NEW TECHNIQUES FOR CARTILAGE REPAIR AND REPLACEMENT

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Injury to the cartilage of the knee joint is one of the most common orthopaedic presentations. Few orthopaedic problems have received more attention in recent years than the latest advances in cartilage repair, regeneration and replacement. Surgical procedures have advanced to such a stage that patients now expect there to be alternatives to artificial joint replacement in the treatment of their arthritic condition. Patients also recognize the techniques of yesterday will be improved upon tomorrow, and question whether to delay current treatment options in anticipation of promising new ones.

A number of the newer surgical techniques being utilized have shown promising results in short-term treatment of cartilage dysfunction in the knee. This, as well as an improved understanding of post-operative treatment programs has restored function and diminished symptoms in an increasingly large number of people. However, for many of these newer techniques, there is a lack of long-term follow-up.

This chapter presents a brief description of structure, biomechanics, evaluation of articular cartilage injuries and presents some of the surgical techniques designed to stimulate cartilage repair and regeneration.

ARTICULAR CARTILAGE

Articular cartilage covers the end of bones in joints. The smoothness and thickness of the cartilage determines the load-bearing characteristics and mobility of joints. Lesions on the chondral surfaces of joints interfere with the smooth motion of the joint. This type of damage can cause mild to significant symptoms of pain, instability and stiffness. Two and a half centuries ago, Hunter first recognized that damaged articular cartilage does not have the capacity to repair itself.1 This observation has led to a wide variety of treatment approaches for focal chondral defects in the knee with varying levels of success. Treatments such as drilling, abrasion, microfracture, and debridement have been shown to provide symptomatic pain relief and improved function,2-24 although there are very few prospective controlled comparative studies. Most of these techniques have shown the repair process is dominated by the production of fibrocartilage instead of normal hyaline cartilage. The fibrous component of the repair is believed to be produced by fibrocytes carried to the repair site by blood introduced to the lesion by surgical or traumatic means. Other treatment options such as periosteal grafting, osteochondral autografts and allografts, and autogenous chondrocyte cell transplantation2-4, 6, 13, 14, 22, 25-35 have also shown promising results in reduction of pain and dysfunction and will be discussed further. Normal hyaline articular cartilage has never been successfully, reliably reproduced by any technique to date.

ANATOMY

Articular cartilage is a thin, smooth, low friction gliding surface with a remarkable resiliency to compressive forces. It is a material only a few millimeters thick yet with excellent wear characteristics. Its mechanical and structural capacity is dependent on the integrity of its extracellular matrix. Chondrocytes sparsely distributed throughout a matrix of structural macromolecules work together with a hydrated extracellular glycosaminoglycans to attract and then sequentially extrude water. Extracellular components of collagen, proteoglycans, noncollagenous proteins and water to provide the shear, compressive, and permeability characteristics of cartilage.9, 14, 36-39 This charged mechanical interaction permits cartilage to perform its mechanical functions without appreciable wear.9, 36-38 It is the composition and highly complicated interaction of these components that makes regeneration and replacement techniques challenging.

Water constitutes between 65-80% of the entire wet weight of articular cartilage36, 37 and is about 15% more concentrated at the surface than in the deeper zones.36 Chondrocyte cells produce the extracellular matrix. Distributed throughout the matrix, chondrocytes compose less than 5% wet weight and are the derivative of pleripotential mesenchymal cells that are able to give rise to bone, fat, skin, cartilage, and tendon.31, 36-38

Collagen makes up about 15-22% of the wet weight and contains 90-95% type II collagen fibers with a small percentage of types IX and XI.36-38 This is what provides the high tensile stiffness, strength and resiliency of the tissue. Proteoglycans constitute about 4-10% of the total wet weight and are a mix of large aggregating (50-85%) and large nonaggregating (10-40%) proteoglycans.36, 38 They are responsible for pressure elasticity and charged interactions with water.9, 40 Noncollagenous proteins, elastins, integrins and other macromolecules of protein are responsible for the matrix organization and maintenance.37 The functions of articular cartilage include load transmission and distribution, smooth articulation, and aid in lubrication.14, 30, 36 Load transmission and distribution is due to the ability of the structural matrix to deform, which leads to increased joint contact areas and distributed mechanical stresses.36 It also has the ability to respond to applied loads through fluid exudation and redistribution within the interstitial tissue.

HEALING AND VASCULARITY

The combination of the lack of blood supply and a few cells distributed widely amongst a dense extracellular matrix leads to a limited ability to heal.1, 6, 14, 15, 36 The usual inflammatory response of hemorrhage, formation of fibrin clot, cellular production and migration of mesenchymal cells is absent.14, 36 Other factors such as age, depth and degree of damage, traumatic or chronic condition, associated instability, previous total meniscectomy, malalignment, and genetic predisposition are also factors affecting healing of cartilage.6, 31, 36, 37 Age affects healing in part because in newborns, the multi-functioning mesenchymal stem cells needed for healing account for 1 in every 10,000 cells in bone marrow and reduces to 1 in 100,000 in teens, 1 in 400,000 by age 50 and 1 in 2 million in an 80 year old.31 Depth of the lesion is a factor in healing because surface defects that do not penetrate the subchondral bone have to rely on sparsely populated chondrocytes for matrix remodeling where deeper lesions may introduce a blood supply from the well-vascularized subchondral bone. With the blood comes fibrocytes that modulate to fibrochondrocytes. These cells produce a relativley disorganized lattice of collagen fibers partially filling the defect with structurally weak tissue. Traumatic isolated lesions typically heal better than areas with more degenerative, global defects. Structural instability and/or other associated pathology also cause uneven and often excessive forces onto the articulating surfaces.38, 41-43

EVALUATION

A careful assessment and clinical evaluation of the injured area is critical for accurately diagnosing an injury to the articular surfaces. Some of the more important components to consider when evaluating a cartilage injury are: Was it of acute and/or traumatic nature? Are there other predisposing factors? Is it a chondral or subchondral lesion? Is there any associated osteoarthrosis indicating progressive loss, attempted repair, and structural remodeling? Are there indications of degenerative osteoarthrosis or indications of chronic changes from overuse and/or malalignment? Was there other pathology created at the time of injury?

Terry was the first to describe the incidence of isolated chondral fractures in 1988.16, 44 With the advent of the MRI and improved techniques, chondral or subchondral bone bruises are seen in about 80% of acute anterior cruciate ligament ruptures.14, 45 Whether or not these bone bruises represent forces that have exceeded the lethal threshold for the overlying chondrocytes and therefore will lead to eventual frank lesions is unknown. Patients typically complain of nonspecific episodes of catching, locking, joint-line pain and low-grade swelling.14, 46 Pain is not the primary subjective complaint unless the lesion has penetrated subchondral bone or there is associated synovial irritation.4, 6, 14 Symptomatic catching on the chondral edges, degradative debris and distension of the joint causing synovitis contributes to pain production.4 Obtaining a careful history, noting the exact mechanism and other predisposing factors is essential. However, though some studies note a 94% correlation of specific incidence and tenderness to palpation,16 others have found only a 25-40% correlation of episode and joint line tenderness.47

X-rays and MRI can aid in improving the diagnostic findings. Sensitivity and specificity of MRI techniques have improved in detection of chondral lesions greater than 3 mm in diameter.45 MRI has a low sensitivity for chondral delamination injuries of about 21%.47 MRI is very operator and field strength sensitive and is a function of the pulse sequences and imaging technique used.14 X-rays are preferred for documenting sclerotic changes, osteophytic formation, compromised joint space (in total and non weight bearing positions), and angle of alignment.

CLASSIFICATION

Classifying chondral lesions is difficult, frustrating and probably totally unreliable. The most common classification system used is the Outerbridge system,17 developed as a means for assessing chondral damage to the articular surface of the patella. There are five levels of degeneration: Grade 0=normal articular cartilage; Grade I=softening and swelling; Grade II=partial thickness and early fissuring on the surface, <½ in. in diameter; Grade III=fissuring to the level of subchondral bone, but the bone not visibly exposed, >½ in. in diameter; Grade IV=erosion down to subchondral bone.17 However, there is very poor interobserver correlation between surgeons in describing cartilage lesions. Also, many lesions are a mixture of types. Surface only classifications fail to consider the underlying damage seen by MRI.

TREATMENT

Treatment of articular cartilage defects in the knee has been attempted in numerous studies and all with varying levels of success.2-12, 13-16, 19-24 Success of these approaches has generally diminished over time possibly due to the formation of fibrocartilage, inadequate development of repair tissue, poor cell differentiation and poor bonding to the surrounding articular cartilage borders.4, 12, 48 Although these techniques can result in symptomatic pain relief and improvement in functional status, the long-term results remain mixed. When comparing different conventional therapeutic options, it is important to recognize the goal of surgical intervention. Treatment can be directed at either treating the symptoms or trying to affect articular repair or regeneration.4 Repair refers to the restoration of a damaged chondral surface with new tissue that resembles but does not duplicate the structure, biochemical makeup, function and durability of articular cartilage. Regeneration denotes the formation of new tissue indistinguishable from normal articular cartilage.6, 35, 36, 49 Several investigators have also reported the efficacy of continuous passive motion (CPM) use following these techniques in improving the visual and chemical appearance of the defect.20, 21, 36, 43

There is also the component of other associated pathology in conjunction with focal articular cartilage damage. Personal observations and select studies have suggested that isolated chondral defects heal and recover slower functionally than those combined with other ligamentous injury or surgery.50 This could probably be attributed to the increased cellular activity and cytokine stimulation with combined lesions.50 A few of the more common treatment methods are noted below.

Lavage--Lavage rids the knee of loose articular debris and inflammatory mediators that are known to be formed by damaged synovial joints. Jackson had found a 45% symptomatic improvement in patients at 3½ years. When arthroscopic lavage was performed in conjunction with mechanical debridement, there were improved results with about 88% short term improvement.4 The degree of improvement varied widely however as did the duration.

Subchondral bone marrow stimulation techniques--Cartilage penetration techniques have also received recent favor. The goal of such procedures is to mobilize the mesenchymal stem cells to differentiate into cartilaginous repair tissue. Once disruption of the vascularized cancellous bone has occurred, a fibrin clot is formed and pluripotent cells are introduced into the area. These cells eventually differentiate into "chondrocyte-like"14 cells that secrete type I, II and other collagen types as well as cartilage specific proteoglycans after receiving mechanical and biological cues. The cells produce a fibroblastic repair tissue that on appearance and initial biopsy can have a hyaline-like quality.3, 14, 31, 36 Unfortunately, over time the histological characteristics change into more predominantly fibrocartilaginous tissue.3, 4, 6, 9, 12-14, 28, 36

Abrasion arthroplasty is one such technique that consists of debriding the articular defect to a normal tissue edge so that fresh collagen can be produced in the fibrin clot. The surface of the subchondral bone is exposed and penetrated to a depth of about 1 mm.3, 10, 12 Various reports show 12-53% reduced pain post-operatively.3, 5 One of the potential problems with abrasion arthroplasty is the cell death produced by the heat of the abrasion burr.14 Additionally the destruction of the normal subchondral anatomy handicaps any future repair or regeneration efforts.

Subchondral drilling consists of drilling through the defect to penetrate the subchondral bone. The technique was first popularized in the late 1950's by Pridie,8, 18, 19 and subsequent findings suggest the repair tissue introduced into the area can look like grossly like hyaline cartilage but histologically resembles fibrocartilage.3, 48, 51 Drilling also increases the possibility of cell death through heat necrosis.

Microfracture is another such technique in which the lesion is exposed, debrided, and a series of small fractures about 3 to 4 mm in depth are produced with an awl. Adjacent cartilage is debrided to a stable cartilaginous rim, and any loose fragments and fibrous tissue are removed.

Popularized by Steadman,22, 23 microfracture has a few advantages over drilling. There is no heat necrosis, the awl creates more exposed surface area for clot formation, and the structural integrity of the subchondral bone is maintained.14, 22, 23 However, fibrocartilage is produced. The clinical results are mixed as reported by Rodrigo et al.23

Soft tissue and osteochondral grafts--Stimulating articular cartilage growth through the use of various grafting techniques has recently been reported. Utilizing either autologous tissue or allografts, these procedures are designed to provide a suitable environment for stimulation of the mesenchymal cells to produce type II collagen fibers. The success of such approaches is at least in part related to the severity of the abnormalities, graft and technique utilized, age of the patient, correction of associated pathology, weight bearing restrictions and the use of postoperative continuous passive motion.3, 4, 6, 9, 20, 21, 23, 25-27, 36, 41-43, 50, 51 Intact full thickness grafts suffer the problems of mismatched sizes, immunologic rejection, and tissue structural weakening during the process of revascularization. Prolonged protection of intact grafts has been recommended though this is accompanied by significant disuse osteolysis. Perichondrial and periosteal grafts--Attempts to provide the damaged articular cartilage with a viable durable surface has led to the introduction of soft-tissue grafts consisting of periosteum, perichondrium, fascia, joint capsule and tendinous structures into the defect.3, 6 Introduced by Rubak in the early 1980's following his experiments with tibial periosteal grafts in rabbit knees,32 this technique appears to be most effective in a younger population. This finding reinforces the notion that age has an adverse effect on the growth and production of pluripotent stem cells and chondrocytes as well as their ability to differentiate into the necessary articular chondrocytes. Recently, encouraging results have also been reported with the use of periosteal grafts in isolated chondral and osteochondral defects.28 A critical component for success with these techniques is that the cambium layer must be placed facing into the joint and the surface must be secured adequately to avoid being knocked loose with joint motion. The potential benefits include the introduction of a new cell population along with an organic matrix, a decrease in the possibility of degeneration of the tissue before a new articular surface can be produced, and an increased protection of the graft from damage due to excessive loading.3, 4, 6, 32, 36, 38

Ostechondral autograft--This technique consists of harvesting a bone-cartilage graft harvested from the posterior aspect of the femoral condyle and transplanted into the defect. The technique is also referred to as "mosaic-plasty" because of the mosaic fashion in which the grafts are implanted into the defect.3, 4, 9, 53 A possible attraction is the placement of implants with fully formed articular cartilage matrix with viable chondrocytes into the area of the lesion.6 First performed earlier this decade, the chondral plugs are harvested from the lateral intercondylar notch. Several authors have reported good to excellent results with 70-92% reduction of symptoms and improvement of function in short term observations.3, 4, 9, 26, 27, 53 This technique has also been shown to restore subchondral bone, improve joint incongruity and actually restore an articular surface.3, 9, 13, 20, 27 However, there is a risk of surface incongruity, donor site morbidity, insufficient stability of the graft and problems with mechanical overload.9 There are a limited number of possible donor sites from which grafts can be harvested. Correction of malalignment is crucial factor in the long-term success of this procedure. Whether or not osteophytes will be formed from the harvest sites remains an unknown risk.

Osteochondral allograft--The small number of available graft sites and donor site morbidity could be avoided by the use of fresh or cryopreserved allografts. However, there are additional problems of allograft rejection, disease transmission, mismatch in sizes and congruity, and sparse supply. Those suffering from primary degenerative arthrosis or those with patella defects do not seem to benefit.3, 4, 6, 9

Despite these problems, some investigators have found a 63-77% good result from 2-10 years.9 Patient selection (i.e. younger, compliant), correction for any malalignment, and matching size and inlay fixation may contribute to higher success rates.3 However, allografting requires an open exposure of the joint; severe morbidity occurs if the allograft fails.3, 4, 9 With the recent increase in hepatitis C transmission, we do not believe that widespread allografting will be popular.

Autologous chondrocyte cell transplantation--The limited ability of chondrocyte cells to effectively differentiate, proliferate, and regenerate hyaline cartilage has increased the interest in of transplanting live cells into chondral defects.3, 4, 6, 33, 35, 48, 54 Peterson and colleagues performed experiments in rabbits and reported successful results with transplanting cultured autologous chondrocytes onto patellar defects.55 This technique consisted of injecting the cultivated chondrocytes under a periosteal flap that was sutured over the lesion.53, 55 Oddly, the technique requires that no penetration of the subchondral bone occur in order to prevent the introduction of blood and the circulating fibrocytes. Short term follow-up (6 months) revealed newly formed "cartilage-like tissue"33 covering about 70% of the transplanted area in animals. However, the results deteriorated significantly by one year. Despite this, the investigators proceeded to perform the same technique on 23 patients with cartilage defects in the knee.3, 33, 35 Healthy chondrocytes obtained from an uninvolved area were isolated and cultured for 14 to 21 days in a lab. The cells were then injected into the defect through open incision and covered with a periosteal flap excised from the proximal medial tibia.6, 33, 35, Postoperative care consisted of 48 hours of CPM use and partial weight bearing for the first 6 weeks, followed by full weight bearing at 10-12 weeks.33 Twenty-three patients underwent the experimental procedure with 16 femoral lesions and seven patellar defects. At three months post-transplant, a second look arthroscopy revealed a similar appearance, color, texture and level borders to the surrounding undamaged cartilage.6, 28, 33, 35 Probing the transplanted area produced a wave-like or spongy appearance suggesting only the beginning stages of early healing. Two years after transplantation, 14 of 16 patients with femoral condyle transplants had good to excellent results with histological examination showing 11 of 15 had the appearance of hyaline-like cartilage.4, 6, 28, 33, 35 Two of the seven patellar transplants had good to excellent results subjectively and only one with histological appearance of hyaline cartilage. The main reason stated for the poor patella response was due to noncorrection of underlying joint abnormalities such as malalignment and lateral subluxation of the patella. This technique has received recent widespread attention both in the medical journals and in the media and stimulated patients to request cartilage transplantation. The initial study as well as subsequent research has shown encouraging results regarding the use and efficacy of this technique for focal chondral defects, not for osteoarthritic joints. It is believed that the degradative enzymatic synovial fluid of the arthritic knee is not conducive to cell transfer by this technique.

Articular Cartilage transplantation (author's preferred treatment)--Due to the limited ability of any technique to stimulate the growth of type II collagen fibers, we have sought a new approach. We had noted that following notchplasty to reduce graft impingement during anterior cruciate ligament surgery, the notchplasty area in the intercondylar groove regenerated hyaline appearing cartilage. Subsequently, we hypothesized that if cartilage had the ability to regenerate in that area, then it should be possible to regrow if transferred to an articular cartilage lesion. The combination of the extracellular matrix present in articular cartilage and the undifferentiated pluropotent stem cells found in cancellous bone should be able to provide an adequate host environment for stimulation of growth of hyaline-like cartilage. We felt that microfracturing the base of the defect to stimulate blood flow and to release the growth factors, limiting weight bearing following surgery and utilizing continuous passive motion post-operatively could produce a new articular repair surface. The development of a paste of articular cartilage and cancellous bone would also aid in reducing the problems associated with surface incongruity of the implanted area, odd shaped lesions, and inlay fixation techniques as encountered in previous findings.3, 9, 13, 26 We also felt that it was important to be able to develop a technique that could be performed arthroscopically to aid in diminishing potential post-operative complications such as soft tissue fibrosis.

The surgical procedure consists of initially identifying the lesion, debriding impinging scar tissue, repairing or resecting torn meniscal cartilages, and performing any ligament repair or reconstruction. Alignment is corrected by medial opening wedge osteotomy for varus deformities using a resorbable wedge (Bionx, Blue Bell, PA.). The criteria for transplantation is arthroscopic confirmation of an osteochondral lesion at the site where the patient subjectively has the worst symptoms or failed treatment of an already existing defect through previous surgery at the site of pain. The lesion is then debrided back to a stable base and loose or fibrillated cartilage is resected. The base is then microfractured until bleeding occurs from the subchondral bone. A trephine (DePuy Orthotec, Tracy, Ca.) is introduced into the intercondylar notch and care was taken to impact it into the margin of the articular cartilage and capture the deeper cancellous bone. The graft is morselized manually in a bone graft crusher, mixing the articular cartilage and subchondral bone forming a paste. The graft is then redirected into the area of the defect and pushed into the lesion and held in place for one to two minutes--allowing the adhesive properties of the bleeding bone to secure the graft in place. Over the past five years, more than 75 patients have had articular cartilage transplantation surgery by this procedure performed by the senior author. Clinical follow-up evaluations in 29 patients noted an improvement in pain complaints in 27 patients from 2.1 pre-op to 0.8 post-op (on a scale of 0-3), reduction in swelling from 0.9 pre-op to 0.4 post-op (scale of 0-3), giving way improved from 1 pre-op to 0.1 post-op (scale of 0-2), and a decrease incidence of locking from 0.5 pre-op to 0.1 post-op (scale of 0-2).51, 56 No patient was made worse by the procedure. Second look arthroscopy with biopsy was performed at least six months post-transplant in 19 patients. Hyaline like articular cartilage was noted in 8 biopsies, indicating early healing and some degree of chondrocyte cloning. Hyaline and fibrocartilage was seen in 7 specimens and purely fibrocartilage was noted in 4 patients--with 3 of those patients demonstrating severe preoperative osteoarthrosis with bone-on-bone changes.51, 56, 57 This technique has shown significant benefits in particular in lesions of the anterior femoral condyle, trochlear groove and tibial plateau. These areas are easily accessible arthroscopically and will have an improved ability to stabilize the impacted graft due to location and instrumentation. Posterior femoral, posterior tibial and patellar defects pose more of a problem in that they are hard to reach arthroscopically and proper instrumentation is still in development. The ability of the fibrin clot to adequately hold and stabilize the graft post-implantation is a potential limiting factor in complete success of this technique. An added component of an adhesive nature is expected to improve the overall results of this procedure.

The results of this study have shown that articular cartilage transplantation is a viable option for patients with traumatic or arthritic chondral defects. It is performed as an outpatient, single arthroscopic procedure and offers the possibility of significant pain relief and a reduction of associated symptoms. The utilization of the extracellular matrix inherent in articular cartilage and cancellous bone seems to provide an adequate healing environment for cartilage regeneration. However, normal hyaline articular cartilage is still not produced.

A critical component of the success of this procedure is careful adherence to a post-operative rehabilitation program. Patients are kept non weight bearing for four weeks and utilize a continuous passive motion machine for six hours a day for those first four weeks. A hinged knee brace is typically used to remind them not to bear weight. They are instructed on a non weight bearing program of isometrics, hip exercises, leg raises, deep water pool workouts, and well-leg stationary cycling with particular emphasis on quadriceps recruitment. If the lesion is in the trochlear groove, than full weight bearing in extension is allowed. At two weeks, two legged stationary cycling is started with low to no resistance. Four weeks post-op, full weight bearing is started along with an increasing intensity strength program of closed-chain focused, non ballistic exercises. Double knee bends, hamstring exercises, weight training, a flexibility program and balance/proprioceptive exercises are initiated and incorporated into a daily/bi-daily routine. Non impact sports and activities such as pool workouts, outdoor bicycling, cross country skiing and assorted cardiovascular machines are permitted for the next two months. Ballistic and/or impact sports are delayed until after the third month and upon completion of a functional strength test.

Other associated pathology--When assessing treatment options and surgical intervention for articular cartilage damage, it is imperative that predisposing risk factors that may affect healing be taken into careful consideration. Is there advanced arthrosis of the tibiofemoral joint? Is there ligamentous instability? Does the patient have a collapsed joint space due to the absence of meniscal tissue? Is there clinical symptoms or degeneration in the hip or ankle? What is their age and activity level? These are all important things to take into consideration when deciding to perform other associated procedures. Prioritizing by subjective and objective findings helps to develop a logical progression of the course of treatment. Ligamentous or structural instability should be repaired if the patient is symptomatic. Absence of a joint space due to previous total meniscectomy may need to be addressed by osteotomy and/or meniscal transplantation in order to protect the cartilage graft. The size of the lesion, age, clinical findings of other joint pathology suggesting an underlying disease process, weight, motivation and compliancy should also be taken into consideration.

Osteotomy (high tibial or distal femoral)--Several studies have shown that alignment correction by osteotomy in conjunction with other marrow-stimulation techniques show improved results over performing either independently.3, 4, 6, 12, 30, 54, 58 Correcting structural varus or valgus deformities decreases the focal stresses on the involved compartment distributes the weight bearing component. The most common technique is a high tibial osteotomy to improve the varus knee malalignment. The effects of malalignment may be seen by standing radiographs, examining the gait pattern, a clinical exam, and/or by subjective symptoms.58 A new technique developed at our clinic utilizes a resorbable lactide wedges inserted in a tibial osteotomy to realign the leg. The wedge is subsequently replaced by bony ingrowth. The technique may eliminate donor site morbidity and reducing the possibility of intaoperative over correction

Unloading braces--Non operative management of the malalignment of unicompartment arthritis includes the insertion of an unloading shoe wedges or braces. Clinical experience has also found that proper application of a varus or valgus unloading brace (DePuy/OrthoTech, Tracy, CA) can provide symptomatic relief as well as improved ability to tolerate functional activity. We have also found that patients with standing uniaxial malalignment have difficulty effectively recruiting the appropriate musculature to maintain strength of the involved leg. These braces reduce the pain-inhibition cycle and allow for more effective muscular development. Unloading braces are typically fit pre-operatively for use during exercise and activity and are also used post-operatively to protect the repaired articular surface.

Meniscus implantation/replacement--Once it has been determined that joint space compromise is a factor in the patients complaints, then meniscal treatment options should be considered. The use of allografts, autografts, and synthetic polymeric structures have been used in previous numerous models with varying degrees of success.59 Due to the complexity of the the tissue, meniscus shape and function has never been able to be modeled or reproduced effectively. It is this inherent intricacy that has eluded practitioners' ability to provide effective treatment for this condition. The most common and relatively successful technique to date is the use of allograft meniscal transplantation surgery using a frozen meniscus. Over 1600 such implants have been performed nationwide with only fair follow-up studies conducted on their use and efficacy. The most common problem post-implantation is shrinkage of the meniscal tissue, yet the results are currently moderately encouraging. There has been no reported benefit to cryopreservation of meniscal cartilages, and therefore we now use fresh frozen menisci from our tissue transplant bank.

The surgical technique of meniscus transplantation consists of removal of almost all of the remaining meniscus and preparation of the capsular bed for suturing. The allograft meniscus is prepared with bone plugs attached. Tunnels are made anteriorly and extending to the anterior and posterior horns of the meniscus to accept the bone plugs.60 The implant is introduced arthroscopically with sutures at both horns extending into the tunnels for proper fixation. Zone specific meniscus repair sutures are then brought into place and the outer rim of the meniscus is then captured and the knots tied directly over the capsule.60 Partial weight bearing post-operatively is encouraged for one month as long as there is no associated articular cartilage surgery. The use of a continuous passive motion machine and a good strengthening program are also critical for success following this procedure.

SUMMARY

New techniques and treatments for articular cartilage injuries are progressing at a rate that make true regeneration of hyaline cartilage a near term possibility. At this time our recommendations for patients with traumatic or arthritic lesions (excluding drug therapy) include operative procedures designed to preserve the underlying bone, repair the defect with adequate tissue, and diminish the symptoms. Our recommendations also include non operative treatments such as unloading braces and wedges to diminish destructive biomechanical forces, exercises to strengthen surrounding muscles, increase joint motion, tune up proprioception, improve cardiovascular conditioning and improve the patient's mental outlook.