INTERNATIONAL MEDICAL SCIENCES ACADEMY IMSA

The Journal of International Medical Sciences Academy
2017; (October – December); Vol 30; No. 4

ORIGINAL ARTICLE

Assessment of the Functional Outcome after Arthroscopic Mosaicplasty for Localized Osteochondral Defects in the Knee

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ABSTRACT

Background: Full-thickness chondral defects of weight-bearing articular surfaces of the knee are a difficult condition to treat. Our aim is to evaluate the mid- and long-term functional outcome of the treatment of osteochondral defects of the knee with autologous osteochondral transplantation with the OATS technique (Often refered to as Mosaicplasty).

Methods: Twenty four patients were included in this study. Twenty patients were male (Serving soldiers) and four were female with a mean age of 30.5 years (range: 21-46 years). The cause of the defect was trauma accounting for 75% , osteochondritis dessicans 16.66 % and AVN 8.33 % . The sizes of the graft used ranged from 6mm to 10mmn with 33.33 % patients with size 7mm, 25% patients with 8mm. There was a preponderance towards the Right knee accounting for 75% of the total knees. The study revealed the most common site of involvement was medial femoral condyle accounting for 83.33% of all knees. Average length of stay ranged from 5 days to 10 days with 75% of patients who were discharged on the 05th postoperative day. Incidence of concomitant other injuries to the knee were 83.33%.

Results: Based on Tegner and Lysholm scoring scale at the end of 24 months 91.66% patients had excellent results with 8.33% patients with fair results. No correlation was found between patient age at operation, the size or site of the chondral lesion and the functional outcome.

Conclusion: We believe that autologous osteochondral grafting with the OATS technique is a safe and successful treatment option for focal osteochondral defects of the knee. It offers a very satisfactory functional outcome and does not compromise the patient's future options.

Introduction

Articular cartilage is complex tissue that is able to withstand tremendous force over many cycle but does not have the ability to heal even after minor injury. Articular cartilage forms the load-bearing surfaces of all synovial joints. Its highly organized structure provides the biomechanical properties necessary for the tissue to withstand multiple forces created during movement. Following injury, articular cartilage has limited healing potential because the cells have minimal mitotic activity and the matrix lacks a vascular supply [1,2,3]. Advances in the treatment of cartilage defects are utilizing tissue engineering repair techniques in an attempt to regenerate and develop tissue with structural and mechanical properties similar to those of normal

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Received: 02.03.17
Accepted: 29.03.17

cartilage. The main functions of articular cartilage in synovial joints are to provide a low-friction surface for motion and to resist tensile, shear, and compressive forces [4,5,6]. Articular cartilage varies in specific composition within the same joint and between different joints, but it consists of the same basic components and structure throughout all joints [7,8,9]. Grossly, articular cartilage appears as a smooth, homogeneous tissue approximately 2 to 5 mm thick [7]. When probed, healthy cartilage is firm and resists deformation. Diseased cartilage is soft, deforms when probed, and may contain visible surface disruptions. Articular cartilage consists of a sparse population of chondrocytes embedded within a highly hydrated extracellular matrix composed of collagen and proteoglycans. The composition of articular cartilage varies with depth from the surface, and it is divided into four structural zones. The matrix is also divided into three regions, and its composition varies with distance from the chondrocyte [5,8]. This precise arrangement of the tissue components provides specific mechanical properties for each zone [10]. Chondrocytes synthesize matrix components and regulate homeostasis of articular cartilage [9]. Articular cartilage has a limited capacity for natural healing owing to lack of blood supply, absence of chondrogenic progenitor cells, and decreased mitotic activity [11]. Cartilage injuries occur through a variety of mechanisms, including a single load of great magnitude or repetitive joint overloading of lesser magnitude [7]. Cartilage injuries have been divided into three categories based on depth of injury: (1) cell and matrix damage without visible surface changes; (2) cartilage disruption with visible fibrillations, fissures, flaps, or defects; and (3) visible cartilage and subchondral bone disruption [12].

Current surgical treatments for cartilage damage include arthroscopic débridement, microfracture, autologous chondrocyte implantation, and osteochondral transplantation [2,3]. Osteochondral autograft transplantation is the transfer of one or more cylindrical osteochondral autografts into the cartilage defect, providing a congruent hyaline cartilage covered surface. The autografts are harvested from the non-weight-bearing area of femoral articular surface like trochlea or the margin of the intercondylar notch.With a combination of different graftsizes, 90% to 100% of the defect can be filled[10]. This technique is limited by the amount of donor tissue available in the knee. Osteochondral autograft transplantation is best for small lesions (<2 cm^2),but good clinical results have been reported with lesions between 2 to 4 cm^2[11].

Materials and Methods

Study design

Assess the functional outcome after arthroscopic mosaicplasty for localized osteochondral defects in the knee. Twenty four cases of localised osteochondral defects were treated with arthroscopic mosaicplasy and were studied prospectively for functional outcome.

Place of study

Base Hospital Delhi Cantt

Study period

From Nov 2014 to Nov 2016.

Study population

All patients with localised osteochondral defects fulfilling the inclusion criteria of study.

Sample size

All patients of localised osteochondral defects fulfilling inclusion criteria were to be included in the study.

Inclusion criteria

1. Age: 15 to 55 years.
2. All those with localized osteochondral defects knee (MR proven or incidental detection during Arthroscopy).
3. The Patients should be skeletally mature with documented closure of growth plates.
4. The Patient who were symptomatic with difficulty in ambulation that have not been relieved by appropriate non-surgical therapies
5. The Patient who had focal, full thickness (grade III or IV) lesions on the weight bearing surface of the femoral condyle. These Patients were assessed for the quality of surrounding cartilage (minimal to absent degenerative changes in surrounding articular cartilage,Outer bridge grade II or less).
6. The Patient should be free from any systemic/ localized infection.

Exclusion criteria

1. Age Less than 15 and more than 55 years.
2. Concomitant other medical illness such as malignancy, vascular insufficiency, local/systemic infections.
3. Global articular cartilage changes i.e. tri-compartmental changes.
4. Fixed flexion deformity of more than 15 degrees,

restricted range of motion of the knee.

5. Previous malunited fractures of the proximal tibia or distal femur with coronal plane deformity of more than 15-20 degrees.

Ethical clearance

Ethical clearance was obtained from institutional ethics committee of Base hospital before the start of the study. Written informed consent was obtained from each subject before the conduct of the study.

Conduct of the study

A prospective and observational study was be conducted by identifying patients attending the Orthopedic OPD at Base Hospital, Delhi Cantt who gave consent for participation in the present study.

The Patients were thus admitted, and they underwent preoperative evaluations which included a detailed history taking and physical examination of the affected knee joint with regard to joint line tenderness, range of motion, laxity of the joint. A preoperative radiological survey in the form plain radiographs, MRI and preoperative investigational protocol for assessment of pre-anesthesia check was performed. Detailed history regarding co-morbidities was documented and patients with co-morbidities were duly excluded.

All the patients with localized osteochondral defects were treated with arthoscopic mosaicplasty in this study between November 2015 to Nov 2017 at Base Hospital, Delhi Cantt.

The cases were followed up for a minimum period of 1 year to 02 yrs and are still on follow up. All surgeries were performed by the orthopedic surgeons on the posted strength of Base Hospital Delhi Cantt.

Surgical technique

Surgical technique involved standard arthoscopic protocols. Preoperative antibiotics were given at the time of induction of anesthesia. Patient were prepared for surgery as per standard International norms. Anterolateral portal was made 1cm below the lower pole of patella and 1cm lateral to the patellar tendon.

A diagnostic arthoscopy was done starting from the suprapatellar pouch to the medial femoral compartment, intercandylar notch was scoped for assessing the integrity of ACL/PCL and rule out tears.

Superficial defects not going up to the subchandral bone were treated with abrasion chandroplosty and micro fracturing. Meniscal tears were dealt according to tear patterns and geography of tears with either repair/ excision and balancing.

The localized osteochondal defects more than 5 mm in size where the subchondral bone was exposed were treated with mosaicplasty. The graft was harvested arthoscopically from the non articulating part of the femoral condyles either medial/lateral (mostly lateral femoral condyles) using a harvester (we used the Mosaicplasty kit of Arthrex). Graft diameter of size equal to the defect measured was harvested. The usual sizes of the osteochondral defects was 6-10 mm in diameter. The larger defects required the insertion of 02 osteochondral plugs (in two cases) and sometimes even 03 osteochondral plugs (in one case only). The depth of the defect was approximately 15mm as measured by the harvester which has markings that are visible arthroscopically.

Figure 1: Depicts the recipient site after it has been prepared for grafting

Once the graft is harvested the recipient area is prepared by creating a trough by an equipment which is similar in shape to the harvester but is 1 mm less in diameter. The depth of the trough created is also 2 mm less than that of the graft which is done so that the implanted graft sits flush with the native articular surface. The graft is placed in the recipient trough with help of plastic cannula which is conical on the front for easy passage into the defect. Once implanted the graft is checked for stability using a probe.

Routine arthroscopic procedure of ACL/PCL reconstruction were carried out either prior to following

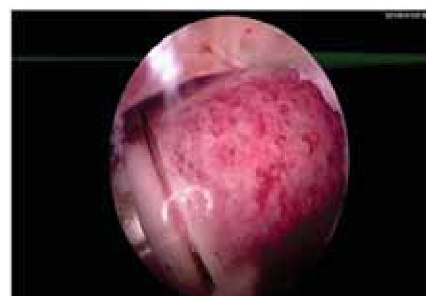

Figure 2: Shows the introduction of the osteochondral peg into the defect

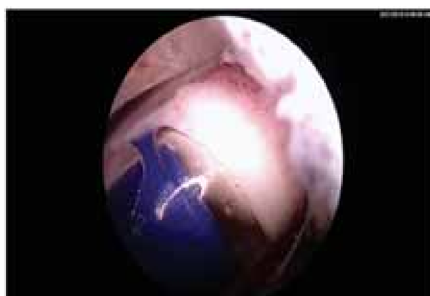

Figure 3: Depicts the final placement of the graft.

a mosaicplasty. Before closure the extracted part of the diseased osteochondral bone was swapped into the donor area. Joint was lavaged and closed. Compressions dressing were done thereafter.

Rehabilitation Protocol and Followup

Post operatively these patients were not allowed to bear weight on the affected limb for 06-08 weeks although range of motion exercises and isometric quadriceps and hamstring exercises were initiated from day 1 of the procedure. Partial weight bearing at 06-08 weeks time was started and the patients were encouraged to bear full weight by 12 weeks from surgery.

Follow up of these patients was done according to **Tegner and Lysholm scoring scale**. Follow up was done at 03 months, 06 months, 01 year and 02 years from the time of surgery and results were documented and data was interpreted.

It was planned that the patient would be rescoped at 06 months (for a relook arthroscopy) for academically documenting the take up of the graft but consent for the above procedure was not given by most patients as it was purely an academic exercise which was explained to the patients. Hence the assessment of the procedure will mostly be by the knee pain score.

Results

All data from cases was collected and compiled. Data was studied in references of gender distribution, Age Distribution, Mode of Injury, Size of the defect (as assessed by the graft size used to treat the defect), Laterality, site of involvement, Average Hospital Stay, Type of defect (based on Outerbridge classification), incidence and types of intra-articular pathology, associated ligament injuries and meniscal pathologies and post operative complications were tabulated. Outcome measures were studied using **Tegner and Lysholm scoring scale** and the outcome was graded as excellent, good, fair and poor at 06, 12 and 24 months.

Gender distribution

In our study we observed a male preponderance with 83.33 percent out of a total of 24 patients.

Age Distribution

Most of the patients in our study were in the age group of 21- 46 yrs with an average age of 30.5 yrs.

Mode of Injury

In our study most of the osteochondral defects were sustained due to trauma in which road traffic accidents accounted for 50% and military training activities accounted for 25% of all injuries. 16.66 % of osteochondral defects were because of osteochondritis dessicans, and 8.33 % of osteochondral defects were because of AVN.

Size of the defect (as assessed by the graft size used to treat the defect)

The sizes of the graft used ranged from 6mm to 10mmn with 8.33 % patients treated with a single osteochandral plug of size 6mm,33.33 % patients with size 7mm,25% patients with 8mm, 16.66 % with size 9mm,8.33% with size 10mm and 8.33% with multiple pegs of different sizes respectively (one patient was treated with 02 pegs and 01 with 03 pegs of assorted sizes).

Side of involvement/ Laterality

In our study there was a preponderance towards the Right knee accounting for 75% of the total knees.

Site of Involvement

Our study revealed the most common site of involvement was medial femoral condyle accounting for 83.33% followed by the lateral condyle which accounted for 16.66% of all knees.

Average hospital stay

In our study the average length of stay ranged from 5 days to 10 days with 75% patients who were discharged on the 05th postoperative day and 25 % patients who were kept for a maximum of 10 days due to effusion and observation for ruling out infection of the operative wounds.

Incidence and types of intra-articular pathology, associated ligament injuries and meniscal pathologies

In our study 50% of patients had concomitant ACL tears, 33.33% patients had meniscal tears and 16.66% patients had isolated osteochondral injuries.

Final Assessment

Based on Tegner and Lysholm scoring scale at 06 months 66.66 % patients had excellent result,25% patients had good result and 8.33 % patients had fair results respectively. At the end of 12 months 75% patients had excellent results with 16.66 % with good results and 8.33% patients with fair results. At the end of 24 months 91.66% patients had excellent results with 8.33% patients with fair results.

Discussion

Treatment recommendation for articular cartilage injury and arthritis includes nonoperative and operative management. Non operative treatments involves decreasing the load of joint by having the patients lose weight, alter activities and strengthen muscles across the joint may help to absorb some of the load. Orthoses or brace also are beneficial, as are analgesics and anti-inflammatory medications. Operative treatment is generally indicated if non operative treatment fails to relieve pain and mechanical symptoms. Treatment options includes visco-supplementation, marrow stimulation i.e. Intaarticular Injection of PRP, transplantation to fill the defect (Autologous Chondrocyte implantation) which is a cell based therapy and use of growth factor of Pharmacological agents. The choice of procedure is based primarily on size of the lesion and the activity demand of the patients

Osteochondral autograft plug transfer (OAT) involves the direct transplantation of osteochondral segments from less loaded regions of cartilage to areas with symptomatic focal defects [15]. Despite concerns of donor site morbidity and limited availability, this method has been demonstrated to reliably restore native hyaline cartilage architecture and the underlying subchondral bone.

Yamashita et al in 1985 described two patients who underwent graft harvest from the superomedial femoral trochlea in a region which “in extension was in contact with neither patella nor meniscus.”Donor sites were filled with iliac crest bone graft, and all segments were fixed using orthogonal mini-cancellous screws [16]. Second-look arthrotomy for screw removal revealed macroscopically intact hyaline cartilage with mild irregularities at the interface between graft and native tissue. Slight surface contour irregularities were noted at both donor and graft sites, but with negligible clinical sequelae. Outerbridge et al in 1995 described the transfer of an osteochondral graft from the lateral facet of the patella to repair a large osteochondral defect in the ipsilateral femoral condyle in 10 patients. A manual press-fit technique was used for graft fixation [17]. Preoperative and postoperative function was assessed using the Cincinnati Knee Score; an average improvement from 43 points (range, 24 to 64) to 93 points (range, 79 to 100) was reported. All patients were satisfied with the procedure, and 70% were able to resume full, unrestricted activity. Second-look arthroscopy revealed solid graft fixation and intact surface hyaline cartilage.

Numerous treatment algorithms have been proposed for the management of articular cartilage lesions. Smaller lesions (<10 mm) are typically managed with simple débridement, citing the limited increase in biomechanical loading and rim stresses around the edges of the defect [18,19,20]. However, more recent studies have raised concerns about the durability of fibrous/ fibrocartilaginous repair tissue [21,22]. Larger lesions (surface area >200 mm^2) and those with defects extending into subchondral bone represent a more complex scenario [15]. However in our study we have used osteochondral bone plugs for osteochondral defects where subchondral bone was exposed even for lesions of size less than 10mm.

Fixation of a loose osteochondral fragment with a bone peg or with tissue adhesive was studied along with comparison of fresh-frozen allografts versus autogenous grafts harvested from the lateral femoral condyle [23]. The authors concluded that precise reconstruction of the articular surface was essential because failures were seen in cases where restoration of joint surface congruity was inadequate.The osteochondral plugs harvested are slightly larger than the defect allowing a press fit implant that will stay in place without the need for additional fixation [10,14]. Ivănescu A et all (Between January 2009 and June 2010) performed 55 transchondral drillings and 10 mosaicplasties on patients with articular cartilage defects of the knee. All patients were followed up at 6 months. Hughston clinical and radiological scales were used to evaluate the patients in the transchondral drilling group. Results: The Hughston Clinic score was 2 in 2 cases (3.6%), 3 in 5 cases (9.9%) and 4 in 48 cases (86.5%), giving over 95% of good results. The Hughston radiological score was 2 in one case (2%), 3 in 4 cases (7.3%) and 4 in 50 cases (90.7%). In another study by the author in 2010 evaluated if mosaicplasty is effective in returning elite athletes to participation in sports.The results of mosaicplasty were prospectively evaluated at 6 weeks,3 months, 6 months, and yearly in 354 patients. Good to excellent results were found in 91% of femoral mosaicplasties, 86% of tibial, and 74% of patellofemoral; 92% of talar mosaicplasties had similar results. The investigators concluded that despite a higher rate of preoperative osteoarthritic changes in the athletic patients, clinical outcomes of mosaicplasty in this group

Table: Comparison of various recent studies with our study carried out at our centre

Authors	Number	Age, Yr	Follow-up	Scoring System	Subjective
Braun Arthritis Res Ther 2008	33 (23M, 10F)	15-59 (34.3)	46-98 mo (66.4)	Lysholm 12-79 (49) >40-100 (86)	27/33 return to sports 31/33 satisfied, would redo
Duany Arch Orthop Trauma Surg 2009	9 (5M, 4F)	18-74 (43.4)	11-120 mo (42.1)	KSS 39-75 (57.9) >43-100 (80.2)	88.9% survivorship (1 conversion to TKA)
Hangody Injury 2008	967			HSS, Cincinnati, Lysholm, ICRS	Femoral 92% excellent/good, tibial 87% excellent/good, troch/patella 74% excellent/good
Marcacci AJSM 2007	30 (22M, 8F)	17-46 (29.3)	7 yr	IKDC 7A, 16B, 4C, 3D at 7 yr; 11A, 12B, 4C, 3D at 2 yr; IKDC subjective 34.8 >71.7	2 yr: 22 return to sports same level, 4 return to sports lower level; 7 yr: 7 same level, 14 lower level
Tetta Eur J Radiol 2009	24 (17M, 7F)	29.9 ± 8.7	96-125 mo (113)	IKDC 31 >82; CSE/ICRS 15C, 9D >7A, 12B, 4C, 1D; Tegner 3 >6	25% return to sports at same preinjury level, 54.2% lower level, 20.8% no sports
Our study	24 (20M,4F)	30.5 (21-46)	06-24 Mo	Tegner and Lysholm scoring scale	91.66% patients had excellent results, 8.33% patients fair results.

demonstrated a success rate similar to that of less athletic patients.

The table given below gives a comparison of various recent studies with the study carried out at our centre with equivocal results.

Conclusion

To conclude the advantage of osteochondral grafting is the implantation of hyaline cartilage without the need for sutures or adhesive, while the disadvantage is the lack of lateral integration with the surrounding cartilage. This technique can be used for both small and medium sized lesions. The donor plugs can also be of variable size to allow for complete fill of the injured defect. The space between the hyaline graft plugs is filled with fibrocartilage and the donor holes are filled with cancellous bone that incorporates quickly which is then also covered by fibrocartilage [24]. It has been shown that mosaicplasty results in good to excellent clinical outcome scores in 92 % of patients depending on the location and size of the implanted tissue. Although a promising surgical procedure, there is potential for donor-site morbidity (even though the grafts are taken from the non-weight bearing part of the knee)[25]. Further limitations include difficulty in matching the contour of the host cartilage and marginal cell death that can precipitate graft degeneration and failure [26].

Osteochondral grafting is a one stage procedure which can be done with ease and has promising results.

Conflict of interest: All authors declare no COI

Ethics: There is no ethical violation as it is based on voluntary anonymous interviews

Funding: No external funding

Guarantor: Prof. Ravindra Chauhan will act as guarantor of this article on behalf of all co-authors.

References

1. Furman BD, Olson SA, Guilak F: The development of posttraumatic arthritis after articular fracture. *J Orthop Trauma.*20:719-725 2006
2. Sui Y, Lee JH, DiMicco MA, et al.: Mechanical injury potentiates proteoglycan catabolism induced by interleukin-6 with soluble

interleukin-6 receptor and tumor necrosis factor alpha in immature bovine and adult human articular cartilage. *Arthritis Rheum.*

3. Szczodry M, Coyle CH, Kramer SJ, et al.: Progressive chondrocyte death after impact injury indicates a need for chondroprotective therapy. *Am J Sports Med.* 37:2318-2322 2009
4. Magnussen RA, Dunn WR, Carey JL, Spindler KP: Treatment of focal articular cartilage defects in the knee. *Clin Orthop Relat Res.* 466:952-962 2008
5. Sharma B, Williams CG, Kim TK, et al.: Designing zonal organization into tissue-engineered cartilage. *Tissue Eng.*13:405-414 2007
6. Tan H, Chu CR, Payne KA, Marra KG: Injectable in situ forming biodegradable chitosan-hyaluronic acid based hydrogels for cartilage tissue engineering. *Biomaterials.* 30:2499-2506 2009
7. Buckwalter JA, Mankin HJ, Grodzinsky AJ: Articular cartilageand osteoarthritis. *Instr Course Lect.* 54:465-480 2005
8. Carter DR, Beaupre GS, Wong M, et al.: The mechanobiology of articular cartilage development and degeneration. *Clin Orthop Relat Res.*
9. Wong M, Carter DR: Articular cartilage functional histomorphology and mechanobiology: a research perspective.*Bone.* 33:1-13 2003
10. Guilak F, Alexopoulos LG, Upton ML, et al.: The pericellular matrix as a transducer of biomechanical and biochemical signals in articular cartilage. *Ann N Y Acad Sci.* 1068:498-512 2006
11. Lin Z, Willers C, Xu J, Zheng MH: The chondrocyte: biology and clinical application. *Tissue Eng.* 12:1971-1984 2006
12. Widuchowski W, Widuchowski J, Trzaska T: Articular cartilagedefects: study of 25,124 knee arthroscopies. *Knee.* 14:177-1822007
13. Hangody L, R´athonyi GK, Duska Z, V´as´arhelyi G, F¨ules P, M´odis L. Autologous osteochondral mosaicplasty.Surgical technique. J Bone Joint Surg Am.2004; 86 Suppl 1:65-72.
14. Hangody L, V´as´arhelyi G, Hangody LR, S¨uk¨osd Z,Tibay G, Bartha L, Bod´o G. Autologous osteochondral grafting technique and long-term results. Injury.2008; 39(Suppl 1):S32-9.
15. Mithoefer K, McAdams T, Williams RJ, et al.: Clinical efficacy of the microfracture technique for articular cartilage repair in the knee: an evidence-based systematic analysis. *Am J Sports Med.*37:2053-2063 2009
16. Yamashita F, Sakakida K, Suzu F, Takai S: The transplantation of an autogeneic osteochondral fragment for osteochondritis dissecans of the knee. *Clin Orthop Relat Res.* 201:43-50 1985
17. Outerbridge HK, Outerbridge AR, Outerbridge RE: The use of a lateral patellar autologous graft for the repair of a large osteochondral defect in the knee. *J Bone Joint Surg Am.* 77:65-72 1995
18. Cole BJ, Pascual-Garrido C, Grumet RC: Surgical management of articular cartilage defects in the knee. *J Bone Joint Surg Am.*91:1778-1790 2009
19. Redman SN, Oldfield SF, Archer CW: Current strategies for articular cartilage repair. *Eur Cell Mater.* 9:23-32 2005discussion 23–32
20. Simon TM, Jackson DW: Articular cartilage: injury pathways and treatment options. *Sports Med Arthrosc.* 14:146-154 2006
21. Mithoefer K, Williams RJ 3rd, Warren RF, et al.: The microfracture technique for the treatment of articular cartilage lesions in the knee: a prospective cohort study. *J Bone Joint Surg Am.* 87:1911-1920 2005
22. Steadman JR, Briggs KK, Rodrigo JJ, et al.: Outcomes of microfracture for traumatic chondral defects of the knee: average 11-year follow-up. *Arthroscopy.* 19:477-484 2003
23. Lindholm TS, Osterman K, Kinnunen P, et al.: Reconstruction of the joint surface using osteochondral fragments: an experimental and clinical study. *Scand J Rheumatol Suppl.* 44:5-46 1982
24. Hill, C.L. Knee effusions, popliteal cysts, and synovial thickening: association with knee pain in osteoarthritis. J Rheumatol, 2001.
25. Alford, J.W. and B.J. Cole. Cartilage restoration, part 1: basic science, historical perspective, patient evaluation, and treatment options. The American journal of sports medicine, 2005.
26. Pearle, A.D., R.F. Warren, and S.A. Rodeo, Basic science of articular cartilage and osteoarthritis. Clinics in sports medicine, 2005.