. Table 3 shows three series with the percentage of patients who received lifelong compensation and the reduced capacity for work which was believed to exist.

Table 3. Lifelong compensation owing to reduced capacity for work after patellar fracture (three series).

Author	Number of patients	Lifelong compensation	Reduced capacity for work (%)	Notes
Järvinen Finland (1942)	86	17%	10–30%	after operative treatment
Schönbauer Austria (1959)	307	16%	≧10%	
Seligo Austria (1971)	89	16%	20–30%	industrial accidents

CHAPTER III

PRIMARY SERIES

Synthesis

The series is compiled of patients who, owing to injury of the knee, were radiographically examined in Göteborg during the period 1959–1964, and received the diagnosis fracture of the patella. Children and adolescents younger than 16 years of age were not included. The only patients included were those with a verified diagnosis of fresh fracture. Those whose diagnosis, fresh or old fracture, was doubtful were excluded, as well as those who had a medial marginal fracture which could have been caused by acute traumatic patellar dislocation (Scheller & Mårtenson 1970).

The series includes 422 fractures in 416 patients, i.e. 242 fractures in 238 males (57%) and 180 fractures in 178 females (43%). The annual number of patellar fractures in males and females is stated in Fig. 1.

The age and sex distribution of the series is given in Fig. 2.

The mean age of the entire series was 48 years, males 42 years and females 54 years. The youngest patient was 16 years and the oldest 89 years of age. The maximum frequency for males was reached between the ages of 30 and 39 years, and for females between 60 and 69 years.

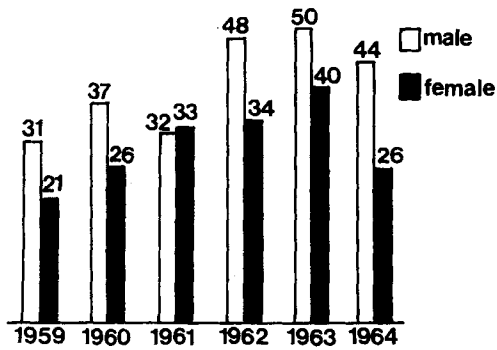


Fig. 1. The annual number of patellar fractures in males and females in Göteborg during 1959–1964.

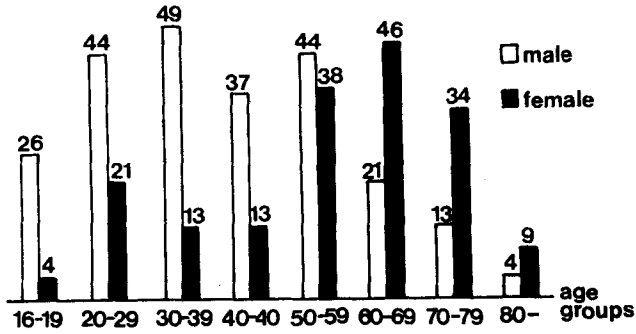


Fig. 2. Distribution of age and sex among 416 patients with fracture of the patella.

The various occupations of the patients are stated in Table 4.

Those who had a mainly sedentary job were regarded as non-labourers. Light manual work was considered to involve active but not heavy work, e.g. shop assistants and foremen. Workers in workshops and building industries were classified as performing heavy manual work.

Methods used in study of series

None of the patients were examined or treated by the author of this investigation at the injury. In order to study the mode of injury, clinical findings, and treatment, the out-patient file cards, case records, and radiographs were checked. Despite the often brief entries in the out-patient file cards the information was satisfactory, however. In 15 cases the radiographs were missing. Copies of notes concerning the periods of sick-leave were obtained from the National Health Insurance Office. All this information, and that collected in connection with the follow-up, was registered, codified and subjected to data

Table 4. Distribution of occupation among 416 patients with fracture of the patella.

Occupation	Number of patients	
Pensioners	93	(22%)
Housewives, non-pensioners	60	(15%)
Non-labourers, incl. students	97	(23%)
Light manual workers	108	(26%)
Heavy manual workers	58	(14%)
Total	416	(100%)

processing at The Gothenburg Universities' Computing Centre under the guidance of Lars-Åke Furingsten, System Manager. The programming was performed by Miss Lena Karling. For the data processing, an IBM 360/65 Computer was used.

Throughout this report statistical analysis was based on the Chi-square contingency table test. In most cases a 2×2 contingency table was used. At one degree of freedom the 95 percentage point of the Chi-square test gives the value of 3.84. At higher values the significance level is less than 0.05 ($p<0.05$). This means that the deviation is significant. At one degree of freedom the 99 percentage of the Chi-square test gives the value of 6.63. At higher values the significance level is less than 0.01 ($p<0.01$). This means that the deviation is strongly significant. In the following these P values will express significant and strongly significant deviations, respectively.

The statistical analysis was performed by Ulf Runze, B.A.

Modes of injury

The patients were classified according to the mode of injury as stated in Table 5.

In traffic accidents involving motor-cars, the injured patients were either the drivers or the front-seat passengers. In falls from a height the vertical drop was calculated to be at least one step.

Fall in the same plane was the most common cause (54%), and various

Table 5. Mode of injury in 416 patients with fracture of the patella.

Mode of injury			Number of patients	
Traffic accident			116	(28%)
Car accident	51	(12%)		
MC, moped, bicycle	53	(13%)		
Pedestrians	12	(3%)		
Fall in same plane			224	(54%)
Fall from height			57	(14%)
Fall in stairs	33	(8%)		
Other falls from height	24	(6%)		
Direct blow (other than traffic accident)			19	(4%)
Total			416	(100%)

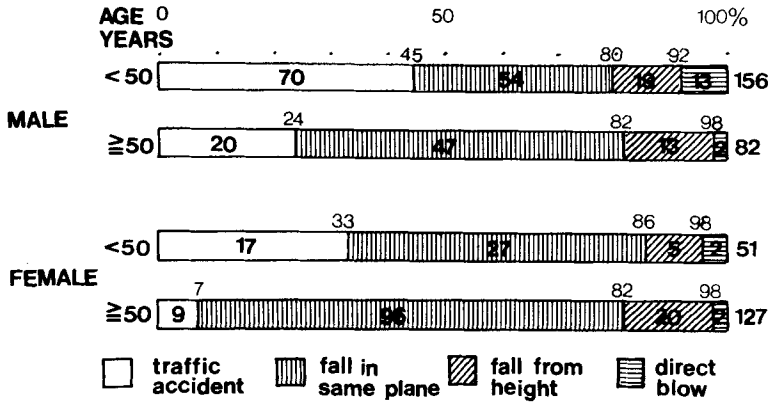


Fig. 3. Mode of injury resulting in fracture of the patella in males and females belonging to various age groups. (The figures refer to percentage and number of patients.)

types of traffic accidents were the next common (28%). Males younger than 50 years of age predominated among those who sustained fracture of the patella in traffic accidents (Fig. 3).

Those who were older than 50 years of age had usually sustained fracture of the patella by falling down in the same plane. 75 per cent of the females older than 50 years of age stated this cause, and 58 per cent of the males ($p<0.01$).

There was no connection between the different categories of occupation and the mode of injury.

Earlier illness or injury

Earlier illness or injury engaging the lower extremities could be observed in 52 patients (12%), Table 6.

Osteoarthrosis-resembling disability meant that the patient had experienced pain in the knee earlier and also stated any treatment received. In 20 cases they referred to the same knee as the injured one. In half of these 20 patients

Table 6. Earlier illness or injury of 52 patients with fracture of the patella.

Earlier illness or injury	Number of patients
Polio or other paralysis	13
Rheumatoid arthritis	8
Osteoarthrosis-resembling disability in the same or the other leg	23
Earlier injury in the same extremity	5
Osteogenesis imperfecta	1
Ankylosis of the knee-joint	2
Total	52 (12%)

who were aged 60 years or more, with the exception of five, osteoarthrosis could be diagnosed on the radiographs.

Localization of side

In 206 patients (49%) the right-sided patella was injured and in 216 (51%) the left one. Of all the patients six had sustained bilateral fractures of the patella, four in traffic accidents, one by falling in the same plane and one by falling from a height.

Open fracture

Open fractures were found in 23 patients (6%). Of these 19 were males and four females. Traffic accidents caused injury to 16 patients, fall in the same plane injured one patient, fall from height was sustained by five patients and direct blow injured one. Transverse fractures with a split lower pole or comminuted fractures were the results in 15 cases. In 19 cases the separation between the fragments exceeded 10 mm. Besides an open fracture 15 patients also had concomitant injuries.

Concomitant injury

Concomitant injuries were found in 64 patients (15%) and are given in Table 7.

Wounds and contusions were not included. Among the skull injuries there were 16 cases of commotio cerebri. There was no case of gross injury to the parenchymatous organs in the series. The group with bone injury of the opposite lower extremity included six cases of patellar fracture. Concomitant injuries were more common in males (18%) than in females (12%). Concomitant injuries in traffic accidents were more frequent (33%) than in other causes of injury (9%). One patient sustained concomitant patellar fracture and luxation of the hip-joint on the same side. At the examination the diagnosis fracture of the patella could be made in all the patients except one. In the exceptional case, which had a non-dislocated patellar fracture, there was an open skull injury with a longstanding period of unconsciousness.

Table 7. Concomitant injuries with patellar fractures in 64 patients.

Concomitant injuries	Number of patients
Bone injury of same lower extremity	17
Bone injury of opposite lower extremity	14
Bone injury of upper extremity	11
Skull injury	18
Thorax injury	2
Back injury	2
Total	64 (15%)

Extension capacity

When it was stated that the patient was unable to extend his leg, this was interpreted as being a loss of active function of the quadriceps apparatus. In cases where it was only with difficulty that the leg could be extended, the function of the quadriceps was regarded as impaired. In the other cases the function was assumed to be preserved. Data regarding the function of the quadriceps apparatus were often missing in the files of ambulant patients. There was a loss of active function of the quadriceps in 137 patients (33%) and impairment in 33 (8%). Preserved extension capability was recorded in 161 patients (39%). In the remaining cases (20%) the data were either missing or incomplete.

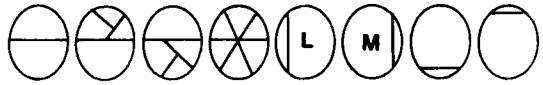
Types of fracture

The radiographic examination at the time of the injury included frontal and lateral projections and nearly always axial projection. The fractures were classified by the author according to the radiographs in groups as indicated in Table 8.

Table 8. Distribution of 422 patellar fractures of various types.

Types of fracture	Number of fractures	
 Transverse fracture with two large fragments	56	(13%)
 Transverse fracture with split upper pole	13	(3%)
 Transverse fracture with split lower pole	74	(18%)
 Comminuted fracture	69	(16%)
 Longitudinal lateral fracture	92	(22%)
 Longitudinal medial fracture	25	(6%)
 Apical fracture	70	(17%)
 Basal fracture	23	(5%)
Total	422	(100%)

Table 9. Mode of injury in various types of patellar fractures.

Mode of injury		Total
Motor car	5 2 13 9 6 4 13 3	55
MC, moped, bicycle	5 5 8 10 10 6 5 4	53
Pedestrians	2 1 1 2 3 2 1	12
Total traffic	12 7 22 20 18 13 20 8	120
Fall in same plane	32 6 36 39 58 8 34 12	225
Fall in stairs	10 10 2 6 1 2 2	33
Other falls from height	2 6 4 6 1 6	25
Direct blow	4 4 2 8 1	19
Total other injuries	44 6 52 49 74 12 50 15	302
Total	56 13 74 69 92 25 70 23	422

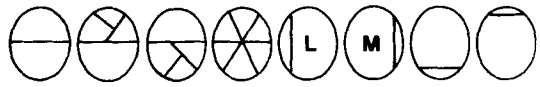
Transverse fractures with a mainly horizontal direction of the split, and two large fragments, were classified in one group. Special groups were composed of cases of transverse fractures where the upper or lower pole was split but where there was a large whole fragment including more than half of the patella. The designation comminuted fracture was a fracture split up in numerous fragments, none of which was larger than half of the patella; stellate fractures were included in this group. Fractures with a mainly vertical direction of the split were classified as longitudinal fractures. Of the longitudinal medial, apical, and basal fractures which together amounted to 118, 91 (77%) were extra-articularly situated.

The total of the transverse fractures was 34 per cent, the comminuted amounted to 16 per cent, the longitudinal lateral to 22 per cent and the remaining to 28 per cent.

The mode of injury, the age and sex connected with various types of fracture are stated in Tables 9 and 10.

The variations of fractures were considerable with each mode of injury. In car drivers and front-seat passengers all types of fracture were represented. Also, in patients who had fallen in the same plane, any of the specified fractures could be found. In this mode of injury, longitudinal lateral fractures formed the largest group (26%). In the rest of the series they amounted to 17% ($p<0.05$).

Table 10. Distribution of age and sex among 416 patients with 422 patellar fractures of various types.

Sex	Age Years		Total
Male	<50	15 8 23 25 34 11 31 13	160
Female	<50	8 7 8 7 3 19	52
Total	<50	23 8 30 33 41 14 50 13	212
Male	≧50	14 2 21 17 14 4 6 4	82
Female	≧50	19 3 23 19 37 7 14 6	128
Total	≧50	33 5 44 36 51 11 20 10	210
Male		29 10 44 42 48 15 37 17	242
Female		27 3 30 27 44 10 33 6	180
Total		56 13 74 69 92 25 70 23	422

Transverse fractures with two large fragments were seen somewhat more often in patients exceeding the age of 50 years as compared with those who were younger than 50 years of age, but the difference in frequency was not significant. This type of fracture occurred equally as often in females as males. A number of different modes of injury was recorded and there was no significant difference in frequency between fractures caused by traffic accidents and those due to other causes.

No significant differences in frequency were observed with regard to age, sex and mode of injury (traffic accidents contra other injuries) in transverse fractures with a split lower pole, comminuted fractures and longitudinal lateral fractures, with the exception that longitudinal lateral fractures were caused by other injuries significantly more often than by traffic accidents ($p<0.05$).

Apical fractures occurred more frequently in persons who were younger than 50 years of age than in those who were older ($p<0.01$). This type of fracture did not reveal any significant difference in frequency with respect to sex or mode of injury (traffic accidents contra other injuries).

The fracture was considered to be non-dislocated if the separation between the fragments was less than 2 mm. The diastasis was regarded as slight if the separation was less than 4 mm, as moderate if it was at least 4 mm but less

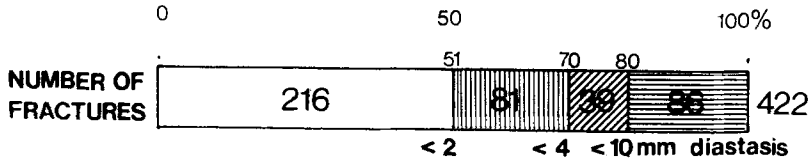


Fig. 4. Distribution of 422 patellar fractures with respect to separation of the fragments.

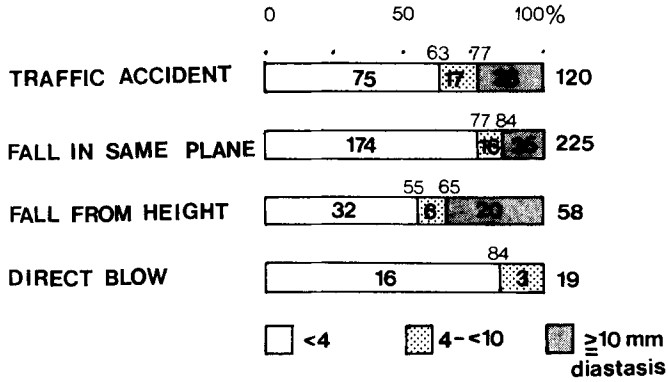


Fig. 5. Distribution of 422 patellar fractures with regard to various modes of injury and resulting separation of the fragments.

than 10 mm, and as considerable, if the separation between the fragments was at least 10 mm. There was no dislocation in 216 fractures (51%), Fig. 4. In a further 19 per cent the diastasis was less than 4 mm. In 125 fractures (30%) the diastasis was 4 mm or more. Of these, 86 fractures (20%) had a diastasis of at least 10 mm.

Considerable diastasis was observed in 35 per cent of the fractures caused by fall from height (Fig. 5). The diastasis was often slight in falling in the same plane.

Transverse fractures with a split lower pole were often dislocated. In 61 per cent there was a separation between the fragments of at least 10 mm (Fig. 6). Considerable diastasis was established also in transverse fractures with two large fragments (29%), and in comminuted fractures (25%). Only in exceptional cases was there a considerable diastasis in transverse fractures with a split upper pole, as well as in apical and basal fractures. In longitudinal fractures the diastasis did not in any case exceed 4 mm.

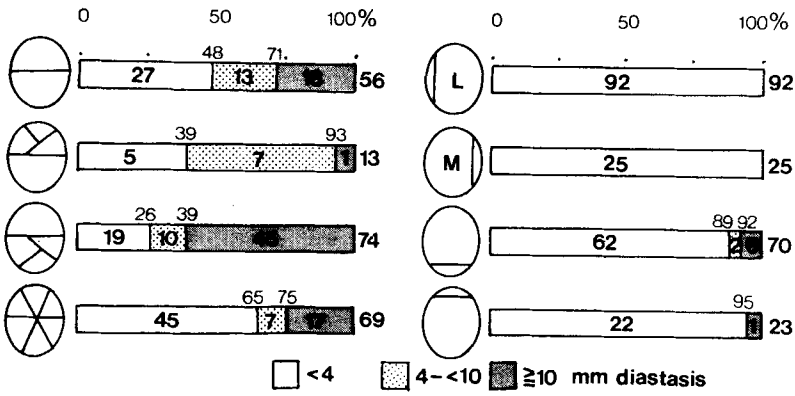


Fig. 6. Separation of the fragments in various types of patellar fracture.

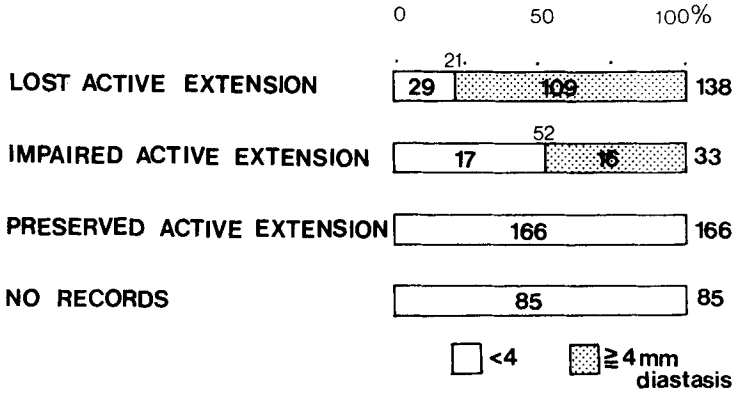


Fig. 7. Function of the quadriceps apparatus with respect to separation of the fragments in 416 patients with 422 patellar fractures.

Of the patients who were considered to suffer from loss of active function of the quadriceps apparatus, 109 (79%) had a separation between the fracture parts of at least 4 mm (Fig. 7). The diastasis did not exceed 5 mm in any of the 16 patients who had impaired active extension of the knee.

A step in the articular surface of the patella of 3 mm or more, in concomitant diastasis less than 4 mm, was found in six patients (Fig. 8). Five of these had preserved active extension of the knee while one had loss of active extension.

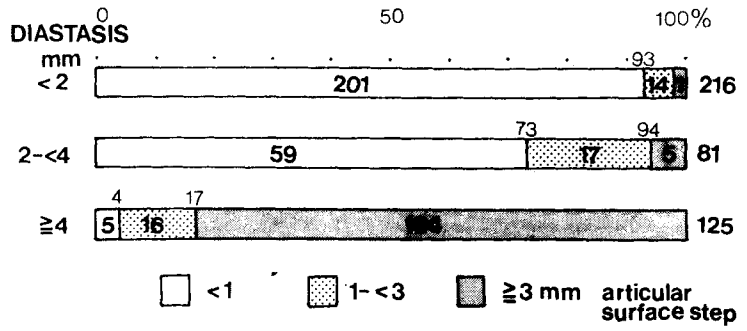


Fig. 8. Relation between diastasis and articular surface step in 422 patellar fractures.

Treatment

On the same day of the trauma 306 patients (74%) came for treatment to the hospital and 83 (20%) within a week. The remaining 27 (6%) did not come to the hospital until one week or more had elapsed. 202 (48%) were treated as in-patients.

The treatment was given at Ekmanska sjukhuset (1/1–15/10 1959), at the two Clinics of Orthopaedic Surgery and at the Surgical Clinics.

The treatment was selected according to the following principles. Non-operative methods were considered applicable if the difference in level between the fragments was less than 3 mm, if the patient could lift his leg with his knee extended and/or if the diastasis between the fracture parts was less than 4 mm. If there was loss of active extension, despite the diastasis being less than 4 mm, the patients were hospitalized. If the extension capability was restored—possibly after puncture of the joint—the patients were not subjected to surgery. In all the other cases surgery was indicated.

Owing to loss of active extension eleven patients were surgically treated despite the diastasis between the fragments being less than 4 mm. In four cases it was stated that the lateral expansions were uninjured and in two that they were torn. In five cases the statements were unreliable.

Five patients were surgically treated despite there not being any loss of active extension and despite the diastasis between the fragments being less than 4 mm. In these cases the lateral expansions were uninjured.

Six patients were not operated on despite the diastasis between the fracture parts being 4 mm or more. Of these, five had impaired active function of extension and one patient had sustained polio and wore a lower extremity support.

Non-operative treatment was performed on 287 fractures in 282 patients

(68%) and operative treatment on 135 fractures in 134 patients (32%). The distribution of non-surgical and surgical treatment with regard to various age groups among males and females is tabulated in Fig. 9.

The methods used in non-surgical treatment are mentioned in Table 11.

Non-surgical treatment, as a rule, included immobilization in plaster reaching from the malleoli to the inguen. In some cases the haematoma in the knee was first punctured. An elastic adhesive bandage was regarded as adequate in some cases, whilst in others no treatment was considered necessary.

Of the 282 non-surgically treated patients, 214 were ambulant and 68 were treated as in-patients. The median period of hospitalization was six days.

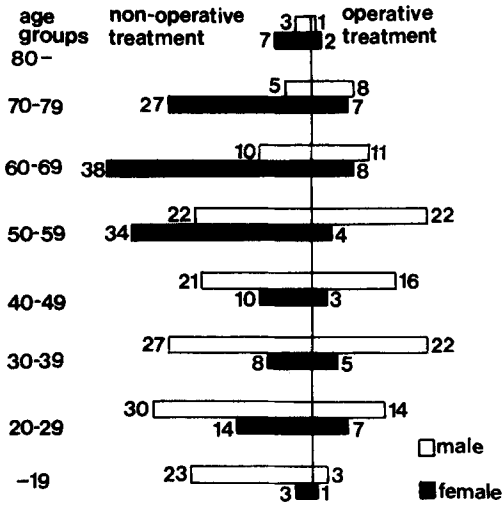
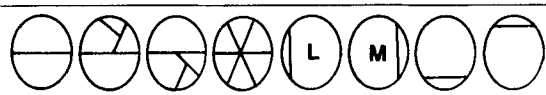


Fig. 9. Non-operative and operative treatment of 416 males and females of different ages with patellar fracture.

Table 11. Non-operative treatment of 287 fractures of the patella.

Treatment		Total
Plaster cast	20 5 14 38 60 10 44 11	202
Elastic adhesive bandage	2 1 3 5 22 12 9 8	62
No treatment	3 2 7 1 9 1	23
Total	25/56 6/13 17/74 45/69 89/92 23/25 62/70 20/23	287/422

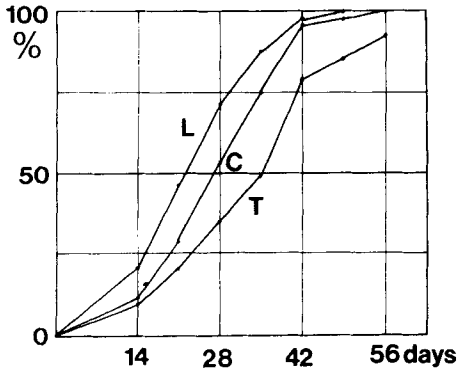
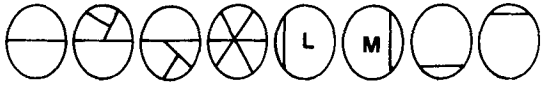


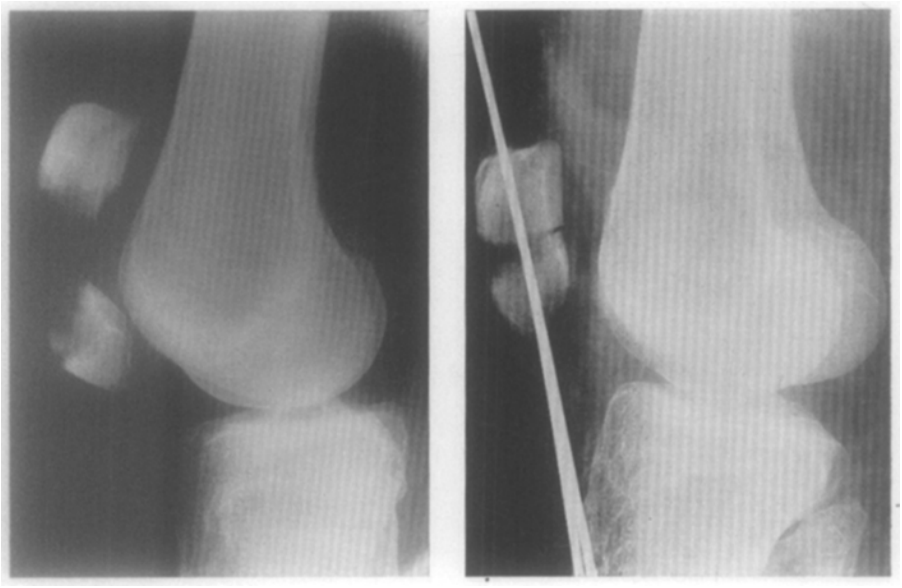
Fig. 10. Cumulative distribution graphs showing period of immobilization in plaster cast in various non-operatively treated types of patellar fracture. (L=longitudinal fractures; C=comminuted fractures; T=all types of transverse fractures.)

Table 12. Surgical methods of treatment for various types of patellar fracture. "Other methods" for osteosynthesis were metal pin (one case), metal wire through cross-drilled holes (two cases), suture with silk, linen or catgut (five cases).

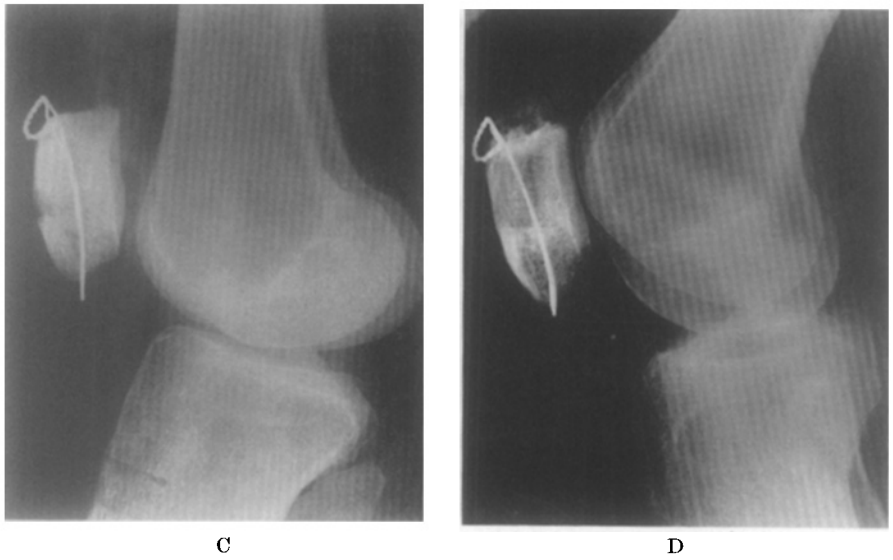
Treatment									Total
					L	M			
Osteosynthesis:									
longitudinally drilled holes	21	3	30	13			2		69
transversally drilled holes	2		1					1	4
encircling wire	5	1	3	3					12
other methods	1	1	2		3		1		8
Partial patellectomy		2	21	3		2	5	1	34
Total patellectomy	1			5					6
Exploration	1							1	2
Total	31/56	7/13	57/74	24/69	3/92	2/25	8/70	3/23	135/422

The approximate median period of immobilization in plaster after non-surgical treatment was four weeks and shorter for longitudinal fractures than for transverse and comminuted (Fig. 10).

When there was an indication for surgery the operation was performed on the same day or on that following. The methods of operation employed are given in Table 12.



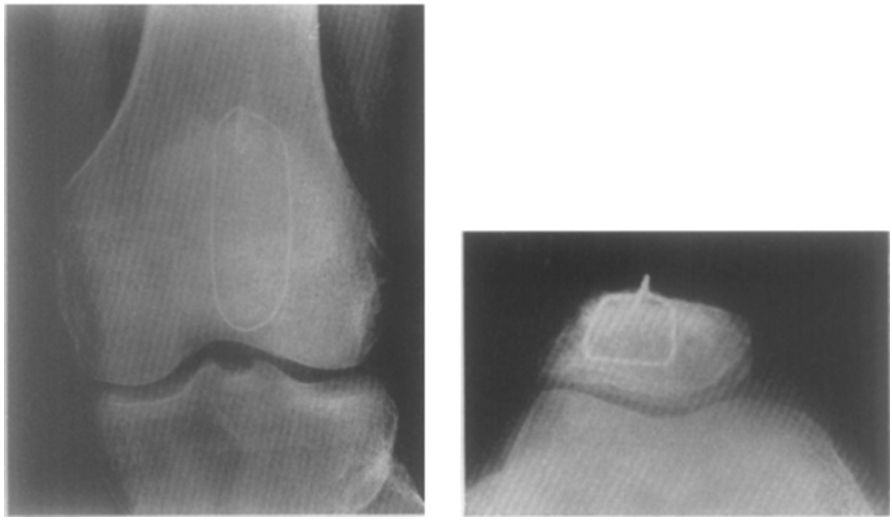
A B



C D

Fig. 11. See text on page 36.

The main principle was to restore the normal anatomy of the patella. The most common method of operation was osteosynthesis with a stainless steel wire inserted through two longitudinally drilled holes. In principle the operation was performed as follows. The operation was made in a bloodless field.



E F

Fig. 11. Transverse fracture of the patella with two large fragments (A) treated by osteosynthesis with metal wire through longitudinally drilled holes (B–C). B shows two Kirschner wires piercing the fragments. (The result eight years later (D–F) was excellent).

After making a medial parapatellar incision the prepatellar bursa was extirpated. The joint cavity was syringed carefully with physiological saline solution. The tear of the lateral expansions was identified. After removing any small fragments the fracture parts were fastened together by means of bone clamps. Two Kirschner wires with a needle's eye were drilled parallelly into the proximal fragment, starting at the basis (Fig. 11). As it was often impossible to drill through both fragments at the same time, the wires were drilled across the line of the fracture far enough to allow distinct impressions to be made in the distal fragment. This indicated where another pair of Kirschner wires could be inserted. A 0.9 mm stainless steel wire was attached to the Kirschner wires and drawn back to the basis where it was tightened with a wire twister. Then the wire ends were recessed into a channel made with an awl in the basis of the patella. Restoration of the articular surface was very much facilitated by inserting a finger into the joint and at the same time hyperextending the knee, thus permitting the articular surface to be palpated (Moberg 1944). After completing the osteosynthesis the tear of the lateral expansions was repaired with catgut or silk.

Partial patellectomy, retaining one large fragment, was the most important alternative to osteosynthesis and was mainly used in transverse fracture with a split lower pole (Fig. 12).

A

B

C

Fig. 12. Transverse fracture of the patella with a split lower pole (A) treated by partial patellectomy (B). (The result ten years later (C) was excellent).

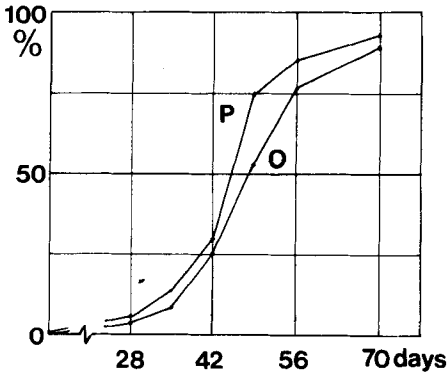


Fig. 13. Cumulative distribution graphs showing duration of immobilization in plaster cast in patellar fractures treated by osteosynthesis and partial patellectomy (P = partial patellectomy; O = osteosynthesis).

Only in exceptional cases—in open fractures—was the patella completely excised.

In open injuries the fracture was surgically treated in 19 out of 23 cases. The operation was performed at the acute stage with one exception. In nine cases osteosynthesis was carried out, in five the patella was partly excised and in another five total patellectomy was performed.

After the operation the leg was immobilized in a plaster cast reaching from the malleoli to the inguen and the knee was fixed in a flexed position of 5–10 degrees. As a rule, there was no drainage. Generally the patient remained in bed for 3–4 days after the operation with the leg elevated. Isometric exercise of the quadriceps muscle was begun on the day after the operation. After a few days leg-raising exercises were instituted. Crutches were used after the mobilization as protecting support, but weight-bearing was allowed.

The median period of hospitalization in operative treatment was twelve days.

The median period of immobilization in plaster cast was 6.5 weeks (Fig. 13). This period did not vary with the methods of operation.

When the plaster cast had been removed the patient was given verbal instructions about extension and flexion exercises. A physiotherapist supervised when necessary.

Complications

No patient died owing to fracture of the patella. There were complications in 19 patients (5%), Table 13.

Four patients sustained refracture after osteosynthesis. In three of these cases the operation had been performed with a stainless steel wire inserted through longitudinally drilled holes. The group "Other Complications" included five patients. Two of these got paralysis of the peronaeus which became permanent in one. Suture migration was found in two patients. Finally, in one patient there was a lengthening of the quadriceps tendon after total excision of the patella; on re-operation shortening of the tendon was performed.

In none of the cases severe infection of the joint set in. No cases of deep thrombosis nor thrombo-embolism were diagnosed.

Re-operations

22 patients (5%) were re-operated on (Table 14).

Release of adhesions was performed in eleven cases. If the mobility was considerably impaired, the patella was mobilized during complete relaxation of the muscles. In no case was this manipulation carried out earlier than two months after the trauma. A sharp hook was inserted percutaneously at the basis

Table 13. Complications in 19 out of 416 patients with fracture of the patella.

	Complications			
Treatment	Wound infection	Refracture	Other	Total
Non-operative		2	1	3
Osteosynthesis	5	4	1	10
Partial patellectomy	1		1	2
Total patellectomy	2		2	4
Total	8	6	5	19

Table 14. Re-operations in 22 out of 416 patients with fracture of the patella.

	Re-operations					
Primary treatment	Osteosynthesis	Total excision	Removal of metal wire	Release of adhesions	Other	Total
Non-operative		1		3	1	5
Osteosynthesis	2		4	6	2	14
Partial patellectomy				2		2
Total patellectomy					1	1
Total	2	1	4	11	4	22

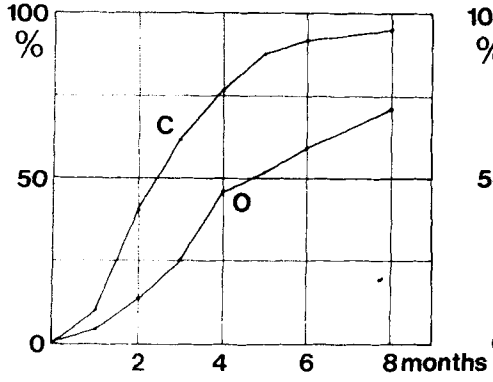


Fig. 14.

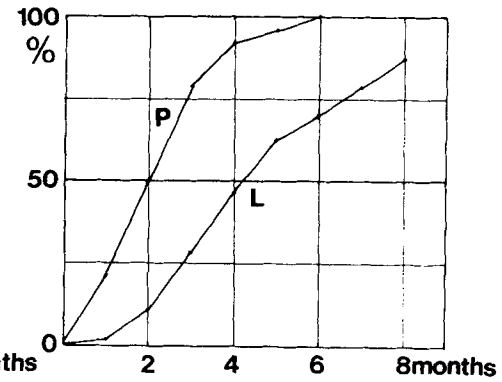


Fig. 15.

Fig. 14. Cumulative distribution graphs showing period of sick-leave after closed and open fracture of the patella. Concomitant injuries are included. (C=closed fracture; O=open fracture.)

Fig. 15. Cumulative distribution graphs showing period of sick-leave in preserved and lost function of the quadriceps in fracture of the patella. Open fractures and concomitant injuries are excluded. (P=preserved quadriceps function; L=lost quadriceps function).

of the patella, lifting the patella slightly. By pressing the thumb against the patella it was carefully worked loose. Small movements from side to side were also brought about. By this careful manipulation it was possible to avoid breaking forces of the fracture line, or tension of the row of sutures. The mobilization had in all cases the intended effect and involved no complications.

Four patients were included in the group of "Other Re-operations": the one mentioned above, on whom a shortening of the quadriceps tendon was performed, two in whom sutural granulomas were extirpated, and one on whom an explorative arthrotomy was done in a late phase because of diffuse joint pain. In this case there was a "slight defect" corresponding to the fracture.

Sick-leave

Of 416 patients, 306 received sickness benefit. The period of sick-leave also depended on factors other than the fracture. There was no difference between the sexes nor between the occupations in the length of time of sick-leave. After open fracture the median period of sick-leave was twice as long as that after closed (Fig. 14). If the extensor function was preserved, indicating a minor injury to the lateral expansions, half the number of patients was discharged after two months (Fig. 15). If there was loss of active extension, four months elapsed before half the number of patients had recovered.

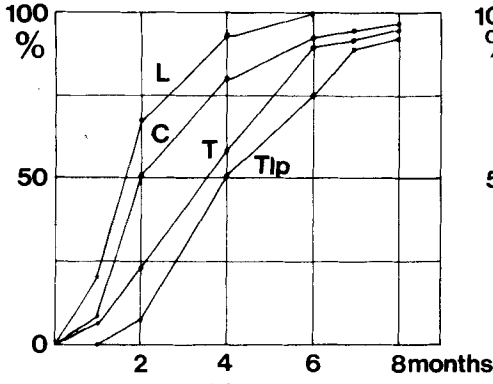


Fig. 16.

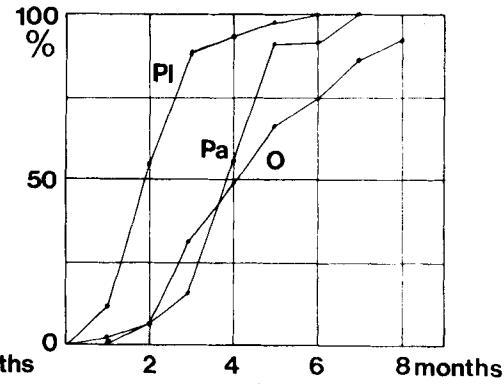


Fig. 17.

Fig. 16. Cumulative distribution graphs showing period of sick-leave for different types of patellar fracture. Open fractures and concomitant injuries are excluded. (L = longitudinal lateral fractures; C = comminuted fractures; T = transverse fractures with two large fragments; Tlp = transverse fractures with a split lower pole.)

Fig. 17. Cumulative distribution graphs showing period of sick-leave with different methods of treatment in patellar fractures. Open fractures and concomitant injuries are excluded. (Pl = plaster cast—non-operative treatment; Pa = partial patellectomy; O = osteosynthesis).

Longitudinal lateral fracture (as well as longitudinal medial, apical and basal fracture) resulted in shorter periods of sick-leave as compared with other types of fracture (Fig. 16).

Of the patients with a longitudinal lateral fracture, 68 per cent were discharged after two months as restored, but of those who had a transverse fracture with two large fragments only 22 per cent.

The median period of sick-leave for patients with a fracture not requiring surgical treatment was half of that required for patients with a fracture treated surgically (Fig. 17).

After four months, 91 per cent of the non-surgically treated patients, immobilized in a plaster cast, had returned to work but only 49 per cent of those on which osteosynthesis had been performed. The median period of sick-leave was slightly shorter after partial patellectomy than after osteosynthesis.

Certificate of disablement

After the treatment was terminated, 19 patients received a certificate of disablement. Two of these had concomitant injuries. Of the remaining 17 patients, five were granted lifelong compensation equivalent to a reduced capacity for work by 10–25 per cent. Temporary compensation was granted to two patients. The reduced capacity for work in the remaining ten cases was not found to exceed 10 per cent.

CHAPTER IV

FOLLOW—UP STUDY

Case series

The follow-up study was carried out during the period 1970–1971. The time of observation varied from 5 to 12 years. The mean time of observation was 8.9 years. The follow-up study included 321 subjects (327 fractures), constituting 91 per cent of those alive at the time of the investigation. 63 subjects had died. 32 subjects were impossible to reach for various reasons. Of the 321 subjects, 247 were thoroughly examined according to the method mentioned below. A further 25 subjects, most of whom were elderly, were examined in nursing-homes, homes for the aged, or in their own homes, but were not radiographically examined. The remaining 49 answered questionnaires, but were not examined. Of these 49 subjects, 21 were asked to come for examination more than four times but refused, 22 lived more than 50 km from the hospital and a further six had died before the clinical investigation was terminated.

From the time of injury to the time of the follow-up, 16 subjects sustained diseases and injuries in the same extremity earlier injured. Of these eleven sustained a fracture of the femoral neck, two other kinds of fracture and three injury of the meniscus. Four subjects were struck by diseases and injuries in the other leg. Two of these sustained a fracture of the femoral neck, one a fracture of the ankle-joint and one injury of the meniscus. These 20 subjects are included in the series.

One subject later sustained a new fracture of the patella of the same leg and was subjected to total patellectomy. He was excluded from the series. Two subjects later fractured the patella of the other leg. These two latter fractures were not treated surgically. The second fracture caused no discomfort. They are included in the series, but the other knee injured later was regarded as uninjured.

When checking the series it was found that of the six subjects who had sustained bilateral fractures of the patella, four had one slightly, and one severely, injured knee, the latter of which only had been surgically treated; one subject was non-surgically treated bilaterally and the remaining was operated on both sides. The condition of the latter subject at the follow-up

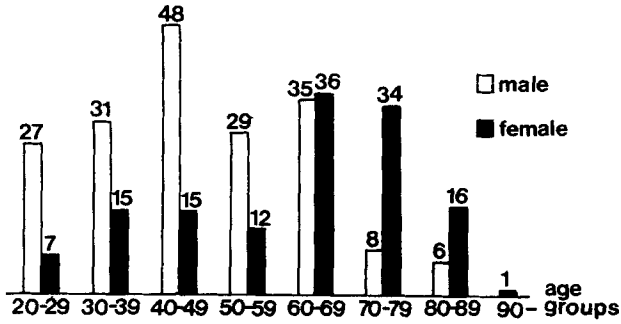


Fig. 18. Distribution of age and sex among 320 subjects with fracture of the patella at the follow-up study.

was affected by the sequelae of a cerebral insult. One knee of the two latter subjects and the slightly injured knee of the other four will in the following be regarded as uninjured. The percentage of the poor results in the final report will not be affected by this exclusion.

In the continued report of subjective symptoms the series includes 320 subjects. The objective and radiographic findings are based on 271 and 246 subjects, respectively.

The distribution of the patients followed up with regard to age and sex is indicated in Fig. 18.

The mean age of the subjects followed up was 53 years, i.e. for 184 males 47 years and for 136 females 61 years. The youngest subject was 21 years and the oldest 96 years of age.

The distribution of non-operative and operative treatment among various age groups of males and females in the follow-up study is stated in Fig. 19.

Methods of treatment of various types of fracture are specified in Table 15.

Methods

A questionnaire was sent to the subjects in which they were asked to state the following symptoms and active function as conceived before and after the injury: pain, swelling, stiffness, unsteadiness, limping, use of stick, capability for walks, mounting stairs, running, and sports. Furthermore, they mentioned further sick-leave because of the same injury, change of occupation, life annuity, and whether they believed that the injury had caused permanent disability.

At the clinical examination between six and twelve months later the questionnaire was verbally discussed. The consensus of the verbal and written answers was satisfactory and, consequently, it was believed that the subjects, whose condition was assessed merely on the basis of the questionnaire, had given an adequate account of their condition.

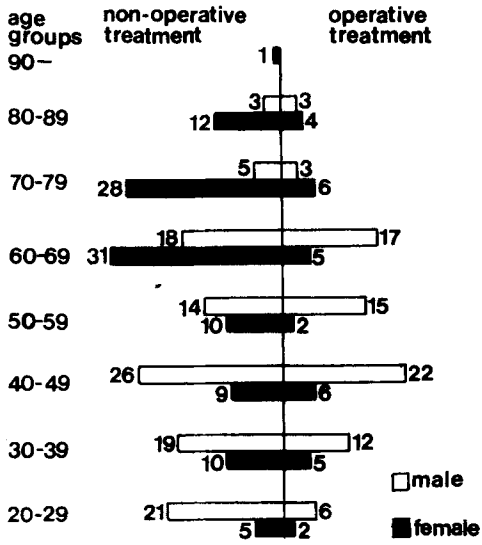
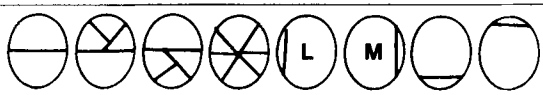


Fig. 19. Non-operative and operative treatment of patellar fracture in males and females of different ages among 320 subjects in the follow-up examination.

Table 15. Methods of treatment for different types of patellar fracture in the follow-up study.

Treatment		Total
Non-operative treatment	18 5 13 29 63 20 51 13	212/287
Osteosynthesis:		
longitudinally drilled holes	17 2 23 10 2	54/69
transversally drilled holes	2	2/4
encircling wire	3 1 3 2	9/12
other methods	1 1 2 3 1	8/8
Partial patellectomy	2 16 3 2 4 1	28/34
Total patellectomy	1 4	5/6
Exploration	1 1	2/2
Total	43/56 11/13 57/74 48/69 66/92 22/25 58/70 15/23	320/422

The nature and degree of pain and the subjectively experienced impairment of function was assessed on the basis of verbal and/or written questioning. Pain and ache were classified according to the following:

1. Temporary ache, e.g. with atmospheric changes or in kneeling posture.
2. Ache, when starting to walk or in connection with a lengthy position, e.g. in a squatting posture.
3. Ache, in connection with exertions.
4. Ache, caused by all activities.
5. Pain at rest.

In analyzing the impairment of function, consideration was taken to the age of the subject. An age limit of 60 years was selected and the functions included were scored (Table 16).

At the clinical examination, walking on a level surface as well as the capability of mounting and descending stairs were assessed. Extension defect and range of mobility of the knee-joints were measured with an angle gauge. The maximal circumference of the calf, the circumference on a level with the patella and the circumference of the thigh, 15 cm proximally to the medial interarticular space, were measured on both legs.

Methods of measuring the extension force of the knee have been elaborated by Clarke *et al.* (1950). He suggests a sitting posture with the knee-joint

Table 16. Estimation of subjectively experienced impairment of function.

Subjectively experienced impairment of function	Age in Years ≧60	<60
Feeling of unsteadiness or weakness	1	2
Limping — following exertions	0	1
— always	1	2
Support — only outdoors	1	1
— always	2	2
Walking distance — impaired (<5 km)	2	2
— severely impaired (<1 km)	4	4
Walking up and down stairs — slowly but with alternating steps	1	1
— mounting stairs with healthy leg first and descending stairs with injured leg first	2	2
Running — impaired	0	2
Sports — impaired	0	2
Maximal score	10	16

flexed through 45 degrees. Tornvall (1963) and Bäcklund & Nordgren (1968) measured the force with the subject in a sitting posture and the knee-joint flexed through 90 degrees. The mean value of the subjects, aged 20–28 years, was in the Tornvall series 50 kgf on the right and 47 kgf on the left side. In medical students of the same age Bäcklund & Nordgren found 65 kgf on the right and 64 kgf on the left side.

The force of the extensor muscles was measured in a special chair designed by Höök & Tornvall (1969) and equipped with a strain gauge dynamometer for measuring isometric power muscles. The knee was flexed through 90 degrees. The maximal force was recorded—often after several attempts, the last value obtained being lower than the highest—and a percentage of the reduction of force was calculated on the force of the uninjured leg. Measurements of the force of the knee extension was made with the assistance of Ewa Landegren, laboratory assistant, Dept of Medical Rehabilitation II, Sahlgren's hospital. In cases when the subjects were examined elsewhere than in the hospital, Zadig's dynamometer was employed (Zadig 1963).

Enlargement of the patella and its mobility was recorded as well as tenderness across the patella and crepitations in the knee-joint.

Radiographs were taken of both knee-joints including frontal, lateral and axial projections; on the injured side, two oblique projections were taken as well. For loading the patellofemoral joint while the axial projection was taken, the subject was standing with the patella to be examined resting against a support, mounted on a special examining stand, and with the knee in a semi-flexed position (Ahlbäck 1968). Other exposures were taken with the subject in a recumbent position. (Ass. Professor Sven Scheller planned the radiographic examination which was carried out by assistants at The Roentgen Department I, Sahlgren's hospital. Recording and assessment of the radiographic findings were performed by the author in conjunction with Ass. Professor Scheller.)

Appraisal of the consolidation of the fracture, fibrous union and pseudarthrosis was included in the radiographic analysis. Cerclage-breakage was recorded as well as articular surface steps, enlargement of the patella, calcium bodies and bone-resembling tissue in the surrounding area, and formation and development of osteoarthrosis. For the estimation of osteoarthrosis the most important factors were changes of the structure—deformation of articular surfaces, presence of cysts, and subchondral sclerosis—and a reduced joint space. The presence of osteophytes was not sufficient evidence for osteoarthrosis to be diagnosed. A source of error could exist as the femorotibial joint—as opposed to the patellofemoral joint—was not examined during weight-bearing of the knee. Osteoarthrosis was recorded and classified according to Kellgren & Lawrence (1957) and Kellgren (1963).

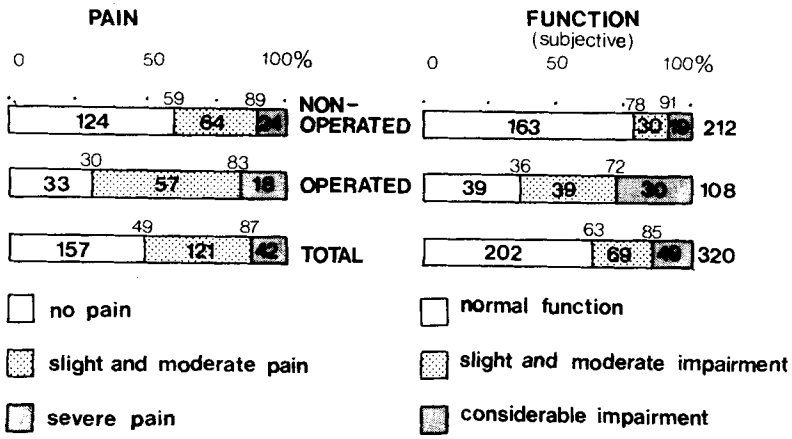


Fig. 20. Subjective symptoms after non-operative and operative treatment of fracture of the patella. (The figures refer to percentage and number of subjects.)

Results

Subjective Symptoms (320 subjects)

When the treatment was ended 78 subjects (24%) did not consider themselves to be fully recovered. At a later date 44 (14%) came for consultation because of discomfort which could depend upon the injury. An operation was performed on eight of these. At the time of the questioning 225 (70%) were satisfied.

The pain in the injured knee was considered as slight if it occurred in connection with kneeling or atmospheric changes, as moderate when starting to walk and as the result of a lengthy squatting posture or during exertions. The pain was regarded as severe if it persisted at rest and/or in all activities. It was found that 157 subjects (49%) had no pain and 63 (20%) had slight pain. Moderate pain was noted in 58 (18%) and severe in 42 (13%) subjects.

The subjectively experienced impairment of function was considered slight if the corresponding score did not exceed 2 points. The impairment of function was moderate if the score exceeded 2 but not 4 and 6 points, respectively. If the score was higher the impairment of function was classified as considerable. No abnormality of the function was stated by 202 subjects (63%). Slight impairment of function was found in 51 (16%), moderate in 18 (6%) and considerable in 49 (15%) subjects.

Subjective symptoms after non-surgical and surgical treatment are indicated in Fig. 20.

None of the 49 subjects who merely answered the questionnaires had severe

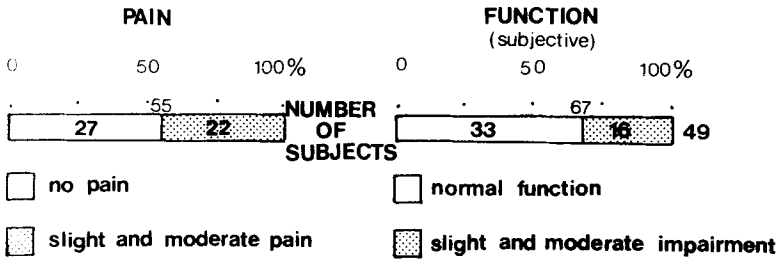


Fig. 21. Subjective symptoms of 49 subjects who merely filled up the questionnaires.

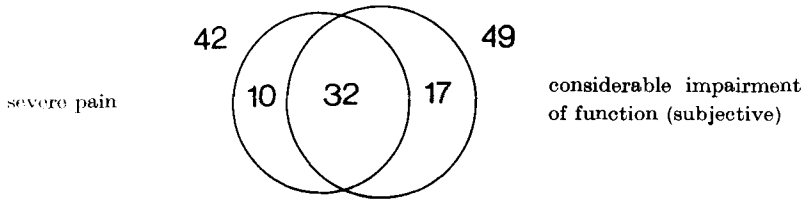


Fig. 22. Severe pain and/or subjectively experienced considerable impairment of function in 59 subjects after fracture of the patella.

pain or subjectively experienced considerable impairment of function (Fig. 21).

Both severe pain and subjectively experienced considerable impairment of function were stated by 32 subjects (Fig. 22).

The occupation of 243 subjects (76%) was the same or similar to that before the injury. The conditions of living of 61 subjects (19%), irrespective of the injury, had changed. Most of these had received their old-age pension. 16 subjects (5%) had received a disablement pension or had changed over to lighter work owing to the injury. Of these, eight had temporary or lifelong compensation.

Objective Signs (271 subjects)

The range of mobility of the injured knee was considered as normal if there was no deficiency of extension and if the knee could be flexed to at least 120 degrees. It was considered as restricted if there was deficiency of extension and/or the bending capacity to a flexed position of less than 120 degrees could be measured. The restriction was regarded as moderate if the deficiency of extension was less than or 10 degrees and/or the bending capacity could be measured to a flexed position of less than 120 degrees but more than 90 degrees. It was regarded as considerable if the deficiency of extension exceeded 10 degrees and/or the bending capacity to a flexed position of 90 degrees or less

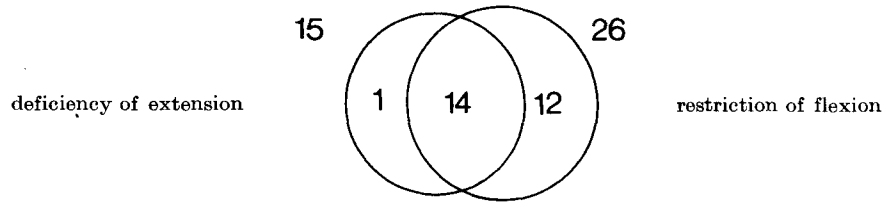


Fig. 23. Restricted range of mobility in 27 subjects after patellar fracture.

could be measured. The range of mobility of the injured knee was normal in 244 subjects (90%). Restricted range of mobility was found in 27 subjects (10%). Deficiency of extension was recorded in 15 subjects (6%). Eight of these had moderate and seven considerable deficiency. The flexion was restricted in 26 subjects (10%). Out of these 14 had moderate, and 12 considerable, restriction. Both the deficiency of extension and the bending capacity to a flexed position of less than 120 degrees were recorded in 14 subjects (Fig. 23).

Out of 27 subjects with restricted range of mobility, 21 (78%) were older than 60 years of age. Operation had been performed on 16 subjects (60%). The median period of immobilization in plaster, 6.5 weeks, was exceeded in 6 subjects (38%) who were surgically treated.

The circumference of the thighs was regarded as equal if the difference in the values measured was nil or less than 1 cm. If the circumference of the thigh was reduced by at least 1 cm, atrophy of the quadriceps musculature was assumed. Atrophy was assessed as moderate if the reduction was less than 2 cm and considerable if the reduction was at least 2 cm. The circumference of the thighs was equal in 185 subjects (68%). Atrophy of the injured side was moderate in 38 (14%) and considerable in 27 subjects (10%). The circumference of the thigh of the injured side was increased in 21 subjects (8%).

The extension force of the knees was regarded as equal if the same value, including a decrease or increase of 10 per cent, was obtained for both sides. The extension force of the injured side was considered to be reduced if the reduction was more than 10 per cent and to be augmented if the increase was more than 10 per cent. The reduction of force was classified as moderate if the reduction was less than 30 per cent, and considerable if the reduction was at least 30 per cent. Equal force was measured in 150 subjects (55%). Moderate reduction of force was noted in 64 (24%) and considerable in 35 subjects (13%). In 22 subjects (8%) the force of the extensor apparatus of the injured knee was increased.

Only in exceptional cases did the force of the extensors exceed 80 kg. The force of the extensors in the healthy knee varied with age and sex, as shown

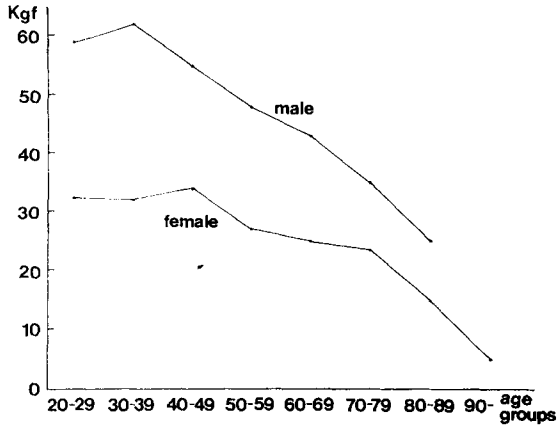


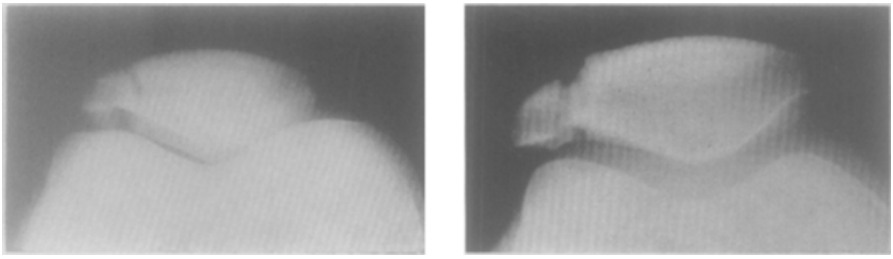
Fig. 24. Mean values of the force of the extensors in the knee of the uninjured side of 271 subjects.

in Fig. 24, in which the mean values are given for males and females in the various age groups.

The rate of considerable reduction of extension force was the same for subjects younger and older than 60 years of age. Considerable reduction of force was found in 20 (23%) of 88 subjects, whose injury caused loss of active extension, and in 6 (5%) of 114 subjects whose capability of extension was preserved despite the injury. Considerable reduction of force was found in 19 (23%) subjects with the fragments of fracture dislocated at least 4 mm, and in 16 (8%) with a diastasis less than 4 mm ($p<0.01$). Considerable reduction of force was found in 23 (26%) operated and 12 (7%) non-operated subjects ($p<0.01$). Out of the 23 subjects operated upon, 16 were subjected to osteosynthesis, three to partial patellectomy and four to total patellectomy (26%, 13%, and 100% of the respective follow-up series).

With an equally large circumference of the thighs, great deviations in the extension force could be obtained. When the circumference of both thighs was the same, the force measured in one subject could be increased by 20 per cent in the injured leg, and in another reduced by 60 per cent. The extension force was reduced in 77 (42%) of the 185 subjects in whom no atrophy was diagnosed. On the other hand, there was no subject who had considerable atrophy and increased extension force in the same leg.

The extension force was reduced in 25 (93%) of the 27 subjects who had restricted range of mobility of the injured knee.



A B

Fig. 25. Longitudinal lateral fracture of the patella (A) treated with immobilization in plaster. (B) shows fibrous union six years later. (The late result was good.)

Radiographic Findings (246 subjects)

25 subjects were clinically but not radiographically examined. 19 were older than 60 years. 22 were not inconvenienced by the knee injury, whilst three maintained that they had persisting disability owing to the injury. Four elderly subjects who were free from symptoms had restricted range of mobility of the injured knee-joint. The circumference of the thighs was equal in all the 25 subjects. Six subjects, three of whom were free from symptoms had reduced extension force of the injured knee.

Union of the fracture, fibrous union, pseudarthrosis, articular surface steps, and enlargement of the patella could be established by radiographic evidence in all the subjects except four on whom total patellectomy had been performed. In 221 subjects (91%) the fracture had united.

Fibrous union was established in 15 subjects (6%), Fig. 25. Out of these, twelve had a longitudinal lateral fracture (Table 17). All 15 subjects were treated non-operatively.

Pseudarthrosis was established in 6 subjects (3%). The fact that they had pseudarthrosis was unknown to all of them. Four were treated non-operatively and two operatively (Table 17).

Table 17. Distribution of various types of fracture among 242 radiographically examined subjects having had patellar fractures, ending in fibrous union, pseudarthrosis, and articular surface steps. The figures in brackets indicate operatively treated cases.

Radiographic findings		Total
Fibrous union	1 2 12	15 (6%)
Pseudarthrosis	1 1 (1) 1 2 (1) 1	6 (3%)
Articular surface step ≧1 mm	7 (6) 4 (1) 10 (9) 6 (2) 7 1 1 4	40 (17%)

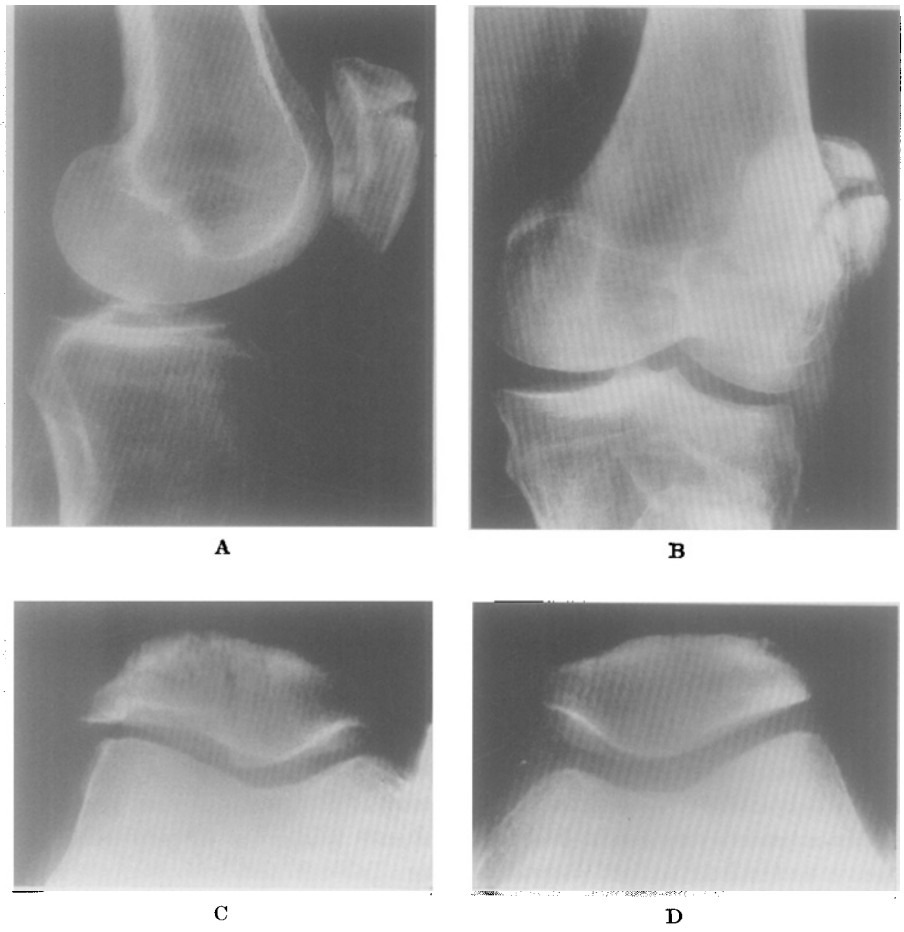
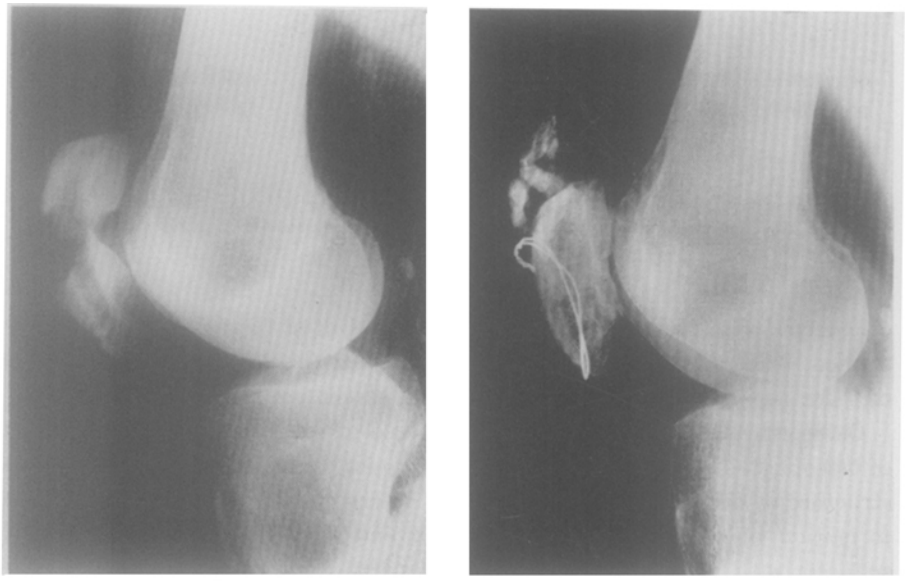


Fig. 26. Comminuted fracture of the patella (A–B) treated non-operatively. Six years later the patella was enlarged (C) compared with the opposite side (D). (The late result was excellent.)

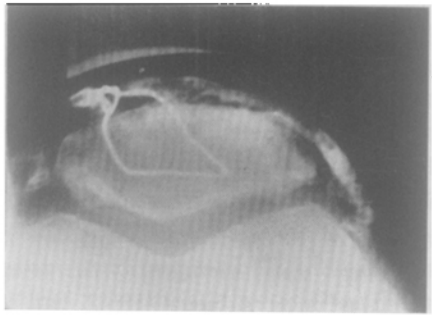
Out of the radiographically examined subjects, 51 were operatively treated by application of a metal wire. In 46 cases the wire was intact, but in five it had broken in one or two places.

A step in the articular surface of the patella of 1 mm or more was established in 40 subjects (17%), Table 17. Out of these 22 were not and 18 were subjected to surgery. In 15 cases osteosynthesis was performed with a stainless steel wire inserted through longitudinally drilled holes.

Enlargement of the patella was considered to exist if an increase of width of at least ½ cm could be measured on the radiograph (Fig. 26). 39 (17%) had



A B



C

Fig. 27. Transverse fracture of the patella with a split lower pole (A) treated with osteosynthesis with a metal wire through longitudinally drilled holes. B and C, seven years later, show bone-resembling tissue in the surroundings of the patella, and articular surface step. (The late result was poor.)

enlargement of the patella of the injured side. Out of these, 22 were non-operatively and 17 operatively treated, constituting 13 and 21 per cent of the respective follow-up series. Enlargement of the patella was established after both osteosynthesis and partial excision.

Sometimes calcium bodies in the surroundings of the patella were visible on the radiograph, and pretty frequently bone-resembling tissue could be seen in the patellar ligament and the quadriceps tendon (Fig. 27). These kinds

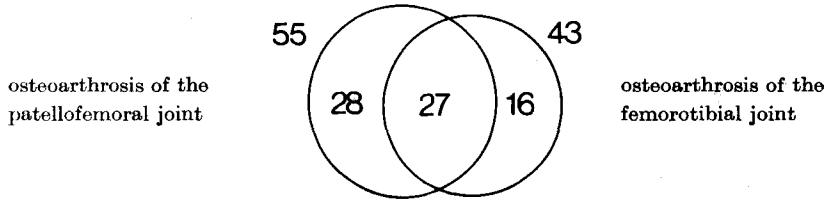


Fig. 28. Osteoarthrosis of the injured knee of 71 subjects after patellar fracture.

of changes were present in 67 subjects (27%). Out of these 56 were surgically treated. The radiographic examination revealed these changes in almost all of those who had sustained partial or total excision of the patella.

Osteoarthrotic changes were not diagnosed on the basis of slight formation of osteophytes and a normal height of the joint space without changes in the structure of the articular surface. Slight osteoarthrosis was established if the formation of osteophytes was moderate and the joint space was slightly reduced with or without structural changes. Moderate osteoarthrosis was present when the formation of osteophytes was moderate or pronounced, the height of the joint space was moderately reduced, and structural changes, such as deformation of the articular surfaces and subchondral sclerosis, were moderate. Considerable osteoarthrosis was diagnosed when the formation of osteophytes and, the reduction of the joint space, were pronounced with a definite deformation of the articular surfaces with sclerosis and formation of cysts in the subchondral bone.

Osteoarthrotic changes in the injured patellofemoral joint were observed in 55 subjects (22%). Out of these, 33 had slight changes, 15 moderate and seven considerable. Osteoarthrotic changes in the femorotibial joint of the injured side were established in 43 subjects (18%). Out of these, 28 had slight changes, eleven moderate and four considerable. The number of subjects with osteoarthrosis of the injured knee totalled 71 (29%), which is illustrated in Fig. 28.

In the patellofemoral joint of the opposite side, osteoarthrotic changes were observed in 19 subjects (8%). Out of these, seven had slight changes, eight moderate and four considerable. In the femorotibial joint of the opposite side osteoarthrotic changes were observed in 23 subjects (9%). Out of these, 16 had slight changes, six moderate and one considerable. The total number of subjects with osteoarthrosis of the opposite side was 27 (11%) as demonstrated in Fig. 29.

Radiographs taken at the time of injury revealed osteoarthrotic changes in the injured knee-joint in 35 subjects (9%).

As degenerative osteoarthrosis may occur simultaneously in both the patello-

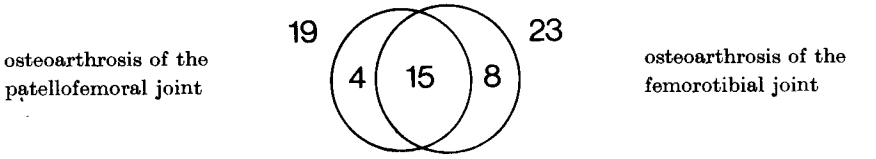


Fig. 29. Osteoarthrosis of the uninjured knee of 27 subjects after patellar fracture of the opposite side.

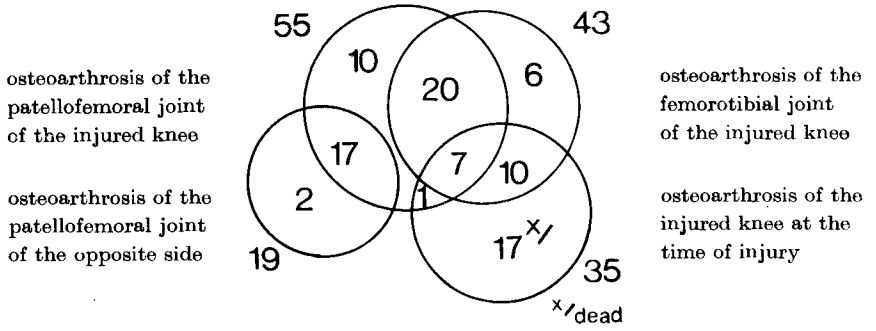


Fig. 30. Osteoarthrosis of the injured knee, as well as of the patellofemoral joint of the opposite side at the follow-up examination, and osteoarthrosis of the injured knee at the time of injury.

femoral and and femorotibial joints of the same knee and, furthermore, develop bilaterally (Ahlbäck 1968), and as osteoarthrosis had been diagnosed in the primary series, a diagram could be traced (Fig. 30) showing the cases in which it could be assumed that the osteoarthrotic changes in the patellofemoral joint of the injured side had developed as a result of the injury. There remained ten cases as stated in the diagram.

However, when patellofemoral osteoarthrosis was observed on the injured side it was also possible to establish whether the osteoarthrotic changes had become increased in comparison with the time of injury and with the opposite side. This type of progressive osteoarthrosis was diagnosed in 24 subjects (10%), none of whom had osteoarthrosis in the femorotibial joint of the injured side.

Osteoarthrosis—irrespective of the genesis and the location—depended on the age of the subjects at the follow-up examination. Osteoarthrosis of the injured knee was found in 42 (39%) of those over 60 years of age, and in 29 (21%) of those under ($p<0.01$). Osteoarthrosis of the knee occurred twice as often in females as in males. Osteoarthrosis of the injured patellofemoral joint was diagnosed in 26 subjects (28%) who were injured in a traffic accident or

by fall from height, and 29 (19%) injured by other modes ($p>0.05$). After open fracture, osteoarthrosis of the injured patellofemoral joint was observed in 9 subjects (60%) and after closed fracture in 46 subjects (20%) ($p<0.01$). After comminuted fracture osteoarthrosis of the injured patellofemoral joint was diagnosed in 17 subjects (42%), and after other types of fracture in 38 (19%) ($p<0.01$). Osteoarthrosis of the injured patellofemoral joint occurred twice as often after operative as after non-operative treatment (35% and 16% of the respective follow-up series) ($p<0.01$). Osteoarthrosis of the femorotibial joint of the injured side occurred just as frequently after operative as after non-operative treatment. The frequency of osteoarthrosis was as large after osteosynthesis as after partial patellectomy (32% and 35% of the respective follow-up series). All four subjects who were radiographically examined after total patellectomy had osteoarthrotic changes in the femoral component of the injured patellofemoral joint.

There was no increase in the frequency of osteoarthrosis of the patellofemoral joint because of fibrous union and pseudarthrosis (24% contra 22% in the other series).

Osteoarthrosis of the patellofemoral joint was found in 16 subjects (40%) with a step in the articular surface of the patella of 1 mm or more, and in 35 (17%) in the other series ($p<0.01$, four cases of total patellectomy excluded). Only seven of these 16 subjects had osteoarthrotic changes which could be assumed to have been formed or developed as a result of the injury. Regarding only those with osteoarthrotic changes of the patellofemoral joint assumed to have been formed or developed as a result of the injury, the frequency of osteoarthrosis was insignificantly higher in those with a step in the articular surface of the patella of 1 mm or more as compared with the other series ($p>0.05$). Osteoarthrosis of the injured patellofemoral joint was insignificantly higher when there was enlargement of the patella (28% contra 22% in the other series, after excluding the cases of total patellectomy) ($p>0.05$). Osteoarthrosis of the injured knee was established in 28 (42%) of the 67 subjects who had calcium bodies and bone-resembling tissue in the surrounding areas of the patella and 43 (24%) in the other series ($p<0.01$).

Correlations

Pain connected with various objective signs is stated in Table 18.

The subjects who had a restricted range of mobility and considerable reduction of force without pain were elderly subjects with osteoarthrosis, irrespective of the injury. Half the number of subjects with fibrous union and pseudarthrosis felt no pain. Some subjects with both osteoarthrosis and an articular surface step of 1 mm or more were free from pain.

Table 18. Subjective symptoms correlated with various objective signs.

Subjective symptoms	Objective signs				
Pain	Restricted range of mobility	Considerable reduction of force	Fibrous union and pseudarthrosis	Articular surface step ≧ 1 mm	Osteo-arthrosis
No pain	7 (26%)	6 (17%)	10 (48%)	12 (30%)	19 (27%)
Slight	3 (11%)	4 (11%)	3 (14%)	9 (22%)	16 (22%)
Moderate	3 (11%)	6 (17%)	6 (29%)	10 (25%)	8 (11%)
Severe	14 (52%)	19 (55%)	2 (9%)	9 (23%)	28 (40%)
Total	27 (100%)	35 (100%)	21 (100%)	40 (100%)	71 (100%)

Out of the 27 subjects with a restricted range of mobility, 22 (82%) had osteoarthrosis at the primary or the follow-up radiographic examination. Out of the 35 subjects with a considerable reduction of force, 21 (60%) had osteoarthrosis at the primary or the follow-up radiographic examination.

Classification of results

The result was considered *excellent* if the subject was free from discomfort without pain or subjectively experienced impairment of function, with a normal range of mobility of the knee-joint and with equal force in the extensor apparatus of both knees. The result was considered *poor* if the injury alone could be assumed to be the cause of pain at rest and/or pain during all kinds of activity. Furthermore, the result was regarded as poor if the injury alone could be assumed to be the cause of at least two of the following three symptoms and signs:

1. Subjectively experienced impairment of function corresponding to a score exceeding 4 and 6 points, respectively.
2. Deficiency of extension exceeding 10 degrees and/or bending capacity to a flexed position of 90 degrees or less.
3. Reduction of force of the extensor apparatus of the knee exceeding 30 per cent of the force of the uninjured knee.

In all the other cases the result was considered *good*. Subjects with a good result formed a heterogeneous group. In this group were included, in addition to those with a good result on account of the injury, also those with a poor result that was not ascribable to the injury but instead probably caused by

another disease. If it had been possible in these cases to assess the real result of the injury, one or other of the subjects might have been referred either to the group excellent or to the group poor results.

Of those who merely answered questionnaires, none were referred to the group poor results. However, it cannot be excluded that one or other might have been included in the group poor results if a complete examination had been carried out.

Of those who were clinically examined, but not radiographically, two subjects were included in the poor results. Possibly one of these or both could have been included in the group good results after complementary radiographic examinations which could have given evidence of osteoarthrosis not being connected with the injury.

Pain at rest and/or pain during all kinds of activity was noted in 42 subjects. In 16 of these the pain could depend on osteoarthrosis of the knee-joint but with no relation to the injury. A further seven had pain which could be caused by some other injury or disease. The remaining 19 subjects were included in the group poor results owing to patellar fracture (Fig. 31).

Impairment of function corresponding to a score exceeding 4 and 6 points, respectively, was subjectively experienced by 49 subjects. In 26 of these the impairment of function could depend on osteoarthrosis, some other disease or injury without any sure relation to the patellar fracture. In the group poor results, owing to patellar fracture, the remaining 23 subjects were included (Fig. 31).

Deficiency of extension exceeding 10 degrees and/or bending capacity to a flexed position of 90 degrees or less was observed in 17 subjects. Eight of these had a restricted range of mobility which could depend on some other injury or disease, especially osteoarthrosis.

Reduction of force of the extensor apparatus of the injured knee, exceeding 30 per cent of the force of the uninjured knee was recorded in 35 subjects. Out of these, 16 subjects had reduced force which could depend on other disease or injury, especially osteoarthrosis.

Deficiency of extension exceeding 10 degrees and/or bending capacity to a flexed position of 90 degrees or less, and/or reduction of the force of the extensor apparatus of the knee exceeding 30 per cent, was established in 46 subjects. To the group poor results, owing to fracture of the patella, 22 of these were included (Fig. 31).

A total of 73 subjects had one or several subjective symptoms or objective signs according to the criteria on which a poor result was based (Fig. 31).

Excellent results were achieved in 145 (45%) and good results in 150 subjects (47%). The results were poor in 25 (8%) subjects. The distribution of the results among males and females is indicated in Fig. 32.

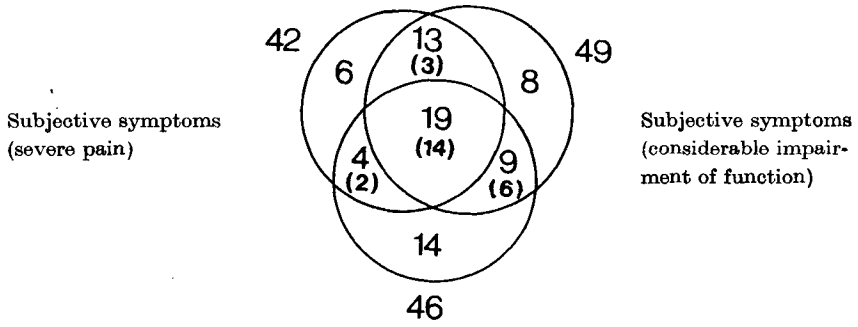


Fig. 31. Subjective symptoms and objective signs of 73 subjects with a poor result in some respect. The figures in brackets indicate the subjects who, according to the classification, were considered to belong to the group poor results owing to patellar fracture.

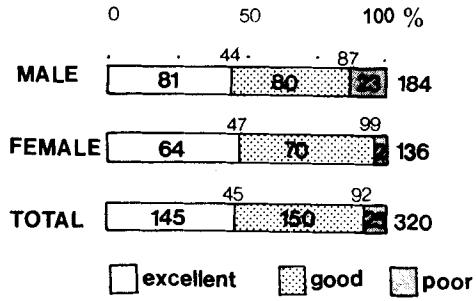


Fig. 32. Late results of patellar fractures in males and females.

There was no difference in the distribution of the results among those over 60 years of age as compared with those under (Fig. 33).

After patellar fractures caused by traffic accidents or falls from height, poor results were more common than after patellar fractures caused by falls in the same plane and by direct blows ($p<0.01$) (Fig. 34).

There were poor results of open fractures in 30 per cent and of closed fractures in 6 per cent ($p<0.01$) (Fig. 35).

In subjects who had a concomitant injury, the result was more often poor as compared with those who had no other injury ($p<0.01$) (Fig. 36).

The results of all types of transverse fracture and comminuted fractures

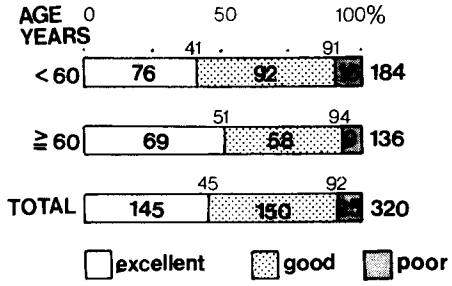


Fig. 33. Late results of patellar fractures in various age groups.

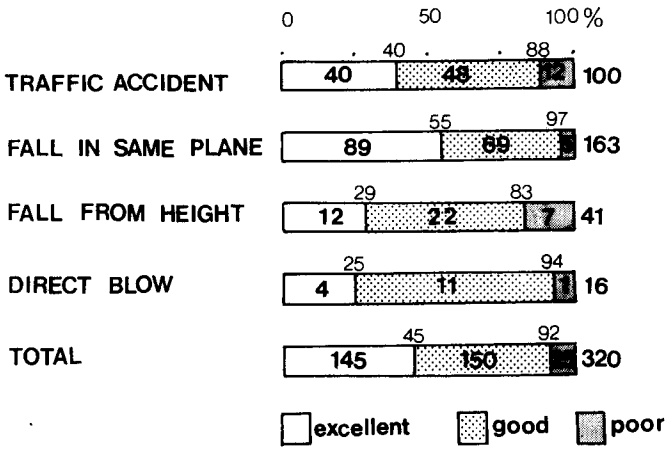


Fig. 34. Late results of patellar fractures as related to the mode of injury.

were equivalent (Fig. 37). The result was poor in one subject who had sustained a longitudinal lateral fracture. Also after longitudinal medial, apical and basal fractures, which generally were extra-articularly situated, the result was poor only in exceptional cases (Fig. 37).

When there was only slight separation of the fragments, the result was excellent or good in 98 per cent (Fig. 38). If the diastasis was considerable, suggesting an extensive tear of the lateral expansions, the result was poor in 20 per cent.

After non-operative treatment the result was excellent in 118 subjects (56%), good in 92 (43%), and poor in 2 (1%). After operative treatment it was excellent in 27 subjects (25%), good in 58 (54%), and poor in 23 (21%), Fig. 39.

The results of various methods of operative treatment are stated in Fig. 40.

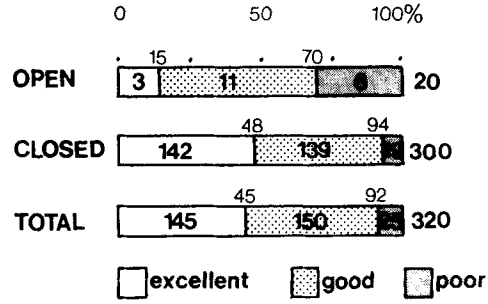


Fig. 35. Late results of open and closed patellar fractures.

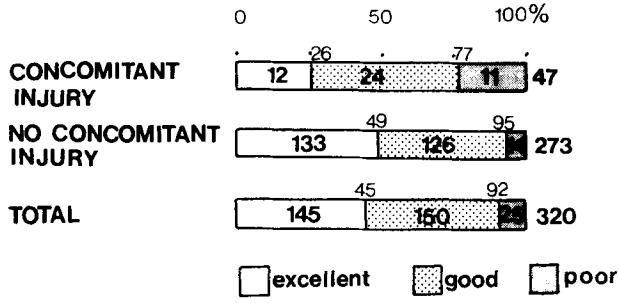


Fig. 36. Late results of patellar fractures with and without concomitant injuries.

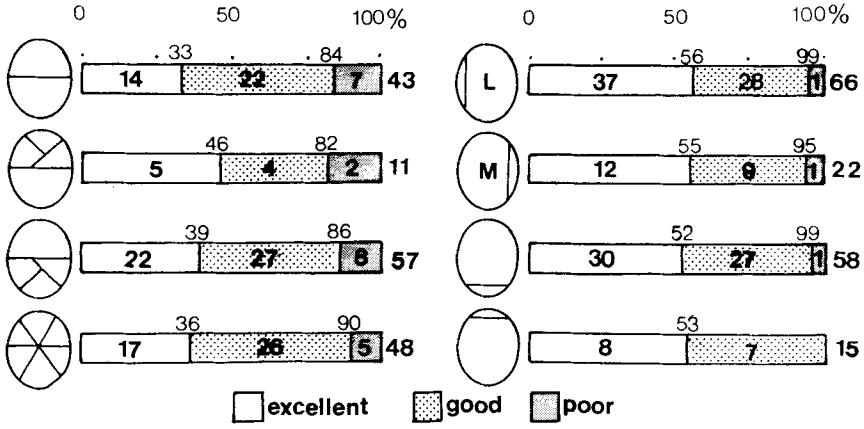


Fig. 37. Late results of various types of patellar fracture.

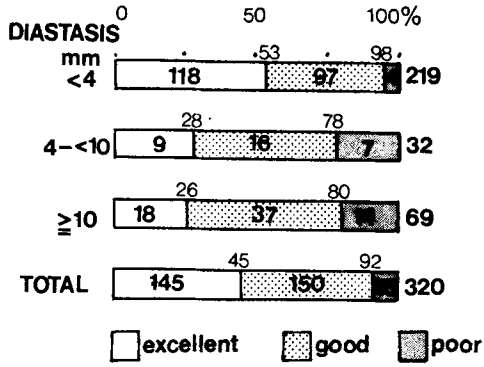


Fig. 38. Late results of patellar fractures with regard to the separation between the fragments.

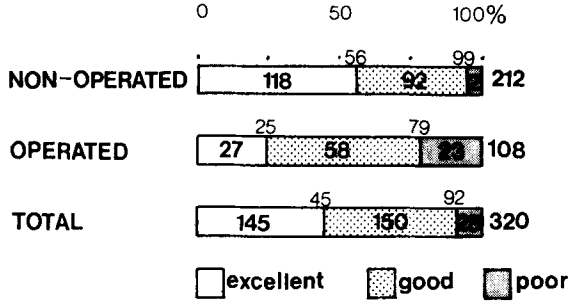


Fig. 39. Late results of non-operative and operative treatment of patellar fractures.

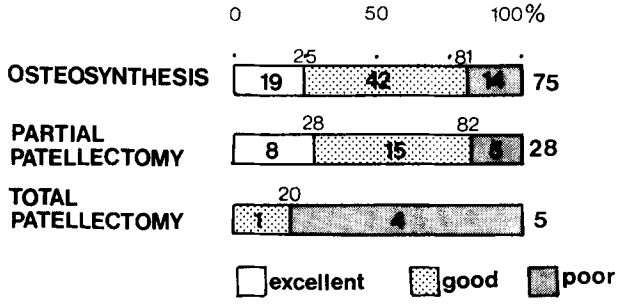


Fig. 40. Late results of various methods of operative treatment for patellar fractures.

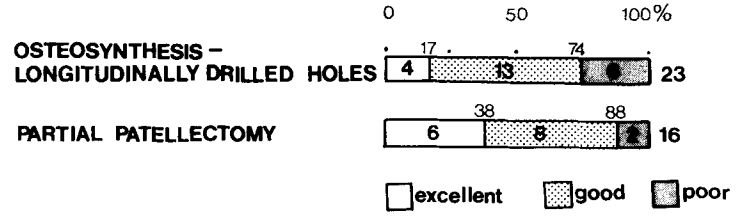


Fig. 41. Late results of transverse patellar fractures with a split lower pole treated by means of either osteosynthesis or partial patellectomy.

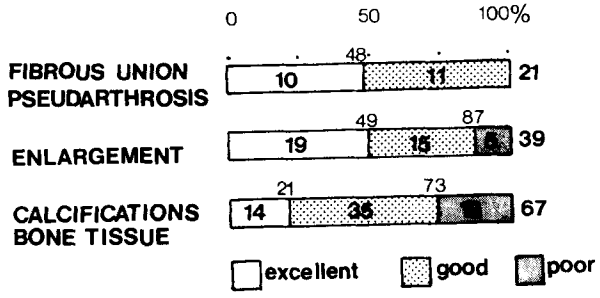


Fig. 42. Late results of fibrous union and pseudarthrosis, of enlargement of the patella, and of presence of calcium bodies and bone-resembling tissue in the surroundings after patellar fracture.

After osteosynthesis and partial patellectomy, poor results were equally frequent (19% and 18% of the respective follow-up series). In none of the cases of total patellectomy was the result excellent.

In transverse fractures with a split lower pole, 23 subjects were treated with osteosynthesis with a stainless steel wire inserted through longitudinally drilled holes, and 16 with partial patellectomy (Fig. 41). The results were poor in 6 subjects (26%) after osteosynthesis and in 2 (12%) after partial patellectomy ($p>0.05$).

With fibrous union and pseudarthrosis, 10 subjects (48%) had an excellent result, 11 (52%) a good, and none a poor (Fig. 42).

Only one of 22 non-operatively treated subjects who had a persisting step in the articular surface of the patella of 1 mm or more, revealed at the follow-up examination, had a poor result; the result was excellent in 9 (41%) and

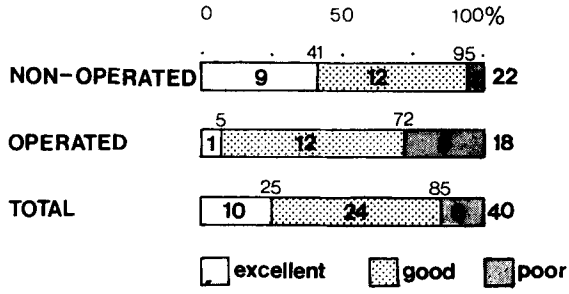


Fig. 43. Late result in 40 subjects with a persisting step in the articular surface of the patella of 1 mm or more after patellar fracture.

good in 12 subjects (54%), Fig. 43. Five subjects (28%) of those operatively treated, with a persisting step in the articular surface of the patella of 1 mm or more, were referred to the group poor results; only one achieved an excellent result.

The result of enlargement of the patella, radiographically verified, and of the presence of calcium bodies and bone-resembling tissue in the surroundings, are indicated in Fig. 42.

All subjects referred to the group poor results, owing to patellar fracture, stated that they were not restored when the treatment terminated, and that the discomfort continued. When the treatment was ended certificates of disablement were issued to 17 subjects owing to sequelae of the patellar fracture, 16 of whom were followed up. Five subjects, in this investigation referred to the group poor results, were not considered by the insurance companies to have reduced capacity for work exceeding 10 per cent (Table 19).

Table 19. Late results of 16 subjects as classified by insurance companies with regard to compensation for reduced capacity for work after patellar fracture.

	Results			
Compensation	Excellent	Good	Poor	Total
No compensation	2	2	5	9
Temporary compensation		1	1	2
Lifelong compensation		1	4	5

CHAPTER V

DISCUSSION AND CONCLUSIONS

Series

Fracture of the patella strikes subjects of all ages. The mean age in this series was 48 years, which is higher than reported by other authors. In conformity with Nummi (1971), the mean age of males was considerably lower as compared with females.

The percentage of injured males was 57 which is less than stated in most other reports.

Several authors state that fracture of the patella occurs in an increasing frequency as a result of traffic accidents. In agreement with Schönbauer (1959) and Nummi, the present series does not support this statement. In males younger than 50 years of age, traffic accidents, however, were the most common cause of patellar fracture. The classification of different types of patellar fracture varies with the authors, and comparisons are difficult to make. The number of longitudinal lateral fractures was remarkably large, probably depending on a careful radiographic examination and, furthermore, on the fact that the series, similar to that of Nummi, included ambulant cases. Both these investigations show—as opposed to an earlier concept—that the longitudinal lateral fracture is a common type of patellar fracture. In conformity with Smillie (1970), it was found that a number of different types of fracture may result from the same mode of injury. From the appearance of the fracture, no sure conclusions could be drawn as to the modes of injury.

The injury to the lateral expansions was of decisive importance for selecting the method of treatment. With a diastasis of 4 mm or more, the tear of the lateral expansions was so widespread that there was loss of active extension in most of the cases. The operatively treated patients constituted 32 per cent of the entire series. This group was of the same magnitude as that of Nummi (35%).

The post-operative complications were few and of the same proportions as those reported by other authors (cf. Nummi, 5%). However, it is remarkable that no cases of thrombosis or thrombo-embolism were diagnosed.

Some authors hold the opinion that several days should elapse after the

injury before applying a plaster cast. In this series a plaster cast was applied immediately. As a rule, this did not involve any disadvantages. However, two patients contracted paralysis of the peroneus after the plaster was applied.

Re-operation was rarely necessary. Only in exceptional cases (4 cases) was there reason to remove the metal wire. Nummi reported 62 extirpations of the metal wire, frequently done because of pain where the wire knot was tied. The low frequency of extirpation of the metal wire in this series, no doubt, depended on the twined end of the wire having been recessed into the patella.

Conclusive comparisons with regard to periods of sick-leave and compensation for disablement between the various series, are frequently difficult to make as the social and economical advantages vary with the diffent countries. The periods of sick-leave in this investigation were equivalent to those of Nummi after both non-operative and various types of operative treatment.

At the follow-up study it was, in conformity with other authors, possible to establish that subjective symptoms occurred to a great extent after patellar fracture. As the period of observation was almost nine years and the mean age, at the follow-up examination, was 53 years, it is necessary to bear in mind that there may be other reasons for the joint discomfort than the sequelae of patellar fracture.

Restricted range of mobility was found mainly in elderly subjects and in those who had osteoarthrosis. Contrary to Ehlert (1963) a long period of immobilization in plaster was not found to prevent the recovery of mobility at long sight.

Measuring of the circumference of the thigh should be combined with recording of the force of the extensors of the knee, in order to allow an adequate interpretation of the quadriceps function. This especially applies when the circumference of both legs is equal in size. The figures obtained, possibly did not represent the maximal force which, according to Clarke *et al.* (1950) and Hallén & Lindahl (1967), is reached when the knee-joint is flexed through 60–75 degrees. The figures recorded were the same as those obtained from an equivalent age group by other Swedish authors.

As other authors have pointed out, the force of the extensors of the knee was often reduced after fracture of the patella and particularly after total patellectomy. The force of the extensor apparatus of the knee is, no doubt, affected also by factors other than the reduced length of the lever (cf. Stener 1969), e.g. painful hydrops of the joint (de Andrade, Grant & Dixon 1965) and inflammatory changes (Tiselius 1969). It is possible that the force of extension after healing of the patellar fracture depends on the tear of the lateral expansions at the time of injury.

The theory, supported by several authors (cf. Schönbauer 1955, J. Böhler 1961, Nummi 1971) that steps in the articular surface of the patella provoke

osteoarthrosis, has not been realized in this investigation. An increase in the frequency of osteoarthrosis of the patellofemoral joint, assumed to have been formed or developed as a result of the injury, was indeed recorded when there was a step of the articular surface amounting to 1 mm or more, but the difference in frequency was not significant. Furthermore, quite a few subjects with a step in the articular surface of the patella experienced no pain.

Thomson (1942) maintained that enlargement of the patella did not occur after partial patellectomy. In this investigation, enlargement of the patella occurred after both partial patellectomy and osteosynthesis and, furthermore, after both non-operative and operative treatment. As opposed to Sørensen (1964) there was no increase in the frequency of osteoarthrosis with enlargement of the patella in this investigation.

Many authors have pointed out that osteoarthrosis may set in after a joint lesion. In this investigation, there were possibilities of establishing the development of osteoarthrosis which could be secondary to the injury, and of that which could depend on other circumstances.

A rather high frequency of osteoarthrosis of a primary type could be expected, as the higher age groups included many females (Hernborg 1969). The frequency of osteoarthrosis, as reported in other series, is probably too high, because no distinction has been made between primary and secondary osteoarthrosis. Nummi agrees that his figures are too high. Sørensen mentions that only in exceptional cases had he access to radiographs taken at the time of injury and, thus, was unable to assess development of osteoarthrosis. Without doubt, however, osteoarthrosis may develop as a direct result of the injury. In this series there was an increase in the frequency of osteoarthrosis after open fracture, comminuted fracture, and operative treatment, whilst the choice of operation method seemed to be of secondary importance. Some of the subjects with osteoarthrosis were free from pain.

Poor results were recorded in 8 per cent of the entire series (25/320). In the group poor results, Fontaine *et al.* (1965) included 10 per cent (8/78), Villiger (1965) 4 per cent (3/82), Detmar (1966) 7 per cent (7/104), Struck (1966) 6 per cent (5/82), and Nummi (1971) 8 per cent (32/391).

There was a distinct male predominance among those included in the poor results following patellar fracture. On the other hand, the late results were equivalent with respect to age over and under 60 years. The mode of injury and other circumstances connected with the trauma were essential. Traffic injury and fall from height, open fracture and concomitant injury were factors which contributed to a poor result.

Excellent and good results of longitudinal, apical and basal fractures were achieved to a large extent. In these fractures the injury to the lateral expansions was often slight. This investigation does not support the opinion held,

for instance, by de Palma (1954) that longitudinal lateral fractures should be treated surgically in order to avoid future discomfort. Despite the fact that fibrous union was most common in longitudinal lateral fractures the frequency of poor results was low.

Excellent, good and poor results were recorded to the same extent in transverse types of fracture as in comminuted fractures. The type of fracture seemed to be of secondary importance as compared with the injury to the lateral expansions.

In conformity with other authors, this series revealed to a great extent excellent and good results of the fractures to which non-operative treatment was applicable. In this series poor results were noted in 1 per cent (2/212) of fractures treated non-operatively. In the group poor, after non-operative treatment, Fontaine *et al.* included 5 per cent (1/20), Villiger 5 per cent (1/21), Detmar 11 per cent (3/27), Struck 4 per cent (2/51) and Nummi 4 per cent (10/236).

In the cases treated operatively, the results were less satisfactory, as expected. Poor results in this series amounted to 21 per cent (23/108).The corresponding figures of poor results in other series are lower. Fontaine *et al.* reported 12 per cent (7/58), Villiger 3 per cent (2/61), Detmar 5 per cent (4/77), Struck 10 per cent (3/31) and Nummi 14 per cent (22/155).

However, the results cannot simply be compared. The late results of a joint lesion can be assumed to depend on other conditions than the injury, and often the extent of consideration taken to this fact is not clearly expressed. Furthermore, the methods of analysis and the criteria vary with different authors.

Excellent, good, and poor results were recorded to the same extent after methods used for restoration of normal anatomy and after partial patellectomy. Too few patients were subjected to total patellectomy for any conclusions to be drawn as to the value of this method of operation. The patients on whom total excision of the patella was performed all had open fractures. The most common method of operation employed in attempting to restore the anatomy was stainless steel wire inserted through longitudinally drilled holes, according to Payr. It was used both for transverse and comminuted fractures. Operative treatment of transverse fractures with a split lower pole could be performed either by osteosynthesis with a stainless steel wire inserted through longitudinally drilled holes or by partial patellectomy. In the follow-up study there were 23 and 16 subjects, respectively, who had been operated on by the use of these methods. Partial patellectomy tended to give better results of this particular type of fracture as compared to osteosynthesis, but the groups of patients were small and the differences not significant.

In no case of fibrous union and pseudarthrosis were the late results poor, a fact experienced also by Nummi.

A step in the articular surface of the patella of 1 mm or more did not affect the late results of non-operatively treated cases. Nor did a persistent step in the articular surface of the patella of 1 mm or more significantly increase the frequency of poor results of operatively treated cases. This may imply that it is not essential to attain exact reposition and that a difference of level of 2–3 mm between the fragments can be accepted and treated non-operatively, if there is no other indication of operation.

Enlargement of the patella did not affect the late results. Nor did the enlargement provoke osteoarthrosis and, consequently, this finding is of little clinical importance. Calcium bodies in the surroundings of the patella, and bone-resembling tissue in the quadriceps tendon and in the patellar ligament gave poor results, approximately to the extent expected, in view of the fact that most of the patients had been treated by surgery. The frequency of osteoarthrosis with these above-mentioned changes, was also just as high as that obtained after operative treatment. The clinical importance of these changes is probably insignificant.

Finally, it is remarkable that all the subjects with a poor result pointed out that they were not restored at the end of the treatment and that the discomfort continued.

Conclusions

Certain misgivings are involved with fracture of the patella inasmuch as persistent disability may result in the form of pain, subjectively experienced reduction of function, restricted range of mobility, reduced force of extension of the knee, and osteoarthrosis. On the basis of a follow-up study of 320 patients, subjected to patellar fracture, the following was found:

1. The mechanism of injury and the severity of the trauma affect the late results of patellar fracture. In traffic accidents and falls from height, and also in open fractures and concomitant injuries there will be a greater risk of a poor result.
2. Various types of fracture may result from the same mode of injury. A particular type of fracture is no true indication of the mode of injury. Nor is it generally possible to give a sure statement of the prognosis on the basis of the type of fracture. However, there is a good prognosis for longitudinal, apical and basal fractures, in all probability depending on the injury to the lateral expansions being slight in most of these fractures.
3. The patient's capacity for extension of the knee, the separation and the difference of level between the fragments are factors to be borne in mind when deciding whether non-operative or operative treatment shall follow. When the extension capacity is preserved, the separation of fragments is

3–4 mm or less, and the difference of level is 2–3 mm or less, excellent and good late results can be expected after non-operative treatment. The prognosis is less good after operative than after non-operative treatment, no doubt, owing to the more serious injury necessitating operative treatment. The choice of operation method is probably of secondary importance as compared with the mode of injury and other circumstances involved with the trauma.

4. After a joint lesion such as a fracture of the patella subjective symptoms and objective signs may depend—particularly with increasing age—on circumstances other than sequelae of the injury, especially osteoarthrosis.
5. It is difficult to come to any definite conclusions when comparing between different series, owing to the varying criteria used for classification. However, after perusal of the literature on the subject and after study of this series, there has not been any reason to recommend the introduction of another method of treatment, nor to advise against the use of any of the methods which were applied in this series.

Suggestion of treatment

On the basis of the literature and this series the following is recommended:

Non-Operative Treatment

The patient's capacity for lifting his leg with the knee extended, the extent of separation and the difference of level between the fragments must be considered when deciding between non-operative and operative treatment. When the extension capacity of the knee is preserved, the diastasis is 3–4 mm or less, and the step in the articular surface is 2–3 mm or less, non-operative treatment is advised. If there is loss of active extension of the knee and the diastasis is less than 4 mm the patient should be hospitalized and the joint should be punctured, pending the development. A severe tear of the lateral expansions involved with this diastasis is most unlikely.

In non-operative treatment immobilization in a plaster cast during four weeks is generally sufficient, the time of which can be reduced in cases of longitudinal fracture. The patient should be instructed to practice active exercise of the quadriceps muscles. Weight-bearing is permitted. Crutches as protecting support are recommended.

Operative Treatment

Loss of active extension of the knee and a diastasis of more than 3–4 mm, and a step in the articular surface of the patella of more than 2–3 mm, are indications for operation.

Restoration of normal anatomy is recommended for transverse fractures with two large fragments and comminuted fractures when the articular surface can be restored.

Repair of the quadriceps apparatus retaining one large fragment is recommended in transverse fractures with a split upper or lower pole, and in comminuted fractures, if the articular surface cannot be restored, and there is a large fragment including more than half of the patella.

Total excision of the patella never seems to be a treatment of choice but is recommended in exceptionally severe cases, e.g. open comminuted fractures or when other methods of treatment have failed.

Irrespective of the operation method selected, it is essential that the tear of the lateral expansions be identified and that the anatomy be accurately restored.

The post-operative procedure is the same irrespective of the operation method selected. Immobilization in a plaster cast with the knee flexed through 5–10 degrees during 6–7 weeks is indicated. The patient should be instructed to practice active exercise of the quadriceps muscles (Svantesson 1971). When the quadriceps muscles can be contracted leg-raising is instituted. Weight-bearing and mobilization on crutches, as protecting support, are permitted when the patient can lift his leg. When the plaster cast has been discarded, the patient should be instructed how to practice active exercises. Primarily, this includes isometric, and later also isotonic extension and flexion exercises—in the beginning without, and later with, increasing resistance. The exercises should be carried out under the supervision of a physiotherapist.

CHAPTER VI

SUMMARY

The series includes 416 patients who were radiographically examined in Göteborg during the period 1959–1964 because of injury to the knee and the diagnosis was a fresh fracture of the patella.

57 per cent were males and 43 per cent females, the mean age was 42 and 54 years, respectively. The maximum of frequency for males was reached between the ages of 30 and 39 years, and for females between 60 and 69 years.

The most common mode of injury was a fall in the same plane (54%), the next common various types of traffic accidents (28%). In 6 per cent there was an open fracture and in 15 per cent a concomitant injury which in almost half of the cases involved the lower extremities.

Transverse fractures were diagnosed in 34 per cent, comminuted in 16 per cent, longitudinal lateral in 22 per cent and others, including longitudinal medial, apical, and basal fractures in 28 per cent. The different modes of injury exhibited a large variety of fractures. 51 per cent of the fractures were non-dislocated and in a total of 70 per cent the diastasis was less than 4 mm. The step in the articular surface in this dislocation was nearly always less than 3 mm. A diastasis of at least 4 mm was established in 30 per cent. A loss of active function of the quadriceps muscles was found in 33 per cent.

Non-operative methods of treatment were considered advisable in preserved extension capacity of the knee, diastasis less than 4 mm, and a step in the articular surface less than 3 mm. 287 fractures in 282 patients (68%) were treated non-operatively, usually with immobilization in a plaster cast during 3–5 weeks. 135 fractures in 134 patients (32%) were subjected to surgery. The most common method of operation was osteosynthesis with a stainless steel wire inserted through longitudinally drilled holes. Partial patellectomy was the next common method of operation, while total excision of the patella was performed only exceptionally. All the methods of operation were followed by immobilization in plaster, the median period of which was 6.5 weeks. Complications occurred in 5 per cent. Re-operation was performed in 5 per cent. The most common re-operation was mobilization of the patella, performed owing to restricted mobility of the knee-joint after the plaster cast had been discarded.

The median period of sick-leave of non-operatively treated patients, immo-

bilized in a plaster cast, was two months, and of those operated on four months. The median period of sick-leave was insignificantly shorter after partial patellectomy than after osteosynthesis.

Follow-up examination was carried out 5–12 years after the injury. The mean time of observation was 8.9 years. The late results of 320 subjects—totalling 91 per cent of those alive at the time of the follow-up—were reported. A questionnaire was filled-up. A clinical examination was performed on 271 subjects. Pain and subjectively experienced impairment of function were recorded as well as the range of mobility of the knee-joint, the circumference of the thigh and the force of the extensors of the knee. The radiographic examination of both knee-joints in 246 subjects gave evidence of union, fibrous union, pseudarthrosis, cerclage-breakage, step in articular surface, enlargement of the patella, calcium bodies and bone-resembling tissue in the surroundings, and formation and development of osteoarthrosis.

70 per cent of the subjects were satisfied and stated that the injury had not caused persisting discomfort. 59 per cent of the non-operatively and 30 per cent of the operatively treated subjects felt no pain. A normal function was subjectively experienced by 78 per cent of the non-operatively and 36 per cent of the operatively treated subjects.

Deficiency of extension of the knee was recorded in 6 per cent, and bending capacity to a flexed position of less than 120 degrees was noted in 10 per cent. The circumference of the thigh of the injured leg was reduced in 24 per cent. The extension force of the knee was reduced in 37 per cent. Reduction of force occurred to a greater extent when the separation between the fragments measured 4 mm or more.

Fibrous union was more often found in longitudinal lateral fractures than in other types of fracture, but caused no poor results. Pseudarthrosis was recorded in 3 per cent and occurred after both non-operative and operative treatment; no case of poor results was noted. A step in the articular surface of the patella of 1 mm or more was observed in 40 subjects (17%), half of whom were operated upon, the majority according to the method of osteosynthesis with a stainless steel wire inserted through longitudinally drilled holes. There was possibly no relation between a step in the articular surface and formation and development of osteoarthrosis in the patellofemoral joint caused by the injury. Enlargement of the patella as well as calcium bodies and bone-resembling tissue in the patellar surroundings did not seem to be of clinical importance. Formation and development of osteoarthrosis could result from the injury, but the occurrence of osteoarthrosis was often independent of the injury and was mainly seen in females in advanced ages.

Excellent results were achieved in 45 per cent and good results in 47 per cent, while poor results were noted in 8 per cent. There was a decided male

predominance among those with poor results. Injury owing to traffic accidents and fall from height, open fracture and concomitant injury entailed a greater risk of a poor result. After longitudinal, apical, and basal fractures, in which the tear of the lateral expansions was frequently slight, the late results were better than after transverse and comminuted fractures which more often involved a considerable injury to the lateral expansions. The result of patients non-operatively treated, was excellent or good in 99 per cent. After operative treatment the result was excellent or good in 79 per cent. The late results were equivalent after osteosynthesis and partial patellectomy, but worse after total excision of the patella, performed only in selected cases with open fracture.

On the basis of a survey of the literature and on this investigation, it has been possible to come to some conclusions and to give recommendations for the treatment of acute fracture of the patella.

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