Primary lateral patellar dislocation — defined as a traumatic displacement of a normal and previously uninjured patellar position in the trochlear groove — is among the most common acute knee injuries in skeletally immature children and adolescents. Usually sports related, it results from a direct blow or fall onto the knee or a noncontact injury that occurs with the foot planted and the tibia externally rotated.

Treatment for patellar dislocation has historically been controversial. Many surgical interventions have been tried, often with unsatisfactory results and no clear evidence as to which is superior. Thus, conservative management remains the standard of care for first time dislocations. No matter what the initial management, failure to return to sport and recurrent instability are relatively common.

**Recurrent dislocation**

Recurrence, in fact, is one of the chief challenges of managing patellar dislocation in young athletes, especially those who are skeletally immature. Recurrent instability is associated with structural abnormalities such as patella alta, increased tibial tubercle-trochlear groove (TT-TG) distance and trochlear dysplasia — development of the femoral trochlear groove in an unusually shallow, flat, convex or deficient configuration (Figure 1).

Some evidence suggests that in very young children, recurrent instability itself may lead to secondary trochlear dysplasia, further increasing the risk of recurrence. Little human research on secondary dysplasia exists, but a study published in *The Knee* in 2013 found that rabbits with patellar dislocation developed trochlear dysplasia over time.

Similarly, few published studies have looked at recurrent dislocation exclusively in skeletally immature children. Studies that include both skeletally mature and immature patients have found high recurrence rates. In 2009, Finnish researchers writing in *The Journal of Bone & Joint Surgery, American Volume* reported a 40 percent risk of recurrence after nonoperative treatment of first-time patellofemoral dislocations. A larger study, published by Mayo authors in 2013 in *The American Journal of Sports Medicine*, found a 38 percent recurrence rate after three years.
of nonoperative treatment. More than half the patients in that study eventually needed surgery to gain stability.

Other studies have shown that a majority of patients who experience patellofemoral dislocation have a chondral or osteochondral injury. Damage to articular cartilage and underlying bone is associated with increased inflammation and degenerative changes. Yet little research exists on the incidence of arthritis among pediatric patients with patellar instability. A few small studies found that 14 to 29 percent of patients develop arthritis a decade or so after the initial injury (Figures 2 and 3).

Diane L. Dahm, M.D., an orthopedic surgeon and researcher specializing in knee injuries at Mayo Clinic’s campus in Rochester, Minnesota, says the potential for arthritis may be related to the number of instability episodes and that surgery after an initial dislocation may help prevent recurrences and associated post-traumatic arthritis.

“Our research is focused on continuing to define key risk factors for recurrent patellofemoral instability in skeletally immature patients and implementing treatment protocols to reduce the risk,” she says.

To aid that effort, Dr. Dahm and colleagues are part of a five-year, multicenter randomized controlled trial that aims to:

- Determine the risk factors for recurrence after first-time patellofemoral dislocation in skeletally immature patients, including patella alta, high TT-TG distances and trochlear dysplasia
- Evaluate medial patellofemoral ligament (MPFL) reconstruction as a surgical intervention after first-time dislocation
- Use MRI to evaluate the development of trochlear dysplasia in patients undergoing either surgery or conservative management for a first-time dislocation

“Strong evidence already exists that skeletally immature patients are at high risk of recurrence, yet the standard of care remains conservative management unless there is evidence of a displaced osteochondral fragment. Otherwise, most patients are treated with a brace and physical therapy,” explains Aaron J. Krych, M.D., a sports medicine clinician and researcher at Mayo’s campus in Minnesota, who is part of the study team. “That is mainly because in the past, surgery for kneecap dislocations — usually medial reefing or MPFL repairs — had an unacceptably high failure rate. But as our understanding of the biomechanics of the patellofemoral joint has improved, reconstruction of the MPFL has become an accepted treatment for recurrent patellar instability. We think some patients would also benefit from this surgery after first-time dislocation.”

The investigators hope to recruit 240 skeletally immature patients with a first-time patellar dislocation who will be randomized to receive either MPFL reconstruction or treatment as usual. They believe the MPFL group will show a significantly lower risk of instability in the five years after the initial injury than will the controls — the study’s primary outcome. Secondary outcomes include functional outcome.
Minimally invasive spine surgery has been adopted more slowly in spine surgery than in other surgical disciplines, primarily due to the difficulty of accessing and visualizing critical structures through small, closed working channels. But beginning in the 1990s, better understanding of spinal biomechanics, more sophisticated instrumentation and refined techniques led to greater implementation of microsurgical procedures, including lumbar decompression and fusion. Though now widely used, the indications and limitations of novel techniques in spine surgery are not always well-understood, and until recently, there has been a lack of scientific evidence to support their safety and effectiveness.

The goal of minimally invasive spine surgery (MISS) is to achieve outcomes equivalent to those of open surgery while minimizing muscle dissection, disruption of ligament attachment sites and collateral damage to soft tissues.

In conventional discectomy, for example, the paraspinous muscles are dissected from the posterior aspect of the lumbar spine and portions of the lamina are removed to gain access to the spinal canal. This allows the removal of disk herniation and relieves pressure on spinal nerves, but the dissection of spinal muscles and supporting tissues can lead to pain and possible instability.

Minimally invasive approaches can spare these tissues and reduce collateral damage. A tubular retractor system is used that dilates rather than dissects muscle. By utilizing sequentially larger tubes, the working channel is expanded without cutting muscle fibers. The reduction in trauma has been shown to reduce immediate negative effects, such as pain and disability, but not long-term outcomes, says Brett A. Freedman, M.D., an orthopedic surgeon specializing in spine surgery at Mayo Clinic’s campus in Rochester, Minnesota.

“When minimally invasive lumbar decompression is performed well with the right patient, there are advantages in the early phase, but the final outcome should be the same as with open procedures. There are no long-term outcomes reported in the literature where minimally invasive techniques led to a better end result than traditional approaches,” he says.

Norwegian researchers confirmed the equivalence of the clinical effectiveness of the two procedures in a multicenter observational study published in The BMJ in 2015. Using prospective data from a large national spine surgery
registry, they compared outcomes for more than 800 patients who had undergone open laminectomy or microdecompression for stenosis of the lumbar spine.

Favorable outcomes, as measured by change in the Oswestry Disability Index, were equivalent at one year. Complication rates and length of surgery were also similar after propensity matching, but patients who underwent microdecompression had consistently shorter hospital stays.

At Mayo Clinic, minimally invasive approaches are used when indicated. But Dr. Freedman cautions that it is far more important to perform all the functions necessary to fully and safely decompress the nerves than to worry about the method used to expose them.

“It is essential to do the same tasks in minimally invasive surgery that are done in open procedures,” he says. “You need to select patients with focal disease that can respond best to small windows of exposure, and you cannot compromise on the aspects of surgery that have been proved to provide full decompression just because you are using minimally invasive techniques. You need to be able to see what you need to see. Otherwise, MISS becomes a mistake.”

Minimally invasive fusion surgery

Spinal fusion has been used to manage a variety of disorders of the lumbar spine, including tumors, spinal instability, deformity and stenosis. But traditional open anterior or posterior surgery requires extensive soft tissue dissection to expose the anatomic landmarks for screw insertion, achieve a proper screw trajectory and develop an acceptable fusion bed.

The tissue injury that occurs is not only associated with increased postoperative pain and a lengthy recovery time but also with significant complications. Anterior surgery requires a relatively morbid incision and may cause vascular complications, postoperative colonic obstruction or injury to the sympathetic chain. Posterior surgery, including posterolateral fusions, posterior lumbar interbody fusions and transforminal lumbar interbody fusions, can lead to dural tears and neural complications such as radiculitis.

One alternative to traditional anterior and posterior approaches is lateral interbody fusion, which is performed using a lateral trajectory that can avoid abdominal and vascular structures as well as the spinal canal and nerves. This approach enables placement of an interbody graft into the disk space while minimizing the risks associated with anterior and posterior exposures. The procedure often requires supplemental fixation, most often in the form of pedicle screws, which can also be placed in a percutaneous minimally invasive fashion in the same setting or in a second stage operation.

“Lateral interbody fusion allows access to the front of the spinal canal in a trajectory that has the least amount of tissue disruption,” Dr. Freedman says. “It is a new and powerful technique that is gaining more favor.”

Clearing up a misconception regarding MISS, Dr. Freedman says it’s not uncommon to need multiple small incisions to complete a minimally invasive fusion, whether approaching the spine from the anterior, lateral or posterior direction.

“The total extent of the skin incision is probably as long as or longer than a standard midline incision. It’s not the length of the skin incision that defines minimally invasive techniques but rather the minimization of collateral tissue damage incurred while trying to reach the spine. The surgery needs to accomplish certain goals in order to correct the pathology. We have to continue to achieve what we have been achieving surgically for decades, and if we can do that with less collateral damage, then that would be ideal,” he explains.

Minimally invasive lumbar fusion is associated with reduced intraoperative blood loss and postoperative pain as well as greater and earlier restoration of function. Although these benefits are significant, especially for patients, Dr. Freedman says that in the long term, it can be difficult, if not impossible, to detect a benefit to minimally invasive spine procedures compared to open ones.

He explains: “The increased chance of complications, especially during the steep learning curve, must be balanced against the uncertain long-term benefit of MISS approaches. That said, our primary promise to the patient is to ‘Do no harm.’ If we can limit the collateral damage and still perform all of the key elements of the surgery to an equivalent or superior degree of completion, then MISS approaches are most appropriate.

“There is a constant desire to do things in a less invasive manner, and this will be increasingly possible as our experience grows and our implants and instrumentation get better. For now, MISS has a limited but growing role in spine surgery. The most important aspect of spine surgery is what the surgeon does to the spine. How he or she gets there is of less consequence. That said, less is more when it comes to collateral damage, so if you can achieve the goals of surgery through less invasive methods, then you have made the best case for use of MISS techniques.”

For more information

Dexamethasone May Prevent Post-Traumatic Osteoarthritis

Nearly 6 million people in the United States have post-traumatic osteoarthritis (OA) — chronic degradation of articular cartilage caused by injuries that damage the joint surface, such as osteochondral fractures and ligament or meniscus tears. This trauma initiates a cascade of events in joint tissues, including disruption of the cartilage matrix, the release of proinflammatory cytokines into synovial fluid, suppression of proteoglycan and collagen synthesis, and apoptosis. Although this is followed by a long, asymptomatic period, metabolic changes in articular cartilage eventually can progress to a symptomatic phase of joint pain and dysfunction.

Treatment may include surgical interventions to prevent progressive joint damage, such as reduction of intra-articular fractures, ligament repair and reconstruction, and joint stabilization. Yet even when joint biomechanics are successfully restored, the risk of post-traumatic OA is high, ranging from 20 to 50 percent. In the ankle joint, the risk may be even higher. Although many medical therapies have been proposed to halt or reverse the progression of post-traumatic osteoarthritis, none has proved particularly useful. Now, however, investigators in the Rehabilitation Medicine Research Center at Mayo Clinic’s campus in Rochester, Minnesota, are evaluating a particularly promising preventive therapy.

Christopher H. Evans, Ph.D., who directs the Rehabilitation Medicine Research Center, explains that the science originates from a collaboration with Massachusetts Institute of Technology professor Alan J. Grodzinsky, Sc.D. In 2011, they published a study in *Arthritis Research & Therapy* evaluating the effect of the glucocorticoid dexamethasone on cartilage subjected to mechanical injury and proinflammatory cytokines. That study built on previous research from Grodzinsky’s group showing that mechanical injury combined with tumor necrosis factor-α and interleukin-6 (IL-6) induced severe matrix degradation in bovine and human knee cartilage explants.

The 2011 study demonstrated that the glucocorticoid dexamethasone prevented matrix degradation, sustained matrix synthesis and prevented cell death after cartilage explants were exposed to injury and inflammatory cytokines. In one series of experiments, dexamethasone was added at the time of injury, and in another, it was added two days before or up to four days after injury to determine if it could protect or rescue cartilage matrix metabolism. In both instances, dexamethasone reduced glycosaminoglycan (GAG) loss and increased proteoglycan biosynthesis in bovine cartilage and suppressed GAG loss in human cartilage explants, leading researchers to conclude that the drug may have long-term protective effects (Figures 1 and 2).

Based on these studies, Dr. Evans, Sanjeev (Sanj) Kakar, M.D., a hand and upper extremity surgeon at Mayo Clinic’s campus in Minnesota, and colleagues have initiated a human clinical trial testing intra-articular dexamethasone as a preventive treatment for early-onset post-traumatic OA after distal radius fracture.

Dr. Evans says one major obstacle to in vivo trials of glucocorticoids in joint disease is the perception that they damage cartilage. “Glucocorticoids have commonly been used to treat joint problems, but the rule of thumb is that you shouldn’t inject an inflamed joint more than three times, so that has limited investigations,” he says. “But although that is the case with existing disease, we argue the effects are different if you are trying to prevent disease. Moreover, we are advocating a single injection at a very low dose to block inflammation mediators so that joint recovery can proceed normally. At this dose, the drug will benefit cartilage structure and cell metabolism without unwanted side effects.”

Another obstacle to human testing is the long latency period before arthritis symptoms appear. “Although injury accelerates the onset of

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**Figure 1.** Effects of dexamethasone on collagen loss in bovine cartilage with mechanical injury and IL-1α.
arthritis, it typically takes five to 10 years for it to develop, which is a lifetime for a controlled interventional study. We chose to study wrist fracture because the literature suggests a high incidence and rapid development of post-traumatic osteoarthritis after injury, so it seemed an encouraging place to start for a clinical intervention,” Dr. Evans explains.

The investigators are hoping to enroll 40 patients in the trial. Half will be randomized to receive an injection of 4 milligrams of dexamethasone in the radiocarpal joint within two weeks of injury. The rest will receive a saline placebo. The primary outcome is the incidence of post-traumatic OA at two years, as measured by arthritis pain and joint space narrowing using serial X-rays; the secondary outcome measure is a functional assessment of grip and pinch strength.

To date, about half the patients have been enrolled. “Dr. Kakar wanted to do a large study that would have strong statistical power, but we didn’t have the data on which to base the power analysis. We will build on the data from this study for a larger clinical trial,” Dr. Evans says. “We want to focus on patients who have just had surgery; the logic is that if you wait too long, the arthritic process will already have started, and we would be using dexamethasone as a therapeutic rather than a preventive.” A further discussion of the current trial is in press in the Journal of Orthopaedic Research.

Dr. Evans stresses that if dexamethasone proves safe and effective in future trials, the potential is enormous. “The drug is inexpensive and readily available — it could be administered on the sidelines by a team doctor or in the emergency department immediately after an injury,” he says, noting that dexamethasone has historic ties to Mayo Clinic. “The discovery of cortisone began at Mayo Clinic, where it was first used to treat rheumatoid arthritis. It’s quite poetic that it might be rediscovered here, 60 years later, for preventing arthritic disease in the first place.”

For more information


Minor leg length discrepancies are common — 23 percent of the general population has a discrepancy of at least 1 centimeter. The prevalence of leg length discrepancies requiring correction is about 1 in 1,000, whereas the most severe problems, such as congenital femoral deficiency, are quite rare. Limb lengthening has long been an accepted treatment for both common and complicated discrepancies and deformities, although the indications have broadened considerably over the last 100 years.

Originally used to correct discrepancies resulting from poliomyelitis, war injuries, and fracture malunion or nonunion, limb lengthening is now used for a wide range of congenital, metabolic, oncologic and post-traumatic orthopedic problems. It is also an accepted treatment for short stature — a common feature of some musculoskeletal syndromes. The goal of the Limb Lengthening and Regeneration Clinic at Mayo Clinic’s campus in Rochester, Minnesota, is to improve pain and maximize function for patients with limb deformities and deficiencies while simultaneously managing the underlying disorders.

To accomplish this, the clinic brings together eight subspecialists within orthopedic surgery — including surgeons trained in orthopedic trauma, pediatric orthopedics, orthopedic oncology, foot and ankle surgery, and hand and upper extremity surgery — as well as plastic and reconstructive surgeons, medical geneticists, endocrinologists, and radiologists. Stephen (Andy) A. Sems, M.D., an orthopedic surgeon at Mayo Clinic’s campus in Minnesota and a consultant in the limb clinic, says this reflects the traditional Mayo approach.

“In the Mayo model, experts from different specialties and subspecialties collaborate on each case. This has been the standard throughout the institution for decades, and now we are applying it to limb lengthening,” he says. “Our long-term goal is to provide patients with the highest quality outcomes they can hope for.”

**Limb lengthening devices**

Arguably the greatest recent advance in limb lengthening was the 2011 Food and Drug Administration approval of PRECICE, an implantable intramedullary rod (nail). The rod, which is indicated for limb length discrepancy and short stature, is surgically implanted in the intramedullary canal of the tibia or femur. It has a magnetic metal spindle connected to a series of gears. The gears, in turn, are connected to a coupling and threaded drive shaft that is activated by an external, remote-controlled device operated by the patient. The remote control contains two magnets that rotate the spindle. Depending on the direction, the distracting rod either lengthens or shortens at a maximal rate of 1 millimeter a day, thus achieving 50 millimeters of lengthening in about 50 days. The shortening function can be used for soft tissue problems or to stimulate additional bone formation.

Accurate rate control is one of the major advantages of the new device. Earlier implantable rods were plagued by imprecise distraction, leading to nerve injuries, joint contractures and nonunions.

A review published in 2014 in *Clinical Orthopaedics and Related Research* evaluated the accuracy, precision and associated complications of the PRECICE rod in 24 patients who underwent tibial or femoral lengthening or both between 2012 and 2013. The most common etiologies were congenital leg length discrepancy, post-traumatic growth arrest and fracture malunion.

The mean total lengthening was 35 millimeters, with an accuracy of 96 percent and precision of 86 percent. All patients achieved the intended distraction goal without a change in bone alignment or knee and ankle range of motion. One patient experienced implant failure caused by a nonfunctioning distraction mechanism; six others had nonimplant-related complications, including delayed bone healing. In Mayo Clinic’s experience, the complication rate is less than 5 percent.

“One of the main complications we see is knee joint stiffness with femoral lengthening and ankle joint stiffness with tibial lengthening, so our patients undergo aggressive physical therapy every day during the lengthening and consolidation periods. Maintaining range of motion and preventing contractures during the one- to three-month rehabilitation phase reduces the time to return to normal function,” Dr. Sems says.

The device is usually removed 12 to 24 months after implantation, when the bone has fully healed on all four cortices.

**External fixation**

Some patients needing limb lengthening who have previous implants, associated deformities, active infection or other confounding factors
may need treatment with an external fixator rather than an internal system. The fixator, which consists of two or more rings connected to six telescopic struts that can be lengthened or shortened, allows gradual lengthening and deformity correction by adjusting strut lengths according to a computer-generated treatment plan.

Complications such as pin tract infections and soft tissue tethering as well as the physical and psychological discomfort patients often experience are limitations, but Dr. Sems says experience with external fixators has improved dramatically. “Twenty-five years ago, many patients with limb deficiencies and deformities were told nothing could be done for them,” Dr. Sems says. “But there have been tremendous advances in the last five years and our clinic now has options for almost all patients.”

For more information