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Focal Articular Cartilage Defects of the Knee: Current Review

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Focal Articular Cartilage Defects of the Knee: Current Review

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Abstract- Injuries to the articular cartilage of the knee are common, they have a significant role in degenerative joint diseases, cartilage is unable to regenerate due to its inherent lack of vascular supply.

The management of symptomatic focal traumatic articular cartilage lesions of the knee in active individuals remains a substantial challenge. Although many treatment options are currently available, none of them has fulfilled the criteria for an ideal management solution. Treatment decisions should be based on appropriate evaluation and classification of the pathology. This would enable the treating physician to choose whether to perform a repair or a restoration of the articular surface.

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I. Introduction

Articular cartilage is vulnerable to traumatic injury and subsequent degeneration. These changes are likely related to the limited capacity for cartilage repair, poor vascular supply, and deficiency in terms of the ability of an undifferentiated cell population to respond to insult {1}.

Hyaline cartilage provides the diathrodial joint with a resilient, wear-resistant, low –friction surface with a high compressive stiffness, effectively minimizing peak loads of subchondral bone {2}.

The collagen fibers, those are predominantly responsible for the structure of hyaline cartilage, are highly cross linked by type II, which are highly cross-linked by type IX collagen fibers. Water is the biggest constituent of articular cartilage accounting for 70% to 80% of its total weight [2]. Negatively charged hydrophilic proteoglycans are composed of glycosaminoglycans attached to linear core proteins. The mesh of collagen fibrils and glycoamionglycans inhibits water to a limited degree {2, 3}.

Metabolically active chondrocytes are unique in that they have a relatively low turnover rate and are sparsely distributed within the surrounding matrix maintaining minimal cell to cell contact {4}.

Articular cartilage is further organized into four zones: superficial, intermediate, deep and calcified cartilage zones. Within the superficial zone, chondrocytes appear flat in shape at close proximity to each other and the collagen fibers are aligned parallel to the articular surface. In the intermediate zone, chondrocytes are oblique in shape and collagen fibers are randomly organized in different directions. Deep zone cartilage, however, is characterized by spherical chondrocytes that are arrayed in columns and the collagen fibers are perpendicular to the articular surface. The collagen fibers in the deep zone penetrate through the tidemark into the calcified cartilage to provide structural stability for the articular cartilage on the subchondral bone {5}.

The interaction of the cells, collagen framework, aggrecan, and retained fluid is responsible for complex biomechanical profile and superior loading characteristic of the hyaline cartilage making it difficult to replace or reproduce {4}.

The insult to the articular cartilage can be traumatic or degenerative. Various metabolic factors such as obesity, alcohol abuse, as well as mechanical factors like instability, and joint malalignment are implicated in its etiology {6}. Repetitive compression forces or sudden impacts cause many articular lesions. High shear forces at the subchondral bone junction are especially damaging. The cartilage injuries can be divided into three types: microdamage to the cells without visible damage (bone bruise on MRI), chondral fracture or fracture of the articular surface with subchondral bone penetration {7}.

The treatment of symptomatic focal traumatic articular cartilage lesions of the knee in active individuals remains a substantial challenge. The pronounced growth in athletics participation and increased stress on physical fitness among all age groups contribute to greater expectations regarding the outcome {8}. The goals of surgical treatment are to provide pain relief and improve joint function, thus allowing patients to comfortably perform activities of daily living and potentially maintain or return to higher levels of activity {1}.

Advances in Arthroscopy and the introduction of techniques designed to restore knee articular function through resurfacing have generated considerable interests and research in recent years. Traditional

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surgical methods such as debridement and drilling have come under greater scrutinydue to the recognition that optimal outcome may be associated with restoration of hyaline or hyaline-like articular cartilage. This concept has challenged the clinician to strive for a more complex histological tissue to repair chondral lesions that may be associated with a more durable response to loading over time {4, 9}.

The aim of this study is to assess basic science, indications, advantages, shortcomings and consequences of different procedures of knee articular cartilage surgery.

II. Classification of Cartilage Defects

The classification the articular cartilage injury is needed in order to guide management decisions and understand the pathogenesis of these lesions {10}. Outerbridge in 1960s classified these defects based on their gross appearance during arthrotomies. In grade1 lesions, the articular cartilage is swollen and soft. Grade 2 lesions are characterized by fibrillation, fissures, and cleft less than 1.5 cm in diameter. Grade 3 lesions are characterized by deep fissures extending down to the subchondral bone. Outerbridge grade 4 lesions have erosion of the cartilage to the subchondral bone {11}.

Other classification systems exist that are more comprehensive and take into account factors such as the location of the lesions; however, the Outerbridge classification is the most widely accepted {10}. The International Cartilage Repair Society (ICRS) developed its own classification system to describe more accurately the chondral defects and to allow for uniformity in the research reporting. ICRS grade I lesions include those that demonstrate softening or those with superficial fissures. Grade 2 injuries describe defects that have a depth less than 50 % of the tissue thickness. Grade 3 injuries include defects that have a depth greater than 50% of the tissue thickness. Lastly, IRCS grade 4 lesions are full thickness lesions extending to or through the subchondral bone plate {12}.

III. Diagnosis

Diagnosis of articular cartilage lesions is complex and can be accomplished by a combination of history, clinical examination and radiographic evaluation.

IV. Clinical Presentation

Patients with focal chondral defects of the knee may be asymptomatic. As the articular cartilage is an aneural tissue, the presence of a defect does not necessarily produce pain. Nevertheless, patients with full- thickness chondral defects may demonstrate major limitations in pain and function {13}. Patients with symptomatic chondral defects generally complain of activity related pain located in a region that correlates with the intra-articular location of the defect for tibiofemoral articulation. Patellofemoral lesions generally cause anterior knee pain, worse with prolonged knee flexion or stair climbing. Patients with chondral flaps may also present with mechanical symptoms such as catching or clicking. Thus, it is absolutely vital that the patient to be questioned about the nature and localization of the symptoms {10, 14}.

V. Imaging

Radiographs should include anteroposterior, lateral, Merchant, and 45^0 flexion posteroanterior weight bearing films {15, 16}. Limb alignment is evaluated with full leg-length films. These series of films could show joint space narrowing, osteophytes, cyst formation and subchondral sclerosis, which are consistent with degenerative joint disease; when present, they are considered relative contraindications for the treatment of articular cartilage lesions {17}. Long leg alignment radiographs are used to specify where the mechanical axis lies. If the mechanical axis bisects the affected compartment, realignment may be necessary {17}.

A magnetic resonance image (MRI) is valuable to evaluate the status of the knee ligaments and menisci if it is obscure. The presence of subchondral edema in the area of a chondral defect may signify overload in that region, but it is not always associated with symptoms. Although, MRI is considered as an outstanding tool for evaluation of cartilage injury, a considerable number of chondral lesions may remain undetected until Arthroscopy, especially partial thickness lesions {18, 19}. It has been found that, fat-suppression imaging is more sensitive than standard MRI for detection of abnormalities of the hyaline cartilage in the knee {20}. Furthermore, more recently, specialized fast spin- echo MRI sequences with a high resolution matrix allowed for an exact assessment of articular cartilage in the knee, with little interobserver variability {21}.

The use of bone scanning in the assessment of articular cartilage lesions is still being determined. Joint overload that initiates the increases in osseous metabolic activity of the bone is detectable using scintigraphy. Scintigraphy may be useful in difficult cases in which the source and the clinical importance of periarticular symptoms remain doubt based on the results of the patient's history, physical examination and radiographic studies {22}.

VI. Nonoperative Treatment

Nonoperative treatment includes nonsteroidal anti-inflammatory drugs, viscosupplementation, bracing, weight loss and rehabilitation. These treatments may provide symptomatic relief and have the potential to alleviate some symptoms. Nevertheless, there has been no evidence, to date, that any of these techniques provide structural improvements of the lesions {23}.

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VII. Surgical Options

Operative treatment is broadly classified into three categories, namely, bone marrow stimulation (BMS) techniques, cartilage replacement techniques, and cartilage regeneration techniques.

VIII. Bone Marrow Stimulation (BMS) Techniques

The principle behind bone stimulation procedures is that penetration of the subchondral bone plate leads to bleeding and fibrin clot formation within the chondral defect. Pluripotent, marrow-derived mesenchymal cells migrate into the clot and allow formation of a fibrocartilaginous repair tissue. This tissue provides a more congruous joint surface, leading to symptomatic improvement in the majority of published reports {24, 25}.

Nevertheless, the resultant fibrocartilagenous repair tissue following bone marrow stimulation technique is composed of predominantly type I collagen. Such a repair tissue lacks the normal histological or biomechanical properties of hyaline cartilage. Therefore, it has an inferior stability to compressive and shear forces and tends to deteriorate with time. Abrasion arthroplasty, drilling and microfracture are the three most common methods utilized to violate the subchondral bone {25, 26}.

Microfracture is the most common procedure, it involves a systemic removal of all covering calcified cartilage with a curette. All loose or marginally attached cartilage should be debrided back to a stable rim to get a perpendicular edge. It is of the essence to success of this procedure to create vertical walls of stable articular cartilage to get a "well shouldered" lesion. This improves the local mechanical environment during healing by reducing shear and compression. A surgical awl is used to create holes placed 2 to 3 mm apart, beginning first at the periphery of the lesion. The holes should not be confluent. The fat droplets can be seen coming from the marrow cavity if the approximate depth (2-4 mm) is reached. Once the procedure is completed, the tourniquet (if inflated) should be released and the pump pressure is reduced. One should see blood and marrow fat droplets coming from each hole {25, 27}.

The postoperative rehabilitation program is paramount to the success of this procedure and requires a period of non-weight bearing for femoral condyle lesions and the use of continuous passive motion for up to 6 weeks postoperatively. Patients with a lesion in the patellofemoral joint wear a brace with a flexion stop of 30^0 to limit patellofemoral contact; weight bearing is permitted {17,26}.

The best outcomes are generally reached when this technique is utilized for patients with relatively small cartilage defects and for those who are not physically demanding on their knees. The procedure may be less suited to the patellofemoral joint or the tibia as it has been shown by Kreuz et al in their study {28}.

Knutsen et al found no difference between the outcomes of microfracture and those of autologous chondrocyte implantation for femoral condyle lesions. Nonetheless, patients with smaller lesions did better with microfracture compared to those with larger lesions {29}. Likewise, Gudas et al reported that among patients with lesions exceeding 2 cm^2 in the central part of the medial femoral condyle , those treated with microfracture had lower clinical outcome scores than did those treated with an osteochondral autograft transplantation{30}.

XI. Substitution Techniques

a) Autologous osteochondral grafts

Osteochondral autograft transfer was first reported by Outerbridge and colleagues in 1995 {31}. Osteochondral autograft transplantation is a transfer of one or more cylindrical osteochondral autografts into the cartilage defects, providing a congruent hyaline cartilage covered surface {32}.

The technique can be performed through a small arthrotomy or entirely arthoscopically. After the lesion is identified, the edges are debrided back to stable, healthy cartilage. The base of the lesion is abraded down to the subchondral bone and the number of grafts needed is determined. The autografts are harvested from the-non-weight-bearing periphery of the femoral trochlea or the margins of the intercondylar notch. The appropriately measured tubular chisel is introduced perpendicular to the donor site.it is important to maintain a perpendicular relationship between the donor graft and the articular surface to create well defined vertical walls in the recipient socket as this facilitates congruent plug placement. The chisel is tapped into the donor site for approximately 15 mm to25 mm. The chisel is removed by careful toggling without rotation in order to avoid breakage of the plug. The graft is then pushed out of the chisel from the osseous end to avoid damage to the harvested cartilage. The donor plug is placed over the recipient site and gently advanced into the defect. It is critical to avoid high loads when inserting the graft as this could damage the chondrocytes. The graft is secured in this press-fit manner, and no further fixation is required. Once all grafts have been introduced, the knee should be moved through a full range of movement to ensure graft congruity with the joint surface and their press -fit stability {23, 32, 33}.

Postoperatively, patients are protected from weight bearing for six weeks with the use of a continuous passive motion machine for six hours per day {1}.

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The advantages of ostechondral grafting procedures include being a one stage technique, transplantation of viable hyaline cartilage, and relatively brief rehabilitation period {32}.

The restrictions of this technique include the donor site morbidity and a limited availability of graft that can be harvested, therefore this technique is more suited to small (<4cm^2) lesions. Other potential limitations include differences in orientation, thickness and mechanical properties between donor and recipient cartilage as well as graft subsidence at the surface with postoperative weight bearing {32}.

Donor site healing by natural processes results in filling of the defects with cancellous bone and an overlying cartilage like a cap. Hangody and Kárpáti evaluated the survival of the transplanted hyaline cartilage. The graft undergoes osseous incorporation to the subchondral bone while the transplanted cartilage integrates with the adjacent host articular cartilage with fibrocartilage {34}.

Marcacci et al evaluated 30 patients with full-thickness knee chondral lesions (<2.5 cm) treated with *arthroscopic autologous osteochondral transplantation.* All patients were evaluated at 2- and 7-year follow-up. The International *Cartilage* Repair Society form, and magnetic resonance imaging were used for clinical evaluation. The International *Cartilage* Repair Society objective evaluation showed 76.7% of patients had good or excellent results at 7-year follow-up. In conclusion, the results of this technique at medium- to long-term follow-up were encouraging {35}.

b) Osteochondral allograft transplantation

Osteochondral allograft transplantation is a cartilage resurfacing procedure that involves transplantation of a cadaver graft consisting of intact, viable articular cartilage and its underlying subchondral bone into the defect. The size, depth and location of the defect are crucial factors in tailoring of the donor graft {32}. Osteochondral allograft transplantation provides an alternative for treatment of larger lesions (>2.5 cm^2) or those with significant bone loss. It is commonly a second line treatment option, but can be a first line treatment for high demand patients with large lesions {1,32}.

The allografts can be ‘‘fresh’’ or frozen. Fresh grafts are usually maintained at 4ºC in standard or enriched culture medium for no more than twenty-eight days, which allows chondrocytes to survive after transplantation. The fresh allografts elicit a minimal immune response, the chondrocytes survive, and the bone is successfully revascularized {1,36}.

Allograft transplantation can be done arthroscopically; however, it is most often performed through a small arthrotomy. The lesion is sized with a template, and a correspondingly sized reamer is used to convert the defect to a circular recipient socket with a uniform depth of 6 to 8 mm. An instrumentation system is used to size and harvest a cylindrical plug from the allograft. The donor graft is drilled through its entire depth with a harvester under irrigation with a normal saline solution. The graft is extracted, and a ruler is used to measure and mark the four quadrants of the graft at the depth of the previously measured recipient sites. The graft is then pressed-fit into the socket after careful alignment of the four quadrants to the recipient site.If the implanted allograft is particularly large, fixation may be augmented with bioabsorbable or metal compression screws {1}. Postoperatively, patients are made non-weight bearing for up to 8 weeks and a continuous passive motion is used immediately after the surgery {17}.

Advantages to the use of osteochondral allografts include the ability to achieve precise surface architecture, immediate transplantation of a viable hyaline cartilage as a single-stage procedure, the potential to replace large defects or even hemicondyles and no donor site morbidity. Limitations of osteochondral allografting include limited graft availability, high cost, risk of immunological rejection, possible incomplete graft incorporation, the potential for disease transmission, and the technically demanding aspects of machining and sizing of the allograft {37}. Ghazavi et al used *fresh* small-fragment *osteochondral allografts* to reconstruct *post-traumatic osteochondral defects* in 126 knees. At a mean follow-up of 7.5 years, 108 knees were rated as successful (85%) and 18 had failed (15%). The factors related to failure included age over 50 years, bipolar *defects,* malaligned knees with overstressing of the grafts, and workers' compensation cases (38).

x. Cartilage Regeneration Techniques

a) Autologous chondrocyte implantation (ACI)

Autologous chondrocyte implantation was first described in 1994, by Brittberg and colleagues {26}. Autologous chondrocyte implantation is ideal for symptomatic, unipolar, well contained chondral or osteochondral defects measuring between 2 and 10 cm^2 with bone loss of less than 6 to 8 mm.

The first stage of autologous chondrocyte implantation is an arthroscopic evaluation of the size and depth of the focal chondral lesion and a cartilage biopsy. The total volume of the biopsied material should be approximately 200 to 300 mg. The second stage is implantation of the cells. This is done usually no sooner than six weeks after the biopsy. At the time of implantation, the defect is prepared by removing any existing fibrocartilage down to the underlying calcified layer. Vertical walls are created at the periphery of the lesion with the use of a combination of a number-15 blade and sharp ring curets. The walls of the defect are

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kept as vertical as possible to allow for suture fixation of the graft.

Care is taken to avoid penetration of the subchondral bone plate, as this would stimulate a fibrous response similar to what seen with the microfracture procedure. Next, a periosteal flap that will cover the cartilage defect is harvested from the proximal medial tibia, 2 to 3 centimeters distal to the pes anserinus insertion. All overlying fat and fascial tissue is removed and an appropriately sized flap, typically oversized by 2 mm, is cut sharply with the tissue carefully elevated from the bony surface. With the cambium, or inner layer, of the periosteal flap facing the defect, it is secured to the surrounding cartilage using 6-0 vicryl suture, with the sutures spaced 2 to 3 millimeters apart. The suture fixation is started at the corners of the flap to allow for appropriate tensioning and a small opening is left superiorly for the injection of the cultured chondrocytes. Fibrin glue is applied to fill the gaps between the sutures, creating a water tight pouch, which is checked with a trial saline injection. With the periosteal pouch prepared, the cultured chondrocyte suspension is injected into the defect,focusing on an even distribution within the periosteal pouch.The superior opening is then closed with 6-0 vicryl suture and is sealed with fibrin glue {10,17}.

Postoperatively, lesions of the femoral condyle are treated initially with minimum weight bearing and continuous passive motion . Lesions of the patella-femoral joint are often allowed for weight bearing as tolerated in extension {10}.

b) Outcomes following ACI

Brittberg and associates {39} reported 2- to10-year outcomes of 244 patients with large grade 3 and 4 chondral defects. They found that at a mean follow-up of 4 years, 90% of patients treated for femoral condylar lesions had good to excellent results. A portion of this cohort was followed for a mean of 7.4 years postoperatively, and their results were found to be stable at this longer term time point, with 84% of the overall cohort having good to excellent results. The authors concluded that if ACI is successful, a long lasting, durable repair is achieved {40}.

Nevertheless, Van Assche et al reported on 67 patients randomized to microfracture or ACI. Follow up at 2 years did not show differences in functional outcome {41}.

Recently, Magnussen et al reviewed five randomized controlled trials comparing ACI, osteochondral autograft transfer and microfracture outcomes. All treatments improved clinical outcome measures compared with preoperative assessment, however, no technique had consistently superior results and no study used non-operative control group. The authors recommended that a large prospective study to be conducted and non-operated control to be included {42}.

XI. Summary

Articular cartilage defects of the knee are common, treatment modalities range from palliative to reparative to restorative techniques. Each management plan has its own advantages and disadvantages, futhermore, to date none of these modalities has fulfilled the criteria for an ideal management solution. Nonetheless, all of these procedures improve the clinical status compared with preoperative state. Decision making is supposed to be guided by the patient's physical and physiological demand status, previously failed treatment, and the location and size of the defect.

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