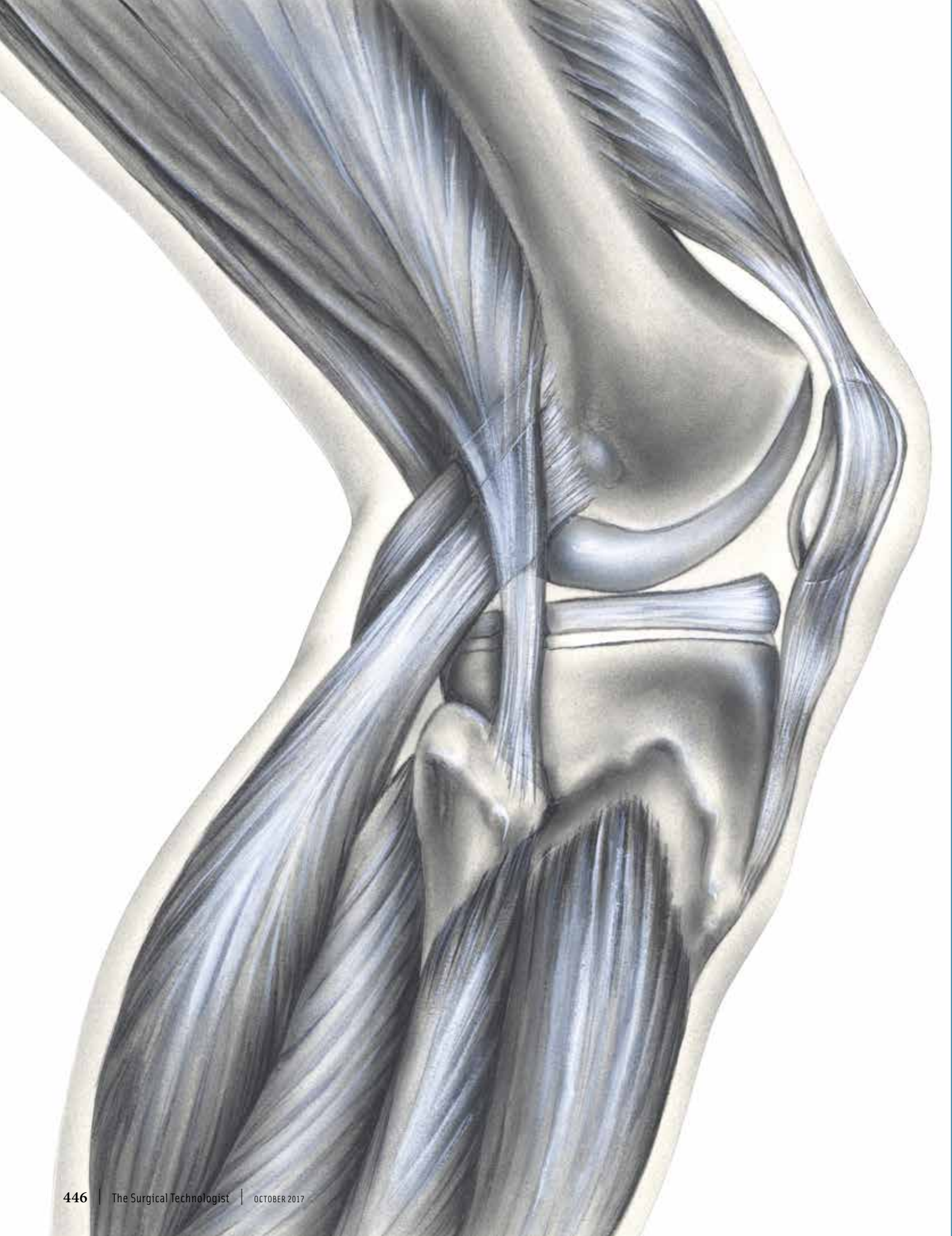


PJACT: Treating Articular Cartilage Defects

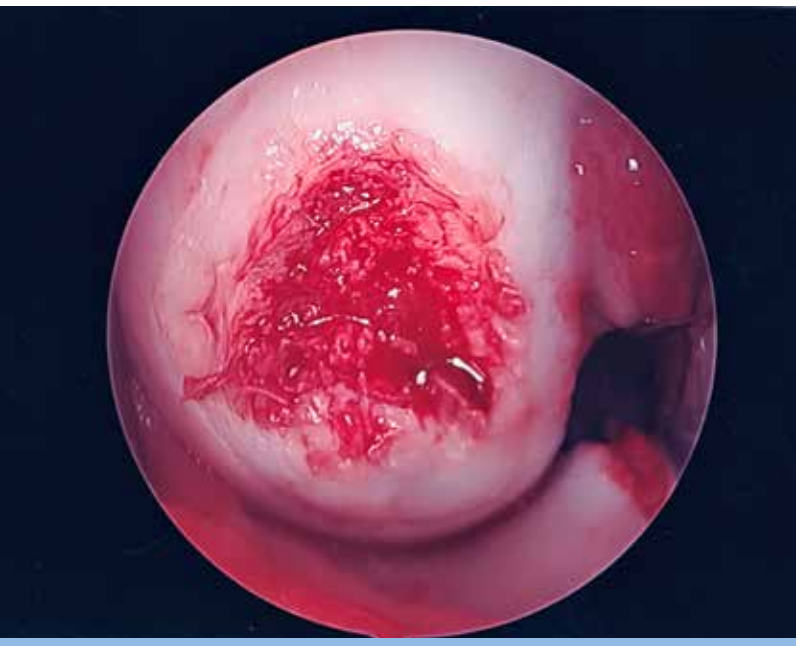
Grace Le Blanc, cst

Articular cartilage defects are a common cause of knee joint pain and disability, and in the United States approximately 30,000 to 100,000 chondral procedures are performed every year.[11] Thus, articular cartilage restoration is the shared goal of many orthopedists, not only because the clinical need is urgent, but also because the need continues to increase due to the population's longer and more active life spans.[4]

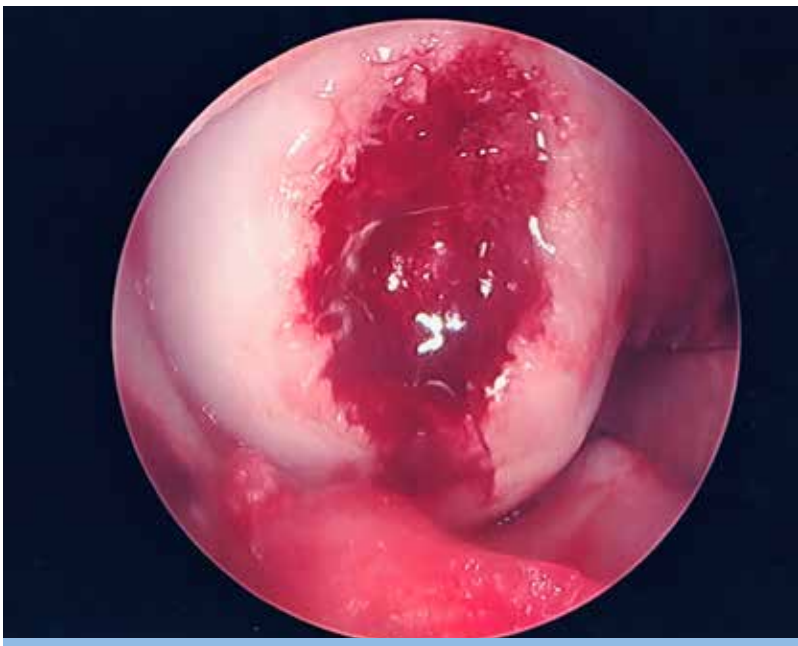
Increasing articular cartilage damage also is commonly seen in athletes. In collegiate, professional and world-class athletes, knee articular cartilage lesions are observed in 36% to 38% of cases.13 There also has been a rise in participation in general organized recreational sports, such as football, soccer, basketball, etc, which has been associated with the increased rate of articular cartilage injuries. Continual wear and tear on articular cartilage can lead to progressive cartilage tissue loss, resulting in early joint degeneration.[8] In this article, a discussion of the anatomy and physiology of knee joint articular cartilage will be presented, as well as an explanation of diagnosing articular cartilage damage. This article's main focus will showcase one of the latest techniques available in cartilage repair: the Particulated Juvenile Allograft Cartilage Transplant (PJACT).

LEARNING OBJECTIVES

- Discuss why there is an increase in patients being treated for articular cartilage damage
- Explain the anatomy and the physiology of the articular cartilage in the knee
- Recall the articular cartilage zones
- Review the technique described in this article for a PJAC transplant
- List the grades used to identify the level of articular damage



In this image, the femoral condyle lesion has been exposed.



The femoral condyle lesion has been debrided in preparation for the graft.

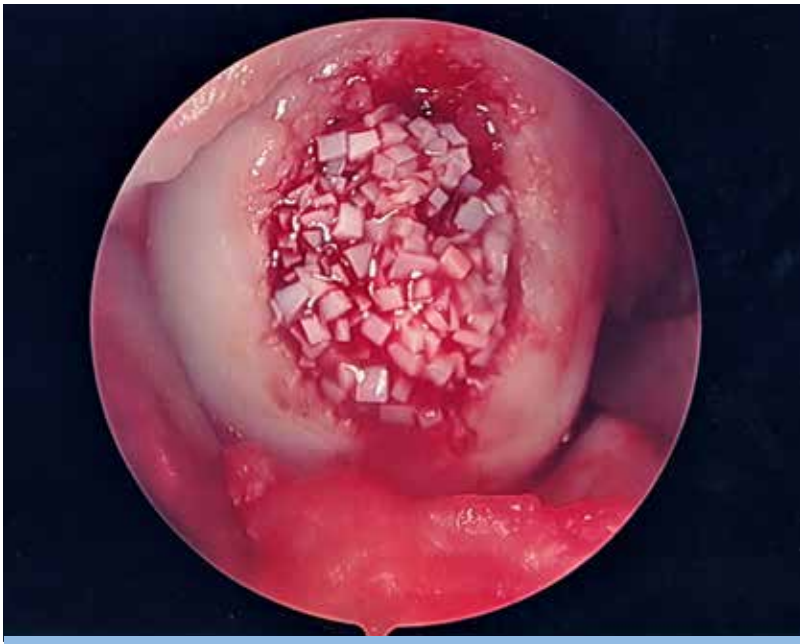
ANATOMY AND PHYSIOLOGY OF ARTICULAR CARTILAGE IN THE KNEE

Articular cartilage consists of hyaline (derived from the Greek word "hyalos," meaning glass[3]) cartilage, one of the three types of cartilage that exist as connective tissues in the human body.[15] Articular hyaline cartilage covers the distal portions of the femur that communicate with the rest of the knee joint: the lateral and medial condyles, and the trochlea. It also covers the tibial plateau, and is found on the articulating side of the patella bone.[12] Articular cartilage has a smooth, lubricated surface with a low friction coefficient, which aids in joint articulation. It is also responsible for distributing weight load on the joint and exhibits superior durability and viscoelastic properties.[2] Articular cartilage thickness ranges approximately from 1-5 mm.[14] Unlike most other body tissues, articular cartilage does not possess any blood vessels, lymphatics or nerves. Rather, in the adult individual it is populated by relatively few chondrocytes (specialized cartilage cells) and a dense extra cellular matrix (ECM). As much as 80% of the ECM wet weight consists of water, with collagen fibrils, proteoglycans and other molecules accounting for the remaining dry weight. Collagen is the structural protein found in greatest abundance in the ECM. Of the various collagen types, Type II collagen is significant in articular cartilage structure, as it accounts for 90% to 95% of the collagen in ECM. Type II collagen fibrils intertwine with proteoglycan aggregates to provide a strong matrix in the ECM. Nourishment of the cartilage tissue is provided by the joint synovial fluid through diffusion.[2]

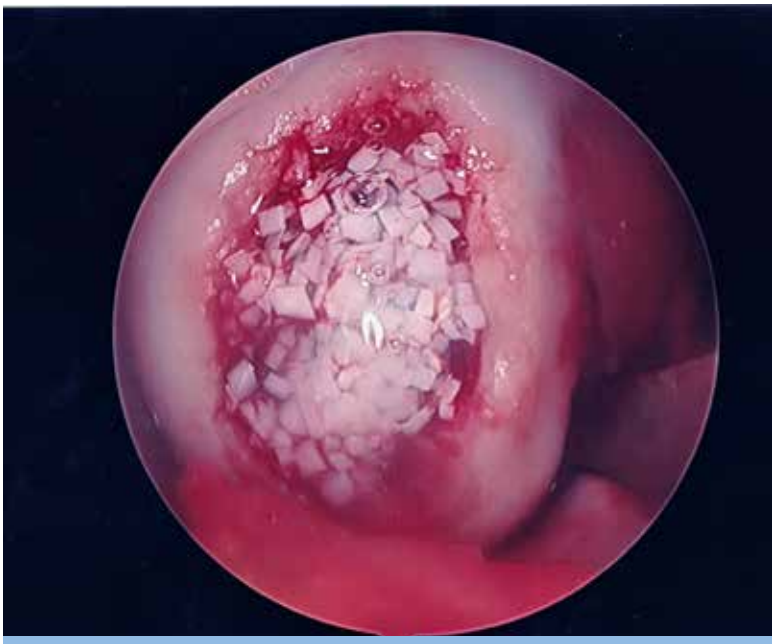
ARTICULAR CARTILAGE ZONES

Articular cartilage is arranged into four zones, with each zone contributing in a specific way with the task of bearing body weight and balancing stress on the joint.

- Superficial (tangential) zone: contributes 10%-20% of the thickness of the articular cartilage. It is responsible for protecting deeper layers from the sheer stresses of articulation. Collagen fibrils are tightly packed together and are aligned parallel to the surface of articular cartilage. Chondrocytes in this layer are flat in shape.
- Middle (transitional) zone: contributes 40% to 60% of the articular cartilage volume. Thicker collagen fibrils appear in this layer, and the proteoglycan content increases. Chondrocytes in this layer take on a spherical shape, and the collagen fibrils are arranged in an oblique manner. This layer provides a bridge between the superficial and deep layers.
- Deep zone: contributes 30% to 40% percent of articular cartilage. This zone provides the most resistance to compressive forces resulting in the collagen fibrils as

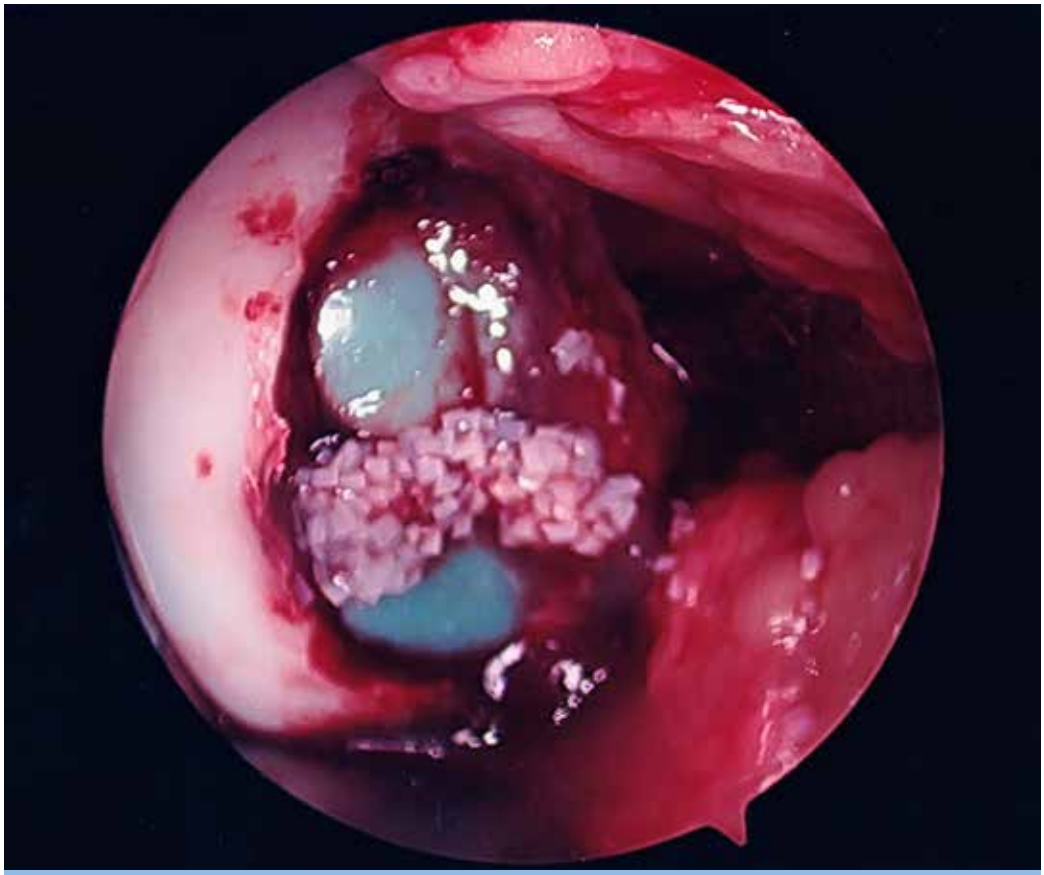


The femoral condyle lesion has been filled with PJAC.



The PJAC graft has been set with fibrin glue.

Articular cartilage is arranged into four zones, with each zone contributing in a specific way with the task of bearing body weight and balancing stress on the joint.



In this case, PJAC has been used along with an osteochondral bone plug to repair an extensive femoral condyle lesion.

All arthroscopy images are courtesy of Dr John Greco, of TOC (The Orthopaedic Center) Huntsville, Alabama

the largest in this layer. They are arranged perpendicular to the surface and in radial patterns. The highest proteoglycan content is in the deep zone. Chondrocytes are columnar in formation, also perpendicular to surface. A visible basophilic line, called the tide mark, separates the deep zone from the calcified zone.[15]

- Calcified cartilage zone: This layer is important in anchoring the cartilage layers to the subchondral bone. Chondrocytes are less dense in this layer in comparison with the other layers, and they also are hypertrophic.[2] The ECM is calcified. This zone is the only zone containing Type X collagen, which aids in cartilage mineralization and structural support.[15]

In the four zones of articular cartilage, it is the stretching and compressing of the collagen fibrils and their cross-links, as well as their precise arrangements within the ECM, that helps account for the overall strength and durability of the tissue. Moreover, the pressurization of water and the frictional resistance of water flow within the matrix of the zones accounts for the ability of the cartilage to function under loads many times the body's own weight.[2]

CHONDROCYTES AND ARTICULAR CARTILAGE HEALING

Chondrocytes account for only about 2% of the adult human articular cartilage structure. These cells originate from mesenchymal stem cells and vary in number and shape, depending on what articular cartilage zone they reside in. Chondrocytes are responsible for establishing a specialized microenvironment and maintaining the ECM. Interestingly, the microenvironment a single chondrocyte cell creates actually traps the chondrocyte within its own self-built matrix. Hence, the chondrocyte cannot migrate to another area of cartilage or proliferate. In fact, chondrocyte cells are so divided that they rarely form direct cell-to-cell signal transduction for communication. This inaccessibility, as well as the low percentage of chondrocytes, accounts for part of the reason that articular cartilage does not heal itself after injury.[2] Moreover, articular cartilage does not possess undifferentiated cells in its layers, and lacks lymphatic, neural and vascular structures. It is also thought to contain high levels of protease inhibitors. All of these characteristics of articular cartilage result in poor regenerative properties.[15]

DIAGNOSING ARTICULAR CARTILAGE DAMAGE AND SELECTING TREATMENT

Cartilage lesions may be the result of an acute injury, such as in athletic trauma, or chronic due to abnormal pressures on the articular surface or other underlying pathological condition.[5,9] In order to diagnose articular cartilage damage, the history of the patient will be taken and a clinical examination will be performed. Radiographic and/or MRI techniques also will be used.[8] A knee arthroscopy may be performed to provide a direct visualization of the articular cartilage tissue, and to perform palliative techniques, such as chondroplasty.[14] When selecting treatment options for articular cartilage damage, several factors will be taken into consideration: patient's age, patient's activity levels, the patient's goals and their expectations. The cartilage lesion profile is another important aspect of determining treatment, including the location of the lesion, the size of the lesion and the depth of the lesion. The surgeon will also consider whether the patient has any existing concomitant factors, which may include: limb malalignment, meniscus insufficiency and knee ligament deficiencies.[4] Any malalignment or unstable bearing between the articulating joint surfaces places undue stress on the articular cartilage, which in addition to contributing to the lesion profile also would inhibit any repair procedure.[13] Thus, concomitant issues such as these must be fixed before any articular cartilage repair is attempted.[14]

The following scale is used in ranking articular cartilage damage:

- Grade 0: normal
- Grade Ia: soft indention
- Grade Ib: superficial lesion
- Grade II: lesions that are less than 50% of articular cartilage depth
- Grade IIIa: lesions that extend greater than 50% of articular cartilage depth
- Grade IIIb: lesions that extend down to calcified layer
- Grade IIIc: lesions that extend down to, but do not break the subchondral plate.
- Grade IVa: osteochondral lesions: these penetrate through the subchondral plate into underlying bone, but not across the entire diameter of lesion
- Grade: IVb: an osteochondral lesion that has penetrated into the subchondral bone throughout the diameter of lesion.[10]

CELL-BASED CARTILAGE REPAIR: PARTICULATED CARTILAGE GRAFTS

In order for articular cartilage to heal properly, active chondrocytes must be present at the articular cartilage defect. Through many research efforts, it was discovered that particulated cartilage was useful in repairing defects. When the cartilage is minced, the ECM that surrounds the chondrocytes is broken up, allowing these cells to escape their matrix and migrate to other areas, where they can form new hyaline. In the case of articular cartilage defects, using particulated cartilage introduces new chondrocytes to the defect and allow these cells to replace the cartilage in those deficient areas.[11] The first use of adult particulated cartilage was detailed in when it was published in 1983. Later on, an implant system for using autologous adult particulated cartilage was created. Unfortunately, study trials of the system were discontinued due to lack of patient enrollment, the cost and return considerations. However, at about the same time the adult cartilage system was being studied, research was conducted on the possibility of using donor juvenile articular cartilage in the same way. After small, successful equine trials,[11] PJAC was approved by the FDA in 2007 for cartilage restoration in the knee, hip, ankle and shoulder.[17]

PJAC OVERVIEW

There are several reasons why juvenile cartilage is considered a leading choice in cartilage restoration. Juvenile cartilage is populated by 10 times more chondrocytes than is found in adult cartilage.[17] In addition to the greater density, juvenile chondrocytes demonstrate a high metabolic rate and a more favorable gene expression for cartilage growth and expansion than do adult cells. Thus, juvenile chondrocytes have an increased proliferation rate.[11] Juvenile chondrocytes also lack certain proteins, which could initiate an allogenic immune response from the host tissue.[6] In order to ensure these qualities in the donor chondrocytes, cartilage explants are taken only from donors younger than the age of 13. Particulated juvenile cartilage is considered to be a fresh allograft; only being viable for as long as 45 days after harvesting.[11] Another aspect of PJAC surgery is that it is a single-step process, unlike some other cartilage repair techniques. For instance: ACI (Autologous Chondrocyte Implantation) surgery is a cell-based cartilage repair technique that has demonstrated much clinical success; however, the total ACI procedure requires two scheduled surgeries and associated costs are higher.[14]

> In the four zones of articular cartilage, it is the stretching and compressing of the collagen fibrils and their crosslinks, as well as their precise arrangements within the ECM, that helps account for the overall strength and durability of the tissue.

PJAC INDICATIONS/CONTRAINDICATIONS

PJAC is indicated for the treatment of symptomatic articular cartilage defects in younger patients, generally younger than 55 years old. PJAC should be reserved for use on cartilage lesions involving at least 50% of cartilage depth. Many experts agree that the size of the lesion, including any preprocedural debridement, should be at least 1-6cm for surgical options to be considered.[2] Also, PJAC is most suitable for patients whose BMI is below 35kg/m2.[11]

In addition to possible concomitant abnormalities in the knee joint structure, contraindications for PJAC also include: superficial lesions, lesions with uncontained margins and lesions that extend significantly into the subchondral bone. However, uncontained lesion profiles and lesions with subchondral bone deficiency may still benefit from PJAC, if it is supported with another technique. In the case of an uncontained lesion, successful clinical results have occurred when PJAC was covered with a collagen membrane and suture anchors. If there is significant subchondral bone loss, an osteochondral bone plug may be placed in the deepest point of the defect, with the remaining lesion filled with PJAC.[11]

PJAC TRANSPLANT TECHNIQUE

PJAC surgery, while not labor intensive, does involve delicate preparation and delivery during surgery. The surgical approach discussed here involves a medial femoral condyle lesion.

The patient, after transport to the OR table and anesthesia induction, will remain in the supine position. A tourniquet and Bovie pad will be placed on the patient. Although PJACT is performed through a mini arthrotomy, the surgeon may conduct an arthroscopy first to perform palliative techniques or repair concomitant issues if needed. If that is the case, the patient's legs will be positioned in preparation for the arthroscopy, and the appropriate leg holders will need to be obtained. Although the surgeon may not perform an actual arthroscopy, a camera and light source may be set up to enable images to be taken of the procedure.

After the operative leg is prepped and dried in the usual manner, the foot and lower leg is covered with an impervious stockinette and self-adherent wrap. Down sheets, a split U-drape and an extremity drape will be used to create the sterile field. After participating in the time-out, the surgeon will exsanguinate the operative leg with an Esmarch bandage, and the tourniquet will be inflated. In order to access the medial femoral condyle, a vastus-sparing medial parapatellar incision will be made. Rakes and/or Army/Navy retractors will be used for exposure. The knee joint capsule will be incised and the joint surfaces will be exposed. Upon gaining access to the knee joint, the leg will be flexed up and held in place in order to gain maximum exposure of the femoral condyle and to prevent the graft from being dislodged. Z retractors, Smillie retractors and/or a Hohmann retractors may be used at this point. The chondral lesion will then be prepared to receive the graft. In order to ensure that the lesion has stable, vertical walls, the edges of the lesion will be delineated with a #15 scalpel. Any diseased or damaged cartilage will be cleared away from the lesion with the use of a curette. If the tourniquet is inflated, it is recommended that it be deflated to ensure that the subchondral bone has not been penetrated. If subchondral bone bleeding occurs, it can dislodge the PJAC graft if not stopped beforehand. The application of fibrin glue or epinephrine-soaked cottonoids can be used to control the bleeding.[11] The defect will need to be measured with a sterile ruler, and the diameter of the lesion will be noted. The PJAC will be delivered to the field in small sterile packages; one package is intended for every 2.5cm^2 of lesion area. While the surgeon prepares the defect, the surgical technologist will prepare the PJAC and the accompanying fibrin sealant product for implantation on the backtable. The preservative medium inside the PJAC package will be aspirated from the cartilage with the aid of a syringe and needle, or tube less than 1mm in diameter (such as an 18ga angiocath tip and syringe). As much fluid as possible will be aspirated, leaving behind the cartilage particles in the package.[18] The fibrin sealant is a combination of BAC2 (fibrinogen) and thrombin, which will be delivered to the field in vials.[1] A sterile fibrin applicator also will be delivered to the field. The surgical technologist will draw up both the fibrinogen and thrombin into the applicator. The two compounds will not mix until they are pushed through the applicator into the application tube. The surgical technologist will need to ensure that the sealant flows through the application tube smoothly by discharging a few drops through the tubing. The surgeon will administer a thin layer of the sealant to the prepared lesion surface, and then the lesion is ready for the PJAC.

The PJAC may be delivered to the lesion in a variety of ways. One common method involves using a sterile piece of foil to make an impression of the lesion, which then is filled with the PJAC and sealant.

The PJAC may be delivered to the lesion in a variety of ways. One common method involves using a sterile piece of foil to make an impression of the lesion, which then is filled with the PJAC and sealant. Once the mold is stable, it is carefully removed from the foil and inserted into the lesion.[18] The PJAC then will be loaded into a small delivery cannula (in this case, the sterile sheath of a spinal needle) and a dampened sterile cotton tip applicator will be used to push the PJAC into the lesion. The surgeon will use a small, flat instrument, such as a Freer elevator, to arrange the particles within the lesion. The particles will need to be in a single layer, and should sit below the surrounding cartilage at a depth of approximately 1 mm. This action protects the graft surface from enduring excessive stress. The PJAC layer will then be coated with more fibrin sealant. The graft will

need to set, which may take 3 to 10 minutes. If any suction must be applied to the wound, it will need to be performed carefully to avoid removing any particles from the graft. Vigorous irrigation must be avoided. Once the graft is set, the surgeon will take the joint through a range of motion to confirm the implant's stability. The joint capsule, fascia layers and skin will then be closed with suture according to the surgeon's preference. Pain control medications may be injected into the knee. Sterile gauze or ointments, along with dressings such as 4x4s, ABDs, soft rolls and elastic bandages may be applied.[11]

PATIENT REHABILITATION

For grafts occurring in the tibiofemoral compartment, patients are generally non-weight bearing for two to six weeks, depending on the size of the graft. Patients will be placed in a hinged-knee brace locked in extension immediately following PJACT surgery. The brace may be worn for as long as two weeks. Afterward, the orthopedist may require CPM (continual passive motion) exercises.[11] Below is a summary of expected recovery times, which vary among patients.

- Phase I (Months 1–3): Regain full weight bearing on operative area and full range of motion
- Phase II (Months 4–6): Continue recovery from surgery and progress toward achieving normal activity levels
- Phase III (Months 7–9): Progress toward regaining full muscular strength in operative area
- Phase IV (Months 10–18): Patient's goal is to optimize desired activity level[16]

PATIENT OUTCOMES

The use of PJAC is still relatively new in the field of restorative cartilage techniques, and clinical data is still being collected. However, a two-year study conducted on 25 patients who had knee lesions treated with PJACT showed solid results. The patients experienced significantly less symptoms, such as knee pain, and showed an improvement in function as well as the ability to partake in sports for at least two years post-operatively. A biopsy of tissue taken from a graft repair site at two years post-op demonstrated good type II collagen expression, high proteoglycan content, viable chondrocytes and good integration of the repair tissue into the surrounding cartilage and underlying bone.[17] Another study, taking place over five years and including 71 patients, many of were active in sports, also demonstrated similar successful results.[7] Thus, it would seem that the innovative technique of PJACT is meeting the urgent need for cartilage repair and restoration today's active populations.

ABOUT THE AUTHOR

Grace Le Blanc, CST, graduated from the Huntsville Hospital School of Surgical Technology in 2014 as an AST Honor's student. Since graduation, she has have worked as a surgical technologist at Huntsville Hospital in the orthopedic department specializing in total joint replacements and sports medicine injuries. She is currently pursuing an undergraduate degree in health and wellness management.

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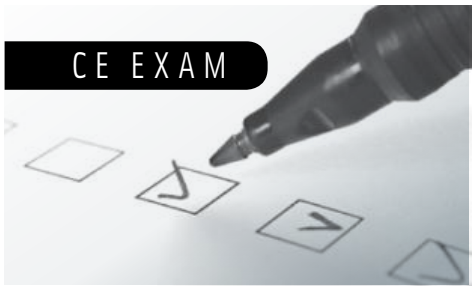

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PJACT: Treating Articular Cartilage Defects

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1. **Articular hyaline cartilage covers the _____ portions of the femur that communicate with the rest of the knee joint.**
a. Proximal
b. Anterior
c. Superior
d. Distal

2. **Articular cartilage thickness ranges approximately from ____.**
a. 1-3 mm
b. 2-5 cm
c. 1-5 mm
d. 1-5 cm

3. **As much as 80% of the ECM wet weight consists of _____.**
a. Water
b. Collagen
c. Protein
d. Molecules

4. **____ collagen is significant in articular cartilage structure, as it accounts for 90% to 95% of the collagen in ECM.**
a. Type I
b. Type II
c. Type III
d. Type IV

5. **Which zone contributes 40% to 60% of the articular cartilage volume?**
a. Deep
b. Middle
c. Superficial
d. Calcified

6. **The first use of adult particulated cartilage was detailed in ____.**
a. 1983
b. 1905
c. 1965
d. 1990

7. **What are/is responsible for establishing a specialized microenvironment and maintaining the ECM?**
a. Collagen fibrils
b. Chondrocytes
c. Cartilage
d. None of the above

8. **Chondrocytes in which layer are flat in shape?**
a. Deep
b. Calcified
c. Middle
d. Superficial

9. **Which grade has lesions that are less than 50% of the articular cartilage depth?**
a. Grade 0
b. Grade Ia
c. Grade II
d. Grade IIIc

10. **After small, successful _____ trials, PJAC was approved by the FDA in 2007 for cartilage restoration in the knee, hip, ankle and shoulder.**
a. Feline
b. Equine
c. Rodent
d. Canine

PJACT: TREATING ARTICULAR CARTILAGE DEFECTS #406 October 2017 2 CE CREDITS $12

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