Patellar Malalignment

A Treatment Rationale

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This paper will provide a review of those aspects of the patellofemoral joint that most often lead to surgical treatment. Without a doubt, patellar malalignment is the most common patellofemoral disorder leading to surgery.

Patellar malalignment may be either permanent, such as in congenital dislocation, or, more commonly, recurrent, such as in patellar subluxation. The eventual outcome of many cases of chronic patellar malalignment is patellofemoral arthrosis. It is for this reason that surgery is undertaken in cases that do not respond to conservative treatment.

In recent years, many ingenious surgical techniques to correct patellar malalignment have been described. Despite the large number of surgical procedures, as well as the multitude of factors contributing to the development of patellar malalignment, most surgeons use singularly or in combination three basic surgical procedures: 1) correction of the valgus angle of the patellar tendon (distal realignment), 2) release of the tight lateral restraining structures that cause excessive pressure and patellar subluxation (lateral release), and 3) vastus medialis advancement with tightening of lax medial restraints (medial reefing). Also, joint exploration or arthroscopy is often required to detect and treat other, concomitant intraarticular problems.

Few long-term comparisons of various methods of surgical treatment using adequate numbers of patients are available, so there is little consensus today on which surgical procedures to use and when. Despite this, however, a sound understanding of patellofemoral biomechanics and pathophysiology will help the therapist understand the multitude of surgical procedures, their theoretical application, and, more importantly, the postoperative rehabilitation.

A brief review of patellofemoral joint anatomy, biomechanics, and pathogenesis will aid in the subsequent discussion of the treatment of patellofemoral malalignment.

ANATOMY AND BIOMECHANICS

The patella was originally only a sesamoid bone in the quadriceps tendon. Along with the femur it has adapted through evolution and with the development of the bipedal gait has become an integral part of the knee extensor mechanism with all of the characteristics of a "true joint."

Acting as a fulcrum, its primary function is to increase the extending moment of the quadriceps femoris muscle (Fig. 1). Forces transmitted from the patella to the femoral sulcus increase as knee flexion increases. The patellofemoral compression forces are less than body weight during walking and increase to 2.5 times body weight during such activities as stair climbing.\(^1\)

Normal function depends upon adequate stabilization, which is provided by both active and passive elements of the extensor mechanism. Passive stabilization is provided by the bony contours of the femoral sulcus and the configuration of the patella as well as by thickenings of the capsule. The depth of the patellofemoral groove and height of the lateral femoral

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\(^1\) A. \(x_1\) and \(x_2\) denote the position of the patella and RF represents the reaction force at the patellofemoral joint.
condyle buttress the patella against lateral dislocation. The patella is held in the groove superiorly by the quadriceps femoris tendon and anteriorly by the patellar tendon as the quadriceps femoris muscle contracts. The passive ligamentous stabilizers consist of thickenings of the capsule, extending from the midportion of the patella to the medial and lateral femoral condyles. These have been described by Kaplan and are termed patellofemoral ligaments. The most important of these is the medial patellofemoral ligament, which helps prevent lateral displacement. The lateral patellofemoral ligament is part of the lateral retinaculum, which is composed of two layers. The first is a longitudinal superficial layer of fascia. The second is a distinct deep layer of transverse fibers that form the bulk of the lateral patellofemoral ligament. These fibers are an expansion into the retinaculum of the vastus lateralis muscle and the iliotibial tract. Sometimes these ligamentous structures may be excessively tight, contributing to lateral patellar tilt, malalignment, and excessive patellofemoral compressive forces.

The chief active stabilizer of the patella is the vastus medialis obliquus (VMO) muscle. The importance of this muscle to knee function and patellar position was first described by Duchenne in the middle 1800s. More recent studies by Lieb and Perry found that the primary function of the VMO is patellar alignment.

A remote stabilizer of the patellofemoral joint is the pes anserinus group of muscles: the sartorius, gracilis, and semitendinosus. Through its internal rotatory action on the proximal tibia, the pes anserinus helps to maintain alignment of the tibial tubercle with the femoral sulcus.

As previously noted, stability provided by the femoral groove through the patella depends primarily on the shape of the groove and the patellar configuration. Six types of patellae have been described by Wiberg and Baumgartl. As shown in Figure 2, the type I and II patellae are the most stable, with equal distribution of forces over the well-formed medial and lateral patellar facets. The other types of patellae are more prone to unequal stresses and thus to lateral luxation. Patella type and femoral sulcus anatomy can be determined by axial radiographic views of the patella.

Cruveilhier in 1840 observed that a contracting quadriceps femoris muscle will seek the shortest route between origin and insertion and stated that "the tendon of the triceps femoris is directed slightly downward and inward and the ligamentum patellae downward and slightly outward, so that the tendon and the ligamentum patellae form an obtuse angle open laterally." This has subsequently been referred to as the "Q" angle and is determined by drawing one line from the middle of the patella to the center of the tibial tubercle and a second line from the center of the patella to the center of the anterior-superior iliac spine on the pelvis (Fig. 3). An increase in the "Q" angle above 15 degrees may increase the tendency for lateral patellar malposition, but by itself is not diag-
nostic. An increased “Q” angle associated with another deficiency of the extensor mechanism may, however, allow the patella to sublux more easily.

**The Law of Valgus**

When considering the ever-present valgus “Q” angle, and the considerably stronger and more fibrous lateral stabilizers of the patella compared to the medial stabilizers, Ficat and Hungerford believed these aspects of the physiology and biomechanics of the patellofemoral joint to be so important to the understanding of both normal and abnormal knee function that they elevated this information to the level of a “law.” They noted that the “law of valgus” helps explain nearly all the pathophysiology involved in this joint and also explains how the delicate balance between the patella and the femur can be restored for symptom-free function. Morphologically, this “law” first finds expression in the predominant lateral trochlear surface. This predominance is evidenced both in size and anterior projection. Second, the more frequently found patellar form (Wiberg, Type II) has a larger lateral than medial facet. The lateral soft tissue elements reinforced by the fascia lata are balanced by similar medial soft tissue stabilizers. These medial soft tissue stabilizers, along with the congruence of the contact surfaces of the joint, offer further stability and thus tend to negate the existing valgus vector. The orientation of the lateral trochlear facet offers further impediment to lateralization of the patella. It is with this understanding, then, that we can discuss the pathogenesis of patellar malalignment.

**PATHOGENESIS**

Because of the “law of valgus,” any stabilizing deficiency in the extensor mechanism will lead to patellar malposition—either by lateral patellar subluxation or dislocation. Deficiencies of the extensor mechanism are of three categories: 1) abnormalities of the patellofemoral configuration, 2) deficiencies of the supporting muscles or guiding mechanisms, and 3) malalignment of the extremity relating to knee mechanics. Often, deficiencies in more than one category will contribute to the patellar malalignment.

**Abnormalities of the Patellofemoral Configuration**

The combination of a low profile of the femoral sulcus and a deficiency of the medial patellar facet predisposes to patellar instability. Usually these deficiencies are developmental, caused by a deficiency of the supporting muscle or by a malalignment that did not allow the patella and sulcus to develop normally. Evaluation of these deficiencies is best made by roentgenographic studies and is not the subject of this paper. Nevertheless, it should be noted that the lateral condyle is higher than the medial and projects anteriorly an estimated 7 mm or more, preventing lateral patellar displacement. Hughston has pointed out that the patellofemoral joint can undergo further development during the last several years of growth. Larson has also noted this and has seen improvement in the sulcus angle and patellar configuration during treatment. This is one of several reasons that conservative treatment in the adolescent is strongly suggested and that when an unstable patellar mechanism requires surgery, it should, if possible, be delayed until skeletal maturity.

**Deficiencies of the Supporting Muscles and Guiding Mechanisms**

Weakness of the anterior medial retinaculum, weakness of the VMO muscle, hypermobility of the patella from poor muscle tone after injury, congenital genu recurvatum with a resultant laxity in the extensor mechanism, patella alta, and tightness of the lateral retinaculum are some of the deficiencies that allow the patella to sublux or dislocate laterally.

Lack of development of the VMO muscle, which is normally attached to the proximal one-third of the patella, allows overpull of the vastus lateralis muscle during walking and running, particularly between midstance and take off, thus enhancing lateral subluxation or dislocation of the patella. In patella alta, only the more vertically oriented fibers that attach to the proximal portion of the medial patella are present, therefore the control of lateral patellar displacement is diminished.

**Malalignment of the Extremity**

A wide variety of structural abnormalities of the lower extremity may influence patellar tracking in the patellar groove. Certainly, genu valgum increases the valgus vector at the knee, thus setting the stage for patellar subluxation or dislocation. Likewise, lateral displacement of the tibial tubercle in relationship to the anterior superior iliac spine enhances the tendency for the patella to displace laterally.

Femoral anteversion with internal femoral rotation causes the femoral sulcus to be more medially placed in relation to the tibial tubercle and thus give, functionally, a more lateral insertion to the patellar tendon and enhance the lateral pull of the quadriceps femoris muscle contraction or valgus vector. Patients being seen for patellar malalignment problems often relate
a history of being treated, as children, for lower extremity malalignment with special orthopedic shoes or leg braces.

Foot mechanics may also alter patellar tracking. During foot strike in running, the foot pronates with subsequent external rotation of the tibia on the femur as the knee extends. Quadriceps femoris muscle contraction with either foot pronation or external tibial rotation enhances the lateral forces acting on the patella. For less active people who run short distances, this problem usually does not manifest itself. However, in the long-distance runner who logs hundreds of miles a year, the abnormal lateral forces directed at the patella may lead to “runner’s knee,” or patellofemoral arthralgia.

The deficiencies discussed above are usually compensated for in the normal knee by muscular strength, the triangular shape of the patella, the depth of the patellofemoral groove, and the restraining action of the passive ligamentous structures. However, when bone or soft tissue deficiencies occur by themselves or in combination, the potential for an unstable patella exists, particularly after secondary insult to the knee. The resultant muscle atrophy and weakness associated with even the slightest knee injury will tip the delicate scales of the extensor mechanism in favor of malalignment. Pain, usually the first sign of patellofemoral difficulties, adds to muscular atrophy and disuse. Voluntary or imposed rest to control pain and inflammation only further creates muscular imbalances. Once patellofemoral arthralgia has subsided with rest, the mistake is usually to resume full activities without proper reconditioning and restoration of muscle balance. Neglecting to appreciate this important principle is perhaps the most common cause of failure of conservative treatment of patellofemoral malalignment.

**TREATMENT**

In this article we will review present-day surgical procedures for treating symptomatic patellar malalignment; however, it is extremely important to realize that the majority of patients with patellofemoral disorders never require surgery and, in fact, respond dramatically to appropriate rehabilitation. The principal goal of a conservative program is to develop excellent quadriceps femoris muscle strength, especially of the VMO muscle.

At the University of Cincinnati Sports Medicine Institute, we have developed a program called “The Patella Protection Program.” Its four phases are designed to minimize the forces across the patellofemoral joint, yet at the same time strengthen the quadriceps femoris muscle mechanism. Our Patella Protection Program is the basis for nonoperative treatment as well as for postoperative rehabilitation of any knee problem.

**The Patella Protection Program**

Our entire approach to rehabilitation of the knee is based on a program that initially minimizes the forces on the patellofemoral joint while allowing for gains in strength of the controlling muscles. Most strengthening programs for the knee have the potential to increase stresses and thus cause subsequent damage to articular surfaces. This program is designed to avoid damaging the patella while returning the injured or postoperative knee to normal strength.

The “Patella Protection Program” is divided into four periods:

1. **Initial Rehabilitation**
2. **Intermediate Rehabilitation**
3. **Advanced Rehabilitation**
4. **Return to Activity and Maintenance**

Each period has specific goals, exercises, and built-in restrictions to guide progression. Our program allows standardization of rehabilitation and is used not only for patellar problems but for all knee injuries. The progression from phase to phase is more rapid in certain conditions, but each patient follows the same guidelines.

**Period 1,** or Initial Rehabilitation, involves the acute or “hot” knee. The goals during this period are 1) to relieve pain, 2) to decrease the atrophic response, and 3) to decrease inflammation. The exercises used during this period are primarily isometrics, in 6 to 10 sets daily of 10 repetitions each. Each contraction is held for 10 seconds, followed by 10 seconds of relaxation (rule of tens). Flexibility exercises for the total lower extremity are included. Thus, initial rehabilitation is designed to prevent the marked atrophy that accompanies injury to the knee, while providing relief from pain and effusion.

**Period 2,** or Intermediate Rehabilitation, is initiated when range of motion is increased and pain and effusion are decreased. The specific goal is to increase muscular strength without increasing pain or effusion. Terminal extension exercises are performed, using a progressive resistance exercise approach. Lateral step-ups are often used during this period. The height of the step is adjusted according to patient’s tolerance.

**Period 3,** or Advanced Rehabilitation, involves the following goals: 1) to obtain maximum strength, 2) to alternate endurance activities, and 3) to obtain normal range of motion. Period 3 is implemented when the patient can perform terminal extension exercises with about 10 to 15 lb (4.5–6.8 kg) of resistance. Isotonic
weight equipment such as Nautilus,* Universal gym,† or free weights is incorporated during Advanced Rehabilitation. The isometric program is discontinued as the isotonic progressive resistance program is implemented. Extension exercises are limited to 0 to 30 degrees, and the individual patient attempts to increase his resistance until lifting about one-fourth of his body weight. Hamstring muscle exercises are conducted through a full range of motion if pain free. Flexibility exercises are continued.

Endurance activities are performed on alternate days. These activities primarily are swimming or cycling, inasmuch as these individuals usually cannot tolerate running. As in all rehabilitation periods, the exercises must be controlled to avoid pain and effusion.

Period 4, or Return to Activity and Maintenance, has the following goals: 1) to return the patient slowly to the specific activities of his choice and 2) to continue strength and endurance training. Isokinetic testing is used to determine strength and endurance levels at this point. A 75 percent level of power and endurance should be obtained in the affected lower extremity as compared to the normal, before the individual is allowed to start a running program; a 90 percent level is to be achieved before he returns to full activity. Rehabilitation is only complete when specific skills necessary for the return to activities can be performed at the same level that the individual could perform before the injury. Flexibility and endurance activities are continued and isokinetic testing intermittently performed to assure maintained strength.

Many acute knee conditions can be helped by this program. These include acute patellar dislocation, inflamed synovial plica, iliotibial band syndrome, patellar tendinitis, Osgood-Schlatter's disease, and other nonoperable knee conditions. Also, those acutely injured knees in which ligamentous or meniscal damage is suspected can initially be placed on the Patellar Protection Program while awaiting definitive treatment.

Many chronic conditions of the knee also can be helped by the Patellar Protection Program. These include patellar subluxations, lateral patellar compression syndrome, postoperative knee cases with prior inadequate rehabilitation, degenerated menisci, degenerative joint disease, rheumatoid joint disease, and chronic knee instabilities. Also, all immediate postoperative knee cases can benefit from this program.

Surgery for Patellofemoral Malalignment

The objective of surgical treatment is realignment of the extensor apparatus and stabilization of the patella in the trochlea during function. When conservative therapy as outlined fails to correct the patient's difficulties, and when multiple deficiencies of the extensor mechanism exist with significant disability, then surgical procedures are usually necessary. The determination of which surgical procedures to use must take into account the complexities of the extensor mechanism, the biomechanics of the patellofemoral joint, and the particular deficiencies that exist. The key to success lies not in applying a single technique to all patients, but in selecting the proper combination for a given individual.

The number of different techniques for patellar realignment and stabilization reported in the literature is astonishing.1617 Surgical procedures for correcting persistent or recurrent patellar malalignment prior to the development of significant patella chondromalacia or patellofemoral arthrosis should be considered "reconstructive" procedures rather than "salvage" procedures and can be divided into three general areas of surgical technique and postoperative rehabilitation.

Lateral Retinacular Release

Lateral retinacular release, or capsulorrhapsy, is the simplest of all surgical procedures and may be sufficient for many patients. This procedure consists of weakening the lateral retinaculum by surgical release. It is done to allow the patella to move more centrally in the groove. Lateral release is particularly valuable in the adolescent because it is a relatively simple procedure and does not involve any bony structures that may interfere with growth. The procedure may be accomplished at the time of arthrotomy in a "z-plasty lengthening" technique as described by Larson,1 or may be done subcutaneously either by direct vision through the arthroscope or indirectly by using digital palpation. Larson believes this procedure should be done in an open z-plasty fashion so as to prevent synovial fat pad herniation through the weakened lateral capsule and to help prevent the most common complication of this procedure, postoperative hematrhrosis.

As can be seen in Figure 4, the lateral release is extensive and includes the entire lateral retinaculum extending from the patellar tendon superiorly and including the majority of the vastus lateralis tendon. The technique of lateral retinacular release lessens the compressive forces on the articular surface of the patella and allows a more longitudinal force of the

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† Universal, PO Box 1270, Cedar Rapids, IA 52400.
vastus lateralis. By lessening the resistance of the lateral patellofemoral ligament, the valgus vector is reduced and function of the VMO muscle is augmented by the improved alignment.

The postoperative rehabilitation for this procedure essentially follows the guidelines for the Patella Protection Program; however, this program cannot be advanced from Phase 1 to Phase 2 until about 10 to 14 days after surgery to prevent a late effusion. Postoperative dressings must be meticulously handled, with constant redressing and application of pressure dressings to the lateral retinacular area. Patellofemoral joint mobilization is encouraged with all patellofemoral joint surgery. Not only should superior and inferior mobilization be accomplished, but also gentle medial mobilization must be instituted to prevent the lateral retinaculum from adhering to the lateral femoral condyle or to its previous insertion site near the patella.

Simple lateral retinacular release, by itself, has only recently become popular. The long-term results of this procedure are yet to be compiled. Early reported results by Metcalfe and McGinty have been encouraging. The key to success with this procedure lies in the prevention of postoperative hemarthrosis as well as the achievement of VMO strengthening and reeducation.

**Proximal Realignment**

Proximal soft tissue reconstruction is designed to align the muscle pull on the patella and thus enhance the active action of the VMO. The medial capsule, which includes the medial patellar ligament, is also tightened. Meticulous surgical technique is mandatory when the VMO muscle is to be "dynamically" changed. Those procedures employing proximal realignment combine lateral retinacular release with reimplantation of the VMO muscle laterally and distally on the patella (Fig. 5). Advancing it too far distally may cause excessive pull on the distal pole of the patella, causing rotation if there is a dysplastic or shallow femoral sulcus. If the muscle is advanced too far laterally, contraction of the muscle may cause increased compression of the medial patellar facet.
Fig. 6. Distal realignment. This involves moving the patellar tendon and its bony attachment site to a medial-inferior location on the tibia.\textsuperscript{24}

against the medial borders of the intercondylar groove. An increased incidence of chondromalacia symptoms after vastus medialis advancement has been reported.\textsuperscript{20}

A multitude of other soft tissue procedures designed to "dynamically" as well as "statically" control patellofemoral alignment have been described. These procedures mainly employ the use of the individual hamstring tendons such as the sartorius, gracilis, or semitendinosus tendons. These tendons are left attached to their tibial tubercle insertion site and then transferred to the medial border of the patella. Most of these procedures have not been met with great enthusiasm because of their erratic results.\textsuperscript{21}

Postoperative rehabilitation for proximal patellofemoral realignment focuses mainly on encouraging early motion without disrupting the VMO muscle suture line. Loss of knee flexion is not uncommon when the knee is held rigidly immobilized for six weeks or longer. When this occurs, anesthetic manipulation is often required. Other complications include persistent patellofemoral malalignment and recurrent patellar dislocation caused by disruption and lack of reconstitution of the medial patellofemoral restraints. Gentle range of motion is usually encouraged four weeks after surgery and is combined with patellar mobilization—cephalad, caudad, and medial. When compared to simple lateral retinacular release, VMO advancement prolongs by months postoperative rehabilitation and return to activity. Therefore, we believe that VMO advancement should not be a routine procedure for patellofemoral realignment and should only be done when definite malattachment or dysplasia is confirmed at surgery, or if prior surgical alignment has failed.

**Distal Realignment of the Extensor Mechanism**

When the patella cannot be centered in the femoral sulcus with a lateral retinacular release, or if the tibial tubercle is anatomically lateral to the femoral sulcus, producing a large valgus vector, the patellar tendon may need realignment. Several procedures are commonly being done and in the adult essentially consist of moving the patellar tendon, along with its bony attachment, to a new site on the tibia (Fig. 6). However, detachment of the tibial tubercle is not recommended in the adolescent because of the potential for growth disturbance. If patellar tendon realignment is required for an adolescent, the patellar tendon is usually split and either the medial or lateral half is then transferred to decrease the valgus vector (Fig. 7).

Rehabilitation of a patient after distal patellar tendon realignment will vary according to the procedure used. Those procedures that move the entire patellar tendon along with the tibial tubercle to a new site on the tibia will require bony healing before initiation of any forceful movement. The use of a screw or a staple for fixation decreases the time needed for osseous union before beginning progressive resistive exercises. Very little information is available about the healing strength of the tibial tubercle attachment site; however, arbitrary time restraints can be imposed to ensure proper bony union. Likewise, in the adolescent, when one-half of the patellar tendon is moved either medially or laterally, disruption of this suture site may negate the effect on decreasing the law of valgus.

Usually, after distal tendon realignment, Phase 2 of the Patellar Protection Program can be initiated four weeks after surgery, but weighted, progressive resistive exercises should be delayed until six or eight weeks after surgery and then advanced slowly as the healing tissues strengthen.

When the patellar tendon must be realigned and the patient has a closed epiphysis, we prefer the Elmsie-Trillat procedure, in which the tibial tubercle is elevated, leaving a periosteal attachment distally (Fig. 8).\textsuperscript{22} The tubercle is then rotated medially and aligned with the femoral sulcus and fixed with a screw. The advantage of this procedure is that alignment can be easily adjusted and the knee can be
flexed fully to evaluate the tracking action of the patella before securing the tibial tubercle with a screw. The strength added by the periosteal attachment also appears to be significant and to aid in early healing. We believe the use of this procedure allows an early initiation of progressive resistive exercises for the patient.

Postoperative Rehabilitation

As previously noted, rehabilitation of the knee after surgical extensor mechanism realignment is essentially the same for all procedures, except for the time constraints imposed by healing tissues. Using the modifiers and time constraints as previously discussed for each of the three major areas, the therapist can then confidently apply a postoperative rehabilitation program similar to our Patellar Protection Program.

In our program, progression from one phase to the next requires fulfillment of the various goals that we have outlined. In an athlete, the average time of return to play after a lateral retinacular release alone is about two months. The time for return to play after proximal realignment, or proximal and distal realignment, is usually six months. These time intervals, however, may vary from individual to individual. The ultimate criterion for return to play is a painless knee with a full range of motion and normal or near-normal muscle strength. We encourage the use of patella-restraining braces or taping on return to sport. In the nonathletic knee, times for return to full activity may be significantly lengthened and the criterion for return to work or daily activities may not be as stringent.

The association of chondromalacia with recurrent or persistent patellar malalignment is well known. Therefore, the physical therapist must be aware of the tendency for the chondromalacia to progress after surgery. The effects of immobility and lack of cartilage nutrition are well documented in the literature, and protection of the patella and its compromised cartilagenous surface must be foremost in the therapist’s mind during the early rehabilitation phases. Should signs of increasing chondromalacia occur, such as anterior patellar aching, recurrent swelling, palpable synovitis, or increasing patellofemoral crepitation, immediate measures should be taken to decrease patellofemoral forces. (For further information refer to the article on rehabilitation in this issue.)

Potential Complications

The physical therapist treating patellofemoral disorders should always be aware of the potential complications after patellofemoral joint surgery. The ther-
percent satisfactory and 17 percent unsatisfactory treated by medial patellar tendon transfer, with an results. The major reasons for unsatisfactory results in


