Advanced Surgical Management of Internal Derangement Issues of the Knee and Early to Late Osteoarthritis

by

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Consideration for Arthroscopic Surgical Management of Osteoarthritis of the Knee

Knee arthroscopy is basically microsurgery of the knee as discussed in the articles on this website. There is quite a bit of debate as to the ideal candidate for knee arthroscopy in the early to late degenerative arthritis knee. Over the years, I have come to the conclusion that in many cases arthroscopy for the degenerative knee can be quite successful given the right parameters for treatment. In many cases an artificial knee can be avoided or delayed. This article will discuss my experience and current recommendations for treatment in the degenerating knee.

In diagnosing the patient with osteoarthritis, x-rays are taken initially to determine the severity of the arthritis and its location. MRIs are very helpful as well. Sometimes a CAT scan (a computerized x-ray) is taken. There are several surgical solutions that enable the doctor to tailor surgical procedures to the patient's particular needs and anatomy. Patients may just need an arthroscopic approach, an arthroplasty (replacing the arthritic joint fully or partially) or an arthrodesis (rarely required), which is fusing the joints for better support and pain reduction.

After being involved in over thousands of arthroscopic and reconstructive knee surgeries, including total joints, I have come to the conclusion that many times total joint replacement surgery is not indicated in patients with an early to moderate or even advanced degenerative arthritis.

For every one hundred artificial knees performed, two patients developed an intra-joint infection after surgery, early or late. "Infections after total hip & knee arthroplasty are estimated in studies and range 0.9 to 2.5 % annually, while nationally, infection rate for artificial hips & knees is 1.6%." (Kapadia, 2013). Due to the severity of these infections with potential loss of leg and life, it is important that the most conservative measures are recommended for the patient especially in the treatment of moderately advanced degenerative arthritis.

What is my thinking regarding a patient with an mild to moderately severe arthritis?:

The patient is a 55-year old male teacher works at a local high school. He is also a competitive runner. He has already had one arthroscopic surgery with the medial meniscus removed years previous. He is very active and his x-rays demonstrate that he has moderately advanced degenerative arthritis of the medial (inside) knee. He has severe pain and swelling.

When I look at the patient's knee with a mild to moderately advanced degenerative arthritis, I look at the following list of factors. I look for increased tenderness, abnormal angulation of the knee, loss of motion, inflammation,, swelling and a history of instability, catching, or locking of the knee. Initially in some cases, laboratory studies are indicated to rule out a rheumatological source or infection as a source of the patient's problem (see the Synovial Fluid Analysis Paper). Assuming all studies have been done and are negative, and the patient has undergone physical therapy or a home exercise program and any other conservative treatment, then what viable options are left?

A lot depends on the x-rays of this particular 55-year-old patient. I look for joint space narrowing, subchondral sclerosis, bony deformity (Fairbanks changes), age of the patient, varus-valgus alignment (side to side alignment), osteophytes (extraneous bone formation secondary to arthritis) and loose bodies.

The weight bearing AP frontal x-ray view reveals how much of the protective articular cushioning is present. The weight bearing films demonstrate the depths of the articular "cartilage clear space", which is the width of the space between the bones. In the AP view (frontal) we are measuring the width of the space between the femur (thigh bone) and the tibia (shin bone). Comparison views of the opposite knee are taken. The lateral x-ray view demonstrates the articular cartilage clear space between the patella (kneecap) and the femur (thigh).

The ultimate question arises in patients such as this: where is the pain coming from and what are we treating? Is there joint pain and/or patellar region pain? Is the pain in the bone? In the synovial tissue that lines the joint? Are there loose bodies, i.e. pieces of bone in the knee catching and causing pain and abnormal wear? Is there an unstable meniscus tear? Is there a prior ligament injury? Why is there lack of motion? Is there locking and catching? Is there swelling and what is causing it? Is there a loss of normal alignment and abnormal wear on visualization of the knee upon the patient standing? Does excessive weight contribute and how much is too much? Did the patient have prior surgery? If so, what type?

An MRI is also recommended to assess the various structures about the knee which includes the meniscus, ligaments, articular cartilage joint surfaces and in some cases abnormal membranes (synovium) lining the joint.

My current thinking includes many options:

Is there apparent exposed bone at the joint surfaces with joint collapse diffusely throughout the the joint? Are there large extensive areas of bone and bone articular cartilage loss and osteophyte formation (abnormal bone growths)? With this type of problem which is advanced joint collapse and failure of conservative treatment, then a

total (artificial) knee may be recommended depending on the age of the patient, body weight, or including any other comorbidities.

But there are other options in most cases.

As an operating surgeon, my goal is to avoid total knee replacement, and in my opinion, it is of paramount importance. I am concerned about infection and severe complications with total joint procedures.

Patients want and need an active lifestyle, have a desire to live longer, and they want to be physically active to stay healthy. An artificial knee is not a new knee. It is a synthetic knee that in time will wear. The average age of total knee replacement in this country is around age 55. The average age of total knee replacement in England is 74. Over 45 million Americans have undergone at least one total knee replacement surgery. According to the Health Research Funding Organization more than 650,000 knee replacements were performed in the United States during in a single year in 2010 (Surgery Articles and Infographics).

Knee pain in the western world is becoming epidemic. There are temporizing procedures discussed below that may allow a greater activity level with mild or moderately advanced degenerative arthritis of the knee. Conservative management is usually the initial treatment of choice.

I occasionally recommend orthopedic foot supportive devices called **orthotics**. Orthotics are effective in a number of cases. Custom-made shoes and shoe inserts can provide support for those with osteoarthritis in the knee, foot or ankle. A knee **brace or a cane** can help in reducing the pressure of the affected joint while you stand and walk. Knee supportive braces, called **unloading braces**, attempt to change the angulation of the knee while weight-bearing and to reduce the pressure on the diseased or injured part of the knee.

If, after all conservative measures are unsuccessful, and the patient is still experiencing unremitting pain within the joint with pain, swelling, stiffness, night pain, instability and the symptoms are severely affecting the quality of life. The big risk if the knee is unstable and giving away. Especially if there is mechanical locking and/or catching which can result in secondary injury from falling and hurting another body part.

In my opinion, arthroscopic surgery is recommended for the subset of patients who have mechanical symptoms with catching and locking associated with swelling, chronic pain and have failed conservative treatments. Injection therapies will not cure this type of problem.

As noted, Arthroscopy is basically microsurgery of the joint. The surgery is performed through very small holes in the front of the knee anywhere from two to four in number.

There are very important indications in the severely damaged and stiff knee to recommend arthroscopic surgery right away. If the knee is markedly mechanically unstable with severe pain, locked and unable to bend normally, then arthroscopic surgery is usually recommended right away to restore a more physiological and functional knee with less pain.

Generally, with minimal pain only symptoms, a near full range of motion, and negative lab studies, MRI and xrays, surgical treatment is not recommended.

An additional question arises. Is arthroscopic surgery advantageous for patients who have early to moderate to severe osteoarthritis without mechanical symptoms of catching and locking? Yes, but cases are selected carefully. Additional modalities of treatment are available as well in the knees that do not have mechanical symptoms.

Platelet Rich Plasma

Platelet Rich Plasma (PRP) is a new technique I am using to promote faster and better healing after knee surgery especially in meniscus surgery. I do not normally use PRP on patients unless I perform surgery on them first. PRP will not heal unstable meniscal tears and will not reverse the mechanical symptoms of catching, locking, and giving away.

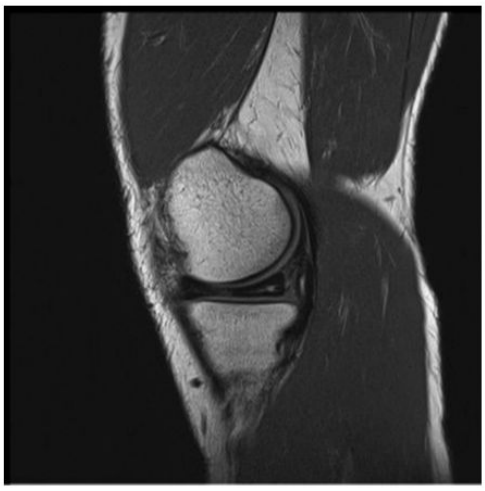

Figure 1. Meniscal lesion before injections (patient 7).

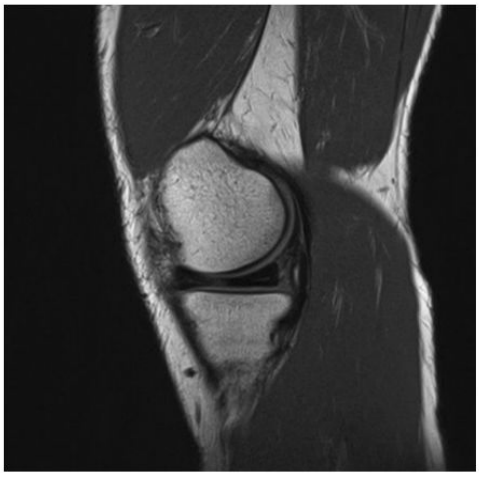

Figure 2. Meniscal lesion 6 months after injections (patient 7).

Figure 1. Source: Blanke, F., *Percutaneous injections of Platelet Rich Plasma for treatment of intrasubstance meniscal lesions.* Muscles, Ligaments and Tendons Journal 2015;5 (3):162-166

Advanced arthroscopic techniques are used to decrease or eliminate the mechanical symptoms. Once surgery is performed to provide a more normal biomechanical knee, PRP is injected into the knee to accelerate the healing process.

As there is evidence that PRP may accelerate the healing of residual meniscus tears in the knee.

Platelets consist of proteins, cytokines, and other bioactive factors located in the peripheral blood. They contribute to the regulation of homeostasis and promote wound repair. **Plasma** contains clotting factors, proteins and ions.

Recent literature suggests that for optimal therapeutic purposes physicians should use a platelet concentration of 1 million platelets per microliter and a 3- to 5-fold increase in growth factor concentration and cytokines" (Mehta, 2008).

In plasma, numerous proteins are contained, such as insulin-like growth factor (IGF), platelet-derived growth factor (PDGF), platelet factor interleukin (IL), platelet-derived angiogenesis factor (PDAF), epidermal growth factor (EGF), transforming growth factor (TGF), vascular endothelial growth factor (VEGF), and fibronectin (Lubkowska, 2012). In the dense granules of platelets such bioactive factors are also found, specifically calcium, dopamine, serotonin, histamine, and adenosine. Such non-growth bioactive factors control inflammation, proliferation, and remodeling in the process of wound healing (Boswell, 2012). PRP is also used in an attempt to slow down the arthritic degeneration process, preserve chondrocytes which are cartilage cells that line the joint. PRP also stimulates ligament, tendon tissue repair, and meniscal healing.

German and Swiss scientists confirmed that PRP percutaneous injections release therapeutic properties for pain relief and promote the decrease in grade 2 meniscal lesions progression in patients over a 6 months time period (Blanke, 2015).

Another study on animals treated with PRP injections for meniscal tissue defects revealed the curative properties of PRP of the inner, avascular meniscus. Subjects treated with PRP showed significantly greater scores for the number of fibro-chondrocytes and production of extracellular matrix compared to the control group (Ishida, 2007). Moreover, several studies suggest the additive effect of PRP-containing growth factors for increased meniscal cells activity and augmentation of meniscal repair and healing during horizontal cleavage meniscal tears repaired via an open surgery. A team of surgeons from France in one such study invited 17 patients for open meniscal repair surgery of horizontal tears extending into the avascular

zone-Group 1, and additional 17 patients underwent same surgery with introduction of PRP injections at the end of the open meniscal repair-Group 2 (De Chou, 2015). The MRI results of this study demonstrated that 5 patients from Gr 2 had full disappearance of hypersignal within the repaired meniscus at 24 months postoperative time-frame (De Chou, 2015). Such evidence suggest the additive effect of PRP to improve outcome results after open meniscal repair surgery. Due to patient's individual meniscal injury variations, PRP can be injected in the knee at the time of surgery or fairly soon after surgery. Meta-analysis of PRP technology confirms that PRP treatment promotes more robust healing in an attempt to preserve the meniscus tissue and to provide faster and better healing of the residual meniscus and knee joint tissues, including the ACL and PCL ligaments.

Currently most health insurance coverage does not pay for PRP treatment. We will discuss various payment options to receive this treatment if it is felt to be advantageous to your condition(s).

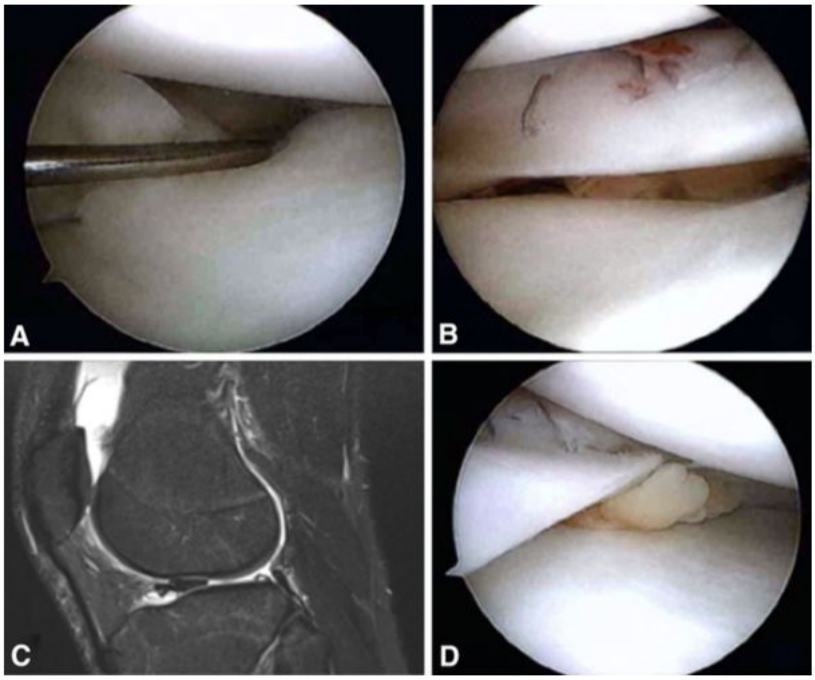

Fig. 1A–D (**A**) An intraoperative image of a displaced meniscus tear is shown. (**B**) An inside-out repair is performed with PRP augmentation. (**C**) MRI demonstrates a bucket-handle lateral meniscus tear and (**D**) PRP augmentation of this meniscus repair.

Figure 2. Source: Griffin, J.W., et al. *Platelet-rich Plasma in Meniscal Repair: Does Augmentation Improve Surgical Outcomes?* Clinical Orthopedics and Related Research. 2015. 472: 1665-1672.

Hyaluronic Acid

Hyaluronic Acid (HA) is also used in post-surgery cases as well or in non-surgical cases applied within the joint to ameliorate arthritis associated pain.

Hyaluronate or hyaluronan is contained in cartilage and the synovial fluid. HA is a large viscoelastic glycosaminoglycan molecule that is contained in synovial fluid and cartilage matrix. Chondrocytes (cartilage cells), fibroblasts (collagen producing cell) and the synovial cells all secrete HA into the joint. HA Is approved by the The Food and Drug Administration (FDA) and is either generated from bacterial fermentation in vitro or from harvested rooster combs. Such HA contain Hylan G-F 20, sodium hyaluronate, and high-molecular weight hyaluronan (McArthur, 2012). In healthy patients, synovial fluid contains a normal HA amount or concentration and serves as a viscous lubricant for healthy knee movements, much like a lubricant in a car.

There is a decreased amount of HA in the synovial fluid of OA patients (Trigkilidas, 2013). In OA patients, where the synovial membrane secretes abnormal proteases, free radicals, and cytokines which leads to the disruption of organic HA synthesis and contributes toward the progression of OA (Brockmeier, 2006). A healthy level of HA is crucial in providing anti-inflammatory properties to regulate cartilage homeostasis, and to slow the chondrocyte apoptosis (cell death) which occurs with OA.

I am using HA gel currently and this substance can last up to six months in the correct patient.

Stem Cell Technology

Mesenchymal stem cells (MSCs) exhibit properties both in multipotent differentiation (cells that may develop into more than one cell type) and immunomodulation (immune response alteration to a desired level) (Wyles, 2015). Based on these unique properties, stem cells have the therapeutic potential to treat osteoarthritis (OA). Since 1990 there have been promising clinical trial results from the U.S., India, Germany, Singapore, and Iran that the intra-joint injection of MSCs can be an effective therapy for treating OA (Sarabi, 2016). Furthermore, clinical trials in Spain have illustrated MSCs injected with more advanced stem cells technology for localized treatment of OA, using bioabsorbable material (hydrogel) as a vehicle carrier (Lamo-Espinosa, 2016). Many of these clinical trials were performed with bone marrow derived MSCs, but other MSCs derived from adipose and the umbilical cord can also have great potential to treat OA, as they share similar characteristics to bone marrow MSCs (Uth, 2014).

In general, adipose and umbilical cord MSCs have a higher culture life expansion potential (have a higher duration to secrete regenerative factors) and may be more readily available, but not necessarily exhibit strong therapeutic regenerative (ability to heal damaged tissue) potential as BM-MSCs.

Interestingly, both allogeneic (donor cells) and autologous (host cells) MSCs have therapeutic potential to treat OA, and it may be that allogeneic MSCs may be a more convenient "off-the-shelf" therapy to utilize due to the immune-evasive nature of MSCs lacking HLA antigens (does not stimulate the host immune response as a foreign substance) and other co-stimulatory molecules to elicit an immune rejection response (Gupta, 2012). Lastly, dosages from 10–100 million MSCs per intra-articular injection are recommended for a therapeutic response to treat OA corresponding to the severity of disease or injury, and the patient's Body Mass Index (BMI) (Lamo-Espinosa, 2016), but potentially a smaller dosage of MSCs could be used in a scaffold (hydrogel) to have a stronger localized treatment effect.

An interesting observation by Mayo Clinic researchers was conducted and published at The American Journal of Sports Medicine regarding the increasingly used bone marrow aspirate concentration (BMAC) as a regenerative therapy for mild to moderate degenerative joint disease of the knee (Shapiro, 2016). In the study 25 patients with bilateral knee pain and bilateral OA were randomly assigned to receive a BMAC into either one knee and a saline placebo treatment into the opposite knee. "Fifty-two milliliters of bone marrow was aspirated from the iliac crests and concentrated in an automated centrifuge. The resulting BMAC was combined with platelet-poor plasma for an injection into the arthritic knee and was compared with a saline injection into the contralateral knee, thereby utilizing each patient as his or her own control" (Shapiro, 2016). The surprising results of the treatment revealed that "bone marrow stem cell injection in one ailing knee can relieve pain in both affected knees in a **systemic or whole-body fashion**," says the study's lead author, Shane Shapiro, M.D., a Mayo Clinic orthopedic physician" (Punsky, 2016).

I consider the stem cell technology as a new technique in orthopedic surgery, aimed to rejuvenate joint and body parts. We are currently researching the use of stem cell techniques in joints, muscles, and tendons. It appears based on the current literature that the technique is promising. We are moving forward, starting to apply the stem cell technology in practice. I am currently using advanced arthroscopic techniques to stimulate the body's own stem cells, while performing various complex surgical arthroscopic procedures.

With failure of conservative treatment, various arthroscopic procedures are being performed including the following:

1. Lavage and debridement
2. Removal of loose bodies
3. Partial meniscectomy (degenerative meniscus tearing with unstable fragments generally causing mechanical symptoms like locking, catching and instability)
4. Resection of bony fragments, i.e. osteophytes which impinge on soft tissues
5. Capsule release procedures,
6. Microfracture
7. Synovectomy
8. Aggressive reshaping the interior of the knee with arthroscopic bony techniques
9. Biologic resurfacing
10. Cartilage transplants

There is evidence in the literature that arthroscopic surgery for early to moderate osteoarthritis of the knee is indicated in many cases. I will present a brief summary of the pertinent medical literature.

J.B. Moseley, MD and his colleagues reported a study in the *New England Journal of Medicine*, concluding that in the control trial involving patients with osteoarthritis of the knee with outcomes after arthroscopic lavage or arthroscopic debridement were no better that those after a placebo procedure. However when one reads the body of the study, it appears that the patients who theoretically would be successful with treatment with arthroscopy were eliminated from the study prior to engaging in the study. Many of the patients who were in the study had symptoms compatible with internal derangement such as torn meniscus with catching, locking, giving way, etc. and opted out of the study and many were quite old. Thus the actual study itself does eliminate a certain subset of the arthritic population, which includes primarily the arthritic knees with swelling, catching and giving way. These patients really wanted the arthroscopic surgery and opted out of the study. The studied knee patients did have pain; however, the study confirmed that the patients were without mechanical symptoms or swelling of the knee were no better than placebo.

An experienced knee surgeon would normally not recommend surgery in this group anyway and would recommend conservative treatment. In addition, the actual level of expertise of the surgeon performing these particular surgeries was also not well documented and may not have been trained or experienced enough to provide the appropriate arthroscopic arthritis knee surgery techniques available. 40% of the people that were selected for the study refused to participate. Patients who had bone-on-bone but no mechanical symptoms were included in the study. No body weights of the

patients were taken, or data addressing the preoperative stiffness of the knees or swelling. 79% of the patients studied were men. The actual age of the group of patients was older, up to age 75. The study was poorly designed.

Hunt and colleagues stated in The *Journal of the American Academy of Orthopedic Surgeons* in 2002 that patients with early degenerative arthritis with mechanical symptoms of locking or catching may benefit from arthroscopic surgery (Hunt, 2002).

The "AAOS Clinical Guidelines Support Document" 2003 stated if avascular necrosis (early bone death) is not present and there is no significant joint space narrowing, then arthroscopic debridement can be considered for the treatment of patients with mechanical symptoms of the knee, meaning locking, catching, giving way, etc. This subgroup of patients with arthritis was felt to benefit from arthroscopic surgery.

A team of scientist from London looked at the effect of a five-year survival analysis of arthroscopic washout of the knee (Lazic, 2014). This particular study found only 18% of patients progressed to major knee surgery within five years of an arthroscopic washout for osteoarthritis. Age greater than 60 years worsened the prognosis considerably.

In my opinion, based on extensive surgical arthroscopic experience and upon reviewing the literature, is that arthroscopic debridement can be quite beneficial with meniscectomy, removal of loose bodies, microfracture, excision of hypertrophic soft tissue and bone and associated with mechanical symptoms with chronic severe pain, stiffness,swelling, locking, catching and giving away..

In the younger population with abnormal mechanical symptoms such as locking, catching, giving way, joint pain,swelling, and instability, and with a normal alignment without severe angulatory deformity is the more the ideal patient for arthroscopy in general.

An article written by Steadman in 2004, 81 patients were studied who underwent osteoarthritis surgery with microfracture (Steadman, 2004). The age of the patients studied who underwent osteoarthritis surgery with microfracture was between 40 and 70 with an average follow-up at 2 – 5 years. At five years, only 13 patients required repeat arthroscopies vs. total joint.The study included subjective parameters such as pain, swelling, limping, walking stairs, sports level, and activities of daily living. The study demonstrated significant improvement over preoperative status.

A team of Japanese researchers concluded that knees with relatively advanced osteoarthritis for which arthroscopic debridement has conventionally been contraindicated, can be treated with a posterior medial capsular release if they are selected properly based on MRI findings (Moriya, 2004). MRI findings were graded into

different categories including a smooth group and an irregular group. The two groups were based on the subchondral contour of the medial femoral condyle. The mean age of the patients at the time of surgery was 71.6 years. The range of motion was restricted in many cases and ranged from 13 degrees to 129 degrees. Overall the average JOA score improved to 71.6 points from 56.3 points preoperatively. The majority of the patients showed significant improvement. Thus it was felt that selected patients would benefit from this particular procedure if they're properly selected based upon MRI findings.

A definitive article by H.O. Leon, MD (2005) from Cuba addressed the issue of osteophyte or abnormal bone formation located within the intercondylar femoral notch which produced narrowing and stenosis of the interior of the knee with loss of motion in the majority of the cases. The femoral notch is the opening in the middle of the knee in juxtaposition to the two cruciate ligaments. If the appropriate procedures were performed, the patient's preoperative flexion contracture (stiffness) resolved in 81% of the cases. 90% had good to excellent pain relief and 74% experienced excellent relief from subjective instability. The author's conclusion stated that abnormal narrowing of the interior of the knee (in the arthritic knee) is a cause of ACL ligament damage, symptomatic instability with pain and loss of normal extension. The author described a structured approach to diagnosis and treatment in these particular patients and also felt that the procedures may prevent disease progression within the knee.

The Ogilvie-Harris and his colleagues performed 211 synovectomies (removing the interior lining of the knee) addressing the degenerative knee over a 10-year period (Ogilvie-Harris, 1995). Results were assessed after 2 years with the criterion of pain, synovitis, effusion, range of motion and function. In rheumatoid arthritic knees, which represent 112 cases, they had good to excellent results in 80% of the patients. In seronegative arthritides, 60% were successful. Pigmented villonodular synovitis (synovial pathologic membrane) was successfully treated with an 11% recurrence rate. Synovial chondromatosis (formation of abnormal hyaline cartilage) was also treated with no recurrences. In patients with nonspecific synovitis or posttraumatic synovitis, the synovitis was improved in 60%, but only half the patients had pain relief and good function. Looking specifically at the posterior portals, there were five complications, all related to the posterior medial portal involving the saphenous nerve and vein. Overall, they felt that excellent results can be achieved with due care and attention to detail at the time of surgery.

A more localized approach was reported by Ikeuchi(2005) who performed a partial synovectomy, where only the anterior part of the synovial membrane (front of the knee) was removed. The conclusion was that localized synovial hypertrophy in the anterior

medial compartment of the osteoarthritic knee does occasionally cause symptoms of pain and catching that resemble damaged meniscal symptoms. Arthroscopic partial synovectomy was effective.

In lieu of qualifying statements and my extensive personal surgical and nonsurgical experience and reviewing the literature, I do feel that appropriate arthroscopic surgery for early to moderate, and even advanced cases of degenerative arthritis is indicated with failure of conservative treatment and should be the first line of operative treatment of the degenerating knee. During the surgery, each specific pathologic problem needs to be addressed, including unstable meniscus tears, torn ligaments, loose fragments of bone, synovial membrane hypertrophy and localized articular cartilage disruption,

The best results occur with a more normal knee alignment without advanced bone-on-bone x- ray findings. Even though I have performed arthroscopic surgery on bone-on-bone patients, the patients have reported on a routine basis significant improvement of their preoperative symptoms. If after knee arthroscopy, the knee does not return to more normal functioning and still has a lack of full extension of the knee (straightening of the knee), and the patient still continues to experience lack of flexion (or bending backwards), then this particular subgroup of patients, in my opinion, will eventually be candidates for total knee replacement.

I explain to the patients regarding total knees that the devices have improved greatly over the years, but a total knee is basically glue, metal and plastic. It is not a normal knee and never will be, and it's likely if the patient lives long enough that a replacement (revision) will be required, much like a car after so many years of usage will need to be replaced.

Revision total knee surgery is another magnitude of surgery. It requires an expertise and experience. The literature states that the revision surgeries are not as successful as the primary. In fact, they are at least 20 – 30% not as successful. Revision surgery also requires another open type procedure, which places the patient at risk again for more serious complications such as infections, which are also more common in revisions.

What other techniques or procedures are available for treating the patient who fails advanced arthroscopic surgery? Other minimally invasive options are currently available.

Other options consists of various biological resurfacing procedures for early to moderate arthritis which include the following:

1. **Microfracture**, which is an attempt to regrow the surface membrane of the knee which is called hyaline cartilage is the normal type of cartilage found lining the interior of the joint.

2. **Osteochondral allografts** (cadaver source) where one transplants articular cartilage with bone from another part of the knee to the osteoarthritic lesions or using autograft (using the patient's own articular cartilage and bone). Occasionally a high tibial osteotomy(changes the abnormal angulation of the leg) and/or a meniscus allograft can be performed but generally is more successful in younger patients. An osteotomy is a cutting of the proximal end of the tibia and changing the alignment to a more normal physiological angle. Most knees have a slight curve to the outside, and this is called valgus alignment. If the knee and lower shin curves to the inside, it's called varus alignment. With osteoarthritis, the angulation is dependant on the side of the knee that is involved. The deformity results in knock knees(valgus) or bow legs(varus) knees.

3. **ACI (Autologous Chondrocyte Implantation)** American Academy of Orthopedic Surgeons (AAOS) defined that Autologous Chondrocyte Implantation (ACI) as the following:

> "ACI is a two-step procedure. New cartilage cells are grown and then implanted in the cartilage defect.
>
> First, healthy cartilage tissue is removed from a non-weightbearing area of the bone. This step is done as an arthroscopic procedure. The tissue which contains healthy cartilage cells, or chondrocytes, is then sent to the laboratory. The cells are cultured and increase in number over a 3- to 5-week period. An open surgical procedure, or arthrotomy, is then done to implant the newly grown cells. The cartilage defect is prepared. A layer of bone-lining tissue, called periosteum, is sewn over the area. This cover is sealed with fibrin glue. The newly grown cells are then injected into the defect under the periosteal cover.
>
> ACI is most useful for younger patients who have single defects larger than 2 cm in diameter. ACI has the advantage of using the patient's own cells, so there is no danger of a patient rejecting the tissue. It does have the disadvantage of being a two-stage procedure that requires an open incision. It also takes several weeks to complete" (AAOS, 2017).

ACI is a technique that is becoming more popular, which is also called Chondrocyte implantation.

- A healthy articular cartilage biopsy is taken from the patient and the defective area of the knee is identified.
- A biopsy of the patient's non-weight-bearing articular cartilage is sent to Genzyme for tissue processing.
- The cells at the laboratory are cultured and then sent to the surgeon after an appropriate amount has been cultured/grown 3 – 5 weeks.
- The cultured cartilage cells are injected into the defect in the bone. The periosteum is the normal membrane that covers all the bones of the body and this membrane is removed from the shin and transplanted into the knee as a barrier for the transplanted articular cells.

4. **Matrix-induced autologous chondrocyte implantation (MACI)**:

> **"Maci** is a new procedure to treat the articular cartilage defects of the knee. Articular cartilage is a tissue that covers the surface of the joints and is responsible for pain-free movement of the bones within the joint. If the articular cartilage is damaged, the ends of the bones rub against each other causing pain. Matrix-induced autologous chondrocyte implantation is indicated for patients with significant cartilage defects causing joint pain, swelling, and catching in the knee.
>
> Matrix-induced autologous chondrocyte implantation is a two step procedure. The first step is performed arthroscopically, where the healthy cartilage cells or chondrocytes is harvested from the non-weight bearing area of the bone. The chondrocytes are sent to the laboratory where the cells are cultivated on a sterile collagen membrane (matrix) for 4 to 6 weeks.
>
> The second stage procedure is performed through an open procedure or arthrotomy. A small incision is made to expose the area of cartilage damage. The chondrocyte cells that have been seeded onto the collagen membrane are implanted into the damaged area in the knee. The MACI procedure helps in regeneration of cartilage and brings back the flexibility of the knee.
>
> Following MACI procedure, you may not be allowed to lift heavy things or bear weight on the area of the cartilage for at least 6-8 weeks, so that the cells adhere to the underlying bone. A knee brace is worn to protect the

> cartilage repair. Physical therapy may be recommended to strengthen the quadriceps and hamstring muscles.
>
> You will be allowed to return to your sports after a year. Jogging or running is not advised until 12 months. Some sports such as swimming and cycling can be started after 6 months and you will not be allowed to play high impact sports for 1 year. You can return to your work from two to six weeks after surgery" (Flanigan, 2013).

Additional questions need to be asked regarding the degenerating knee include: Is the pathological problem localized on the x-ray or MRI? Is it unipolar or located on one side of the knee? Is it on both sides of the knee and considered bipolar? Is it primarily affecting the lining membrane of the knee?

Is it osteochondral, in other words is the bone inflamed and the knee articular lining involved in the damaged or arthritic region? Is there a deformity of the knee? With advancing arthritis, often the lower leg will begin to angle either to the inside or to the outside, with the lower leg moving in an abnormal angle. The alignment of the knee as far as the various structures including the kneecap is also considered.

What is the position of the kneecap in the straight and flexed position? Many patients have kneecaps that are rendered unstable congenitally or by injury or by arthritis. The kneecap, or patella, needs specific studies performed to adequately evaluate the position of the patella as it relates to the thigh and shin bone. After injury the knee cap is often found in a non anatomic position. Corrective surgery is often indicated but in the minority of the cases.

Another question often asked is when is a meniscectomy required in this type of surgery? (Englund, 2009).

Figure 3: The Multicenter Osteoarthritis Study

"A and **B**, Radiographs of the knee of a subject in the Multicenter Osteoarthritis Study (MOST) who did not have osteoarthritis (OA) at baseline (**A**) but in whom OA had developed at the 30-month visit (**B**). At 30 months, the subject had joint space narrowing and an enlarging marginal tibial osteophyte in the medial compartment (**arrowhead**). **C** and **D**, Examples of meniscal damage in 2 other MOST subjects. Proton-density magnetic resonance imaging scans show a grade 1 meniscal tear (**arrowhead**) extending into the inferior surface of the posterior horn of the medial meniscus (sagittal view) in 1 subject at baseline (**C**), and complete maceration/destruction (grade 4; **arrowhead**) of the body of the lateral meniscus (coronal view) in the other subject at 30 months (**D**). In addition, the well-defined hyperintense area posterior to the torn meniscus (**C**) represents part of a Baker's cyst" (Englund, 2009).

A meniscectomy is removal of the torn meniscus or cushion of the knee, or remodeling of the meniscus. The meniscus does not have an adequate blood supply in the bulk of the meniscus and does not heal well. (See article on The Knee and Meniscus Surgery).

Another team of physicians and scientist in California conducted a study with meniscus repairs in patients undergoing 5712 primary ACL reconstruction (ACLR) (Wyatt, 2013). Among the participants in 4248 (74.4%) patients 1 torn meniscus was registered, and in 1464 (25.6%) patients both menisci were torn. During the study medial and lateral meniscus tears were repaired and a number of participants were offered alternative treatment, such as meniscectomy, trephination, rasped. The results of this study showed that "that younger patient age ($P < .001$), lower patient BMI ($P < .001$), surgeon's sports medicine fellowship training ($P < .001$), higher surgeon case volume ($P < .001$), higher surgical venue volume ($P = .019$), and medial meniscus tears ($P < .001$) were all associated with a higher likelihood of a meniscus repair" (Wyatt, 2013).

Another collaboration between Boston and UCSF researchers examined the association between meniscal damage in knees without surgery treatment and the development of radiographic OA within 30 months follow up period (Englund, 2009). In this study it was discovered that meniscal tears in middle-aged and elderly persons without appropriate immediate treatment are strongly associated with the development of radiographic tibiofemoral OA. Specifically, that treatments aimed at restoring meniscal function may lower this risk of onset and progression of radiographic OA (Englund, 2009).

Another question: is there abnormal or loose bone in the joint and does this require removal? If there is catching and locking, arthroscopy is recommended and the loose bone is removed.

Once an arthroscopic surgery is decided upon, initially the lining membrane of the knee, which is called the synovium will require inspection. If the synovium is markedly hypertrophic (enlarged) and inflamed, it will require at least partial removal. In many cases there is a congenital abnormality of the synovium called plica, which in some cases has been within the knee since birth. Many of these membranes cause abnormal symptoms of pain and discomfort of the knee throughout the life of the patient and can lead to premature arthritis and mimic other problems. Usually at the time of arthroscopy the problem is found and the membrane will be required to be removed (see Plica and Running Article).

Questions that will be answered at the time of arthroscopy include whether or not the hyaline cartilage (i.e. articular cartilage) is fragmented and what is the depth of the fragmentation? Is the lining cartilage frayed to the point that the bone is exposed? If the bone is exposed, then the current thought is that this is an area that causes pain and discomfort. At the time of arthroscopy, the amount of articular cartilage damage is assessed. It is currently felt that if one has 4 cm or less of chondral damage and/or defect that a microfracture technique will be successful approximately 80% of the time. If the lesion is greater than 4 cm, then other options would have to be considered as felt that the microfracture technique is not as successful in these cases (Steadman, 2004).

It is important to subcategorize the articular cartilage pathology of the knee. At the time of surgery, the lining articular hyaline cartilage membrane of the knee must be inspected.

The Outerbridge articular cartilage gradation system for areas of injured hyaline cartilage

- Grade 0 - normal
- Grade I - cartilage with softening and swelling
- Grade II - a partial-thickness defect with fissures on the surface that do not reach subchondral bone or exceed 1.5 cm in diameter
- Grade III - fissuring to the level of subchondral bone in an area with a diameter more than 1.5 cm
- Grade IV - exposed subchondral bone

Source: Knee Guru. Outerbridge Classification. http://www.kneeguru.co.uk/kneenotes/knee-dictionary/outerbridge-classification.

Bony problems include osteochondral defects, bony sclerosis, osteophytes(abnormal bone formation in the joint), deformity – squaring of the inferior femoral condyles, and bone collapse.

Other additional issues, of course, need to be considered whether the knee is unstable and the alignment has to be evaluated objectively as to increased angulatory deformities.

In my opinion, the best patient who can benefit from this procedure arthroscopically is a patient with minor or no joint space narrowing, articular cartilage fragmentation considered grade 2-3, mechanical symptoms of the knee i.e., catching, locking, giving way, chronic intermittent swelling, or more advanced lesions at the articular surface

consistent with a localized uni- or bi- polar bony defects. Cartilage resurfacing is an option. In my opinion, the best way to treat lesions that are less than 2-4 cm is using the microfracture technique. As previously noted, an osteochondral graft is indicated for bone necrosis problems which leads to removing a piece of bone with the associated articular cartilage from a healthy part of the knee and transferring it to the damaged area or using an allograft (cadaver).

As noted above, If the lesion is greater than 4 cm (Steadman's criterion site the microfracture and arthritis article again), then a procedure called ACI (autologous chondrocyte implantation) can be considered, or a larger osteochondral allograft can be considered, and in the future MACI (research) (matrix-supported autologous chondrocyte implantation or other related articular cartilage procedures can be considered. It is the rare patient that qualifies for an osteochondral graft.

With a badly torn meniscus, meniscus allograft (cadaver meniscus) is a consideration and acts as a spacer between the femur and the tibia. The literature is not 100% confirmatory on the use of allograft. This technique is not indicated in patients with arthritic changes in the joint. This procedure is done in the younger patient population in an attempt to provide a more normal structural relationship at the a torn meniscus site which required near complete excision.

Another subgroup of patients includes patients with degenerative osteoarthritis with significant bony involvement. With the bony stage 1, which is consistent with osteochondritis dissecans, bone necrosis, which is a result of losing the blood supply to part of the bony architecture of the knee resulting in bony collapse with pain and occasional deformity. In these cases, I recommend a bone graft with or without MACI. Another option is an osteochondral allograft and microfracture.

With bony involvement inclusive of sclerosis, this should be treated like a chondral lesion. Less predictable results are noted with removal of sclerotic areas of bone. A high tibial osteotomy to change the abnormal angulation in these cases also may be indicated.

With bony stage II (stable osteophytes), a bone debridement would be recommended with removal of rim circumferential osteophytes.

With bony stage III (deformity), in these cases an arthroplasty (artificial join) or maybe a bipolar prosthesis is a consideration?

In bony stage IV – V with collapse and instability, a total knee replacement is definitely indicated, although in some cases I have actually performed arthroscopy providing

some measure of relief, especially in patients who were not the best surgical candidates for medical reasons.

Now, the question arises: does biological resurfacing, meniscus allograft, and procedures such as autologous chondrocyte implantation actually stop the progression of osteoarthritis?

Halbrecht(2006) suggested that autologous chondrocyte implantation of the knee can be successful in improving pain and function, especially in patients with severe articular cartilage involvement. He noted a trend was identified suggesting improvement in major subchondral bone SPECT scan scores at a mean of 29.6 months at follow up post surgery compared to a preoperative bone scan assessment. A limited bone scan with SPECT (Single Photon Emission Computed Tomography = tomographic imaging of metabolic and physiologic functions in tissues, the image being formed by computer synthesis of photons of a single energy emitted by radionuclides administered in suitable form to the patient). While imaging tests like X-rays can show what the boney structures inside your body looks like, a SPECT scan produces images that show how the bone is working.

A SPECT scan can differentiate between minor changes, moderate changes, and severe changes in the bone homeostasis. Bone scans have shown improvement of bone homeostasis after ACI. ACI has been successful in improving pain and function in patients with articular cartilage defects and may improve subchondral bone homeostasis based on bone scan evaluation. He also stated a larger patient population and longer follow up were necessary to confirm statistical significance in the long term efficacy of this procedure in preventing the progression of osteoarthritis. He also stated that cartilage resurfacing techniques for large chondral defects even with early osteoarthritis appears effective when combined with appropriate realignment and meniscal procedures.

As earlier mentioned, ACI/MCI and high tibial osteotomy are being performed when there is minimal joint space narrowing, and physiological varus (bow leg). This operation is performed as a single or two-stage procedure. More commonly, an open wedge osteotomy is performed on the medial aspect of the tibia versus a lateral closing wedge osteotomy, which is more of the historically classic way of reversing genu varus (bow leg) of the knee secondary to osteoarthritis and/or injury.

Physiological/metabolic factors inclusive of obesity are major contributors to degenerative arthritis with or without injury especially to the joints of the lower extremity and spine. The knee is the most commonly affected joint. Obese patients must lose the weight to preserve their knee joints.(See Diet Article as to methods available)

It is felt that genetic factors account for 80% of a person's tendency to develop obesity combined with the horrible diet most of us were raised on that included excessive carbohydrates, ie sugar.

These genes, which are called "thrifty genes", contribute to morbid obesity. The thrifty genes were selected out eons ago in individuals that could lay down fat as fast as possible, much like bears prepare to hibernate by eating an excessive amount of food.

The thrifty gene pool was able to propagate the race due to the fact that they lived longer due to an enhanced ability to retain weight during the early stages of life, and probably during the summer and fall season when food was more abundant.

The thrifty genes are designed to protect us from starvation by allowing us to store large amounts of energy in the form of fat when food is abundant. Fat is a storage food and when times are lean, fat is metabolized for energy to run the body's normal functions.

During our current era, it is the first time in human history that food has been so abundant. The age-old advantage of thrifty genes has been influenced by our unique environment of abundant food sources. Since the regulation of body weight has a genetic component, the genes confer the potential for obesity. The environment determines whether, and to what extent, the potential is realized. In addition, it has been shown that for every pound over the ideal body weight, abnormal forces are generated at both the hip and knee. At the knee, the abnormal forces are estimated at 3 – 5 times normal as relates to the number of pounds actually over the patient's ideal slender weight.If a person is 20 pounds overweight, 60-100 extra pounds are felt at the knee. Knee joints are then more easily damaged due to the excessive mechanical forces placed against the joint with everyday living including turning, twisting, squatting, and bending activities at the knee.

While the actual body weight or size of a patient is an obvious contributor to damage at or above the knee joint, the secondary metabolic abnormalities produced by excessive obesity has led to the Metabolic Syndrome. Western cultures are experiencing a sharp increase in obese, diabetic individuals including younger-aged obese children. The

incidents of type II diabetes in the younger child and adolescent child is increasing dramatically.

It is a scientific fact that patients who maintain a moderate to excessive amount of body weight above the ideal, then approximately 80% of these individuals eventually will develop type II diabetes. The onset of diabetes starts at an early age if one has eaten the traditional American diet riddled with junk food and high carbohydrates. Junk food, by definition, is most food within the middle aisles of the supermarket where one finds chips, donuts, processed foods, etc, and not the periphery where fruits, vegetables, and meats are located.

There is a metabolic solution to the obesity problem and it is based in biochemistry(see Diet article discussion on Diabetes). Simply put, when an individual becomes too heavy and fat-laden, the internal metabolism is changed pathologically. Just envision the inside of the body being covered in maple syrup. Because when excess glucose (sugar) is ingested, the body does not have the ability to use the vast amounts of glucose that is overwhelming the metabolic system and glucose (sugar) is progressively deposited internally. The term is “glucose toxicity”.

Insulin is the hormone responsible for deposition of glucose into the cells and fat storage. Over the years,due to the abnormal diet, excessive insulin is produced to keep the sugar content down and eventually the pancreas is unable to continue to generate excessive insulin to handle the large sugar load and starts to fail, leading to prediabetes and Type II Diabetes and finally Type 1 diabetes.

The metabolism of glucose toxicity leads to diabetes, increased risk of cancer, and premature death with malfunctioning of the immune system due to the cell membrane damage with involvement with too much glycation which is another word for glucose toxicity. It is a known fact that the rate of cancer increases with Diabetes in addition to a myriad number of other abnormalities. .

I have call this the **Maple Syrup Syndrome.**

Increased amounts of what is called advanced glycolytic end products (AGE) are deposited as a result of the breakdown of excessive glucose within the body into the soft tissue and also at the cellular level. Fat is deposited from glucose metabolism in both the intracellular and extracellular spaces.

Excessive circulating glucose in the system produces advanced glycolytic end products(AGEs) and serious damage to the lining membrane of the vessels due to

glucose toxicity, and also leads to high serum cholesterol, hypertension, and atherosclerosis.

Other early abnormal physical findings in early Diabetes include abnormal pigmentation in the armpits, a fatty hump at the posterior aspect of the proximal thoracic spine just below the back of the neck, scar formation in the hands called Dupuytren's contractures, abnormal tightening of the tissues at the feet producing hammer- and claw-toe deformities.

AGE's act as inflammatory markers and produce a generalized systemic inflammatory response in the body, which eventually affects all organ systems and produces, in many patients, a chronic pain syndrome. The abnormal glucose deposition on the surface of the red cells is currently able to be tested by a test called the Hemoglobin A1c test, which evaluates the red blood cell surface membrane as to the percentage of glucose embedded on and in the membrane. A whole system of evaluation of the successive treatment of early and late diabetes is based upon the blood study called the Hemoglobin A1c test.

It should be noted that the dysfunctional cells in the body produced by the diabetic process also become functionally abnormal and many researchers feel that the altered cells are the progenitors of various types of cancers. Some of the cancers in this category include bladder cancer and leukemic syndromes.

How does this abnormal metabolic state in diabetic patients affect the knee?

Based on reviewing the literature, it is my opinion that the knee is weakened in metabolic syndromes such as diabetes and that the vascularity of the bony structure is compromised. It is a well-known fact that diabetic patients do suffer from osteoporosis which is softening of the bone and lack of calcium. The exact mechanism of this phenomena is not well understood but is probably vascular in origin.

Recent literature suggests that obesity itself affects the knee by changing the metabolism inside the knee to produce more lytic chemicals that degrade the articular cartilage and produce premature degenerative changes. In addition to the abnormal mechanical forces generated by excessive body weight that wear out the articular cartilage due to increased stress on the cells that can only take so much pressure and lead to cell death and premature arthritis due to the abnormal stress.

The keys to a healthy knee are multifactorial. We cannot exercise weight off. We have to change our dietary habits, eat more healthy fats, moderate protein, and avoid carbohydrates.. To avoid knee-related problems, we should be concerned as to the types of activities we engage in from an early age. Activities such as contact football,

rugby, soccer, basketball, etc. do produce excessive force at the joint regions. And if the patient is genetically inclined or metabolically pathologic, extensive exercising will lead to premature posttraumatic arthritis especially in the lower extremities.

Probably the most important caveat is to lose weight down to our lean body weight and eat a low carb high fat diet, or Ketogenic diet, or modified fasting regimen (read diet article on web site). All should include calorie reduction to reach the estimated lean body mass, which we can measure scientifically.

It should be noted however that the generally overweight American professional football linemen have been reviewed in a Stanford study and documented that the linemen at the NFL level had an average age of death of 55. Most professional football players only retire from football after they have suffered serious injury and/or disability, which affects them for the rest of their shortened lives.

It is my job as a physician and an orthopedic surgeon to understand this process and to educate my patients so they may reverse their abnormal metabolisms and the excessive joint forces which produce premature arthritis and serious disability, especially as it relates to the knee. Most of us must lose weight to protect our joints if we are carrying around too much body fat.

We can help with our new program that will access your weight and metabolism either before your surgery or after.

As health professionals our role is to share and spread the appropriate knowledge so that our patients can make informed decisions regarding their health.

I have written this monograph directed primarily at various knee treatments and have added additional information for your general health as well. We are starting a new program to assist you in your quest for orthopedic and general health including dietary recommendations and exercise regimens that will protect your joints to augment your dietary health(see Diet Article).

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