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SURGICAL MANAGEMENT OF CHONDRAL DEFECTS OF THE PATELLOFEMORAL JOINT: A NARRATIVE REVIEW

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ABSTRACT – The patellofemoral (PF) joint is vital for knee movement and weight distribution. It is prone to chondral or osteochondral defects, causing pain, swelling, and mobility issues. These defects are common, especially in athletes, with a 36% prevalence of full-thickness cartilage lesions in the PF joint, more often in the patella than the trochlea. Causes include trauma, PF instability, repetitive microtrauma, chronic overload, and osteochondritis dissecans (OCD). Treatment depends on patient-specific, lesion-specific, and joint-specific factors. Surgical options aim to repair or restore damaged cartilage and bone, with the choice of procedure based on the defect's size, location, patient age, activity level, and overall health. This narrative review aims to assess current surgical techniques and establish a therapeutic algorithm. A comprehensive review of 27 studies focusing on six distinct surgical techniques was conducted. We analyzed various surgical techniques for treating patellar chondral defects. Techniques like osteochondral autograft transplantation (OAT), autologous chondrocyte implantation (ACI), and matrix-induced autologous chondrocyte implantation (MACI) were compared. The results indicated that microfracture (MFx) exhibited higher failure rates than ACI and OAT. Cartilage repair techniques generally provided better tissue repair, lower failure rates, and higher return-to-activity rates. The choice of technique depends on factors like defect size and patient characteristics. No definitive optimal surgical approach was identified due to variability in reported data.

Based on the reviewed studies, OAT was mainly used for smaller chondral lesions (< 2 cm^2) with minimal complications and satisfactory outcomes. Advanced microfractures (aMFx)/autologous matrix-induced chondrogenesis (AMIC) techniques were effective for larger lesions (> 2 cm^2) with low complication rates and good outcomes. Scaffold-based ACI showed better improvement and fewer complications compared to earlier ACI versions. More studies are needed to compare osteochondral allograft (OCA) and scaffold-based ACI for larger defects, while particulated juvenile allograft cartilage (PJAC) and synthetic scaffolds require further investigation.

KEYWORDS: Patella, Defects, AMIC, PJAC, ACI, AOT, OCA, Grafts, Narrative review, Chondral defects.

INTRODUCTION

The patellofemoral (PF) joint is a crucial component of the knee. It facilitates smooth movement and weight distribution during activities such as walking, running, and jumping.

The quadriceps mechanism is an important contributor to dynamic patellofemoral joint stability. The convergence of 4 muscles forms the rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius. The tendon results from a confluence of these individual muscle tendons 5 cm to 8 cm superior to the patella and inserts on the proximal pole of the patella[1]. Functioning as a lever, the patella acts to magnify force or displacement depending on the activity and helps to increase the moment arm of the quadriceps. This decreases the amount of quadriceps force necessary to extend the knee[2]. However, it is susceptible to injury and damage, particularly in the form of chondral or osteochondral focal defects. These defects can significantly impact an individual's quality of life, leading to pain, swelling, and limitations in mobility[3].

Chondral/osteochondral lesions of the patellofemoral joint are common and often challenging problems. Chondral defects are seen in 34-62% of knee arthroscopies, while full-thickness focal lesions with an area of at least 1-2 cm^2 are seen in 4.2-6.2% of all arthroscopies in patients younger than 40 years old. The patellofemoral joint is the most prevalent site of these defects, with the patella more commonly involved than the trochlea (64 *vs.* 36%)[4].

The etiology of symptomatic chondral/osteochondral pathology is complex and multifactorial. These defects could occur due to traumatic impaction, PF instability events, repetitive microtrauma and chronic overload in the setting of malalignment or obesity, and osteochondritis dissecans (OCD) lesions[4]. To select an appropriate non-operative or operative treatment strategy, the surgeon must comprehensively understand all patient-specific, lesion-specific, and joint/limb-specific variables[5].

PF cartilage lesions encompass a spectrum of conditions ranging from minor cartilage injuries to more severe lesions involving both cartilage and bone.

The surgical management of osteochondral defects of the patella typically involves techniques aimed at repairing or restoring the damaged cartilage and underlying bone[6]. The choice of surgical procedure depends on various factors, including the size and location of the defect, the patient's age, activity level, and overall health[7].

This narrative review aims to evaluate the state of the art in surgical techniques for establishing a therapeutic algorithm.

SURGICAL TECHNIQUES

Autologous Matrix-Induced Chondrogenesis (AMIC)

AMIC uses bone marrow stimulation techniques to perforate the subchondral bone. Then, to protect the blood clot, the treated site is covered with a bilayer collagen I/III membrane. The membrane is fixed with fibrine sealant or sutures.

Six studies[8-13] evaluated advanced autologous matrix-induced chondrogenesis (AMIC). In the studies proposed by Sadlik et al[9], Gille et al[10], and Waltenspül et al[11] at the final follow-up, patients with intact AMIC grafts demonstrated improvements in various clinical scores [Knee injury and Osteoarthritis Outcome Score (KOOS) was the only score that was common among these]. In the study by Waltenspül et al[11], patients underwent corrective surgery for patellar instability, and the mean clinical follow-up duration was 4.1 ± 1.9 years. Approximately 35.5% of knees were reoperated, mainly for screw removal after associated tibial tubercle osteotomy (TTO). The mean lesion size evaluated in these studies[8-13] was 3 ± 2.1 cm. Moreover, the study by Migliorini et al[14] aimed to compare microfracture (MFx) with AMIC. It had a mean follow-up length of 45.1 months. The aMFx group had only a shorter hospitalization length. At the last follow-up, the AMIC cohort showed significantly greater improvement in International Knee Documentation Committee (IKDC), Lysholm, and Tegner scores compared to the MFx group. The visual analog scale (VAS) for pain was lower in the AMIC group. There were no complications at the mean follow-up. The AMIC group also had a lower failure rate, although there was no significant difference in the rates of revision or arthroplasty between the two cohorts. The use of AMIC in the treatment of patellar chondral defects is highlighted as a technique that shows significant improvement in clinical and functional outcomes, particularly for lesions larger than two cm^2. Studies, including those by Schiavone Panni et al[15] and Bertho et al[16], support

the effectiveness of AMIC in these cases. However, these results indicate that despite these positive outcomes, there is still a lack of standardized failure measures across different studies, making it difficult to compare AMIC directly with other techniques like osteochondral allografts (OCA), autologous chondrocyte implantation (ACI)/matrix-induced autologous chondrocyte implantation (MACI), and osteochondral autograft transplantation (OAT). While AMIC demonstrates promise, particularly for larger lesions, further high-level studies are needed to fully understand its place among other cartilage repair techniques.

Autologous Chondrocyte Implantation (ACI)

ACI is a two-stage procedure in which chondrocytes are harvested from the knee. They are then processed enzymatically, cultured, and finally reintroduced at the site of the defect. The chondrocytes are contained within the defect by using a collagen membrane patch.

Teo et al[17] did not report information on lesion size, while the lesions of other studies[18-22] ranged from 2.1 to 6.8 cm^2. In all the studies[17-22] where ACI was evaluated, the clinical scores increased with improvements evident as early as 6- months follow-up after the surgery. In two studies proposed by Gillogly and Arnold[18] and Mehl et al[19], patients underwent corrective surgery for patellar instability, and the failure rate was described. Mehl et al[19] examined seventy-eight patients. Survival analysis revealed that one patient underwent repeated ACI at the patella, while five patients underwent total knee arthroplasty (TKA), resulting in a 7.8% failure rate after a mean follow-up of 6.5 years, with a five-year ACI survival rate of 98%[19]. Gillogly et al[18] examined 23 patients. However, 40% of knees underwent subsequent surgical procedures, primarily arthroscopic debridement for graft hypertrophy and hardware removal. One clinical failure was observed, with the patient undergoing patellofemoral arthroplasty 5.9 years postoperatively. These data highlight the use of ACI and its variations, such as MACI, for treating patellar chondral defects. ACI/MACI is recognized for its long-term symptom relief and ability to restore activity levels, especially in larger chondral lesions. Despite these benefits, the technique is associated with higher complication and reoperation rates, particularly with first-generation ACI compared to third-generation MACI. Failures in ACI/MACI include graft failure, arthroplasty, graft hypertrophy, and arthrofibrosis. The ACI/MACI technique is suitable for large chondral defects, but its high cost, the requirement for multiple surgeries, and the potential complications highlight the need for further studies to determine its superiority over other techniques, like osteochondral allografts. In summary, ACI/MACI is still a complex and costly choice, necessitating thorough evaluation of each patient and their specific defect features.

Osteochondral Allograft (OCA)

In the OCA technique, an osteochondral plug is harvested from a femoral condylar allograft, and the graft is impacted into the osteochondral lesion to achieve press-fit fixation.

OCA was reported in 3 studies[23-25]. Significant improvements were demonstrated by IKDC scores in all of the studies at the latest follow-up. The lesions ranged from 2.2 to 18.1 cm^2. The results of the survival rate of the allograft were different in the studies. Mirzayan et al[23] reported only two postoperative complications: one patient with Ehler-Danlos syndrome developed severe stiffness that necessitated arthroscopic lysis of adhesions and the other had incomplete incorporation of the donor patella at the proximal patellar screw, which was also removed to resolve his symptoms. Conversely, Lin et al[24] found a survivorship rate of 55.8% over 15 years, while Gracitelli et al[25] observed OCA failures in 8 knees (28.6%) with a mean follow-up period of 9.7 ± 7.5 years for these cases.

OCA is noted for its consistent outcomes, including long-term symptom relief and restored activity levels, particularly for larger lesions. The technique is preferred for lesions larger than 4 cm^2, as highlighted in the reviews by Chahla et al[26] and Ginesin et al[27]. However, OCA has a notable failure rate, with Gracitelli et al[25] reporting a 28.6% failure rate, including cases requiring revision, patellectomy, or conversion to arthroplasty. Despite its effectiveness for large lesions, OCA is considered a costly procedure requiring extensive long-term planning and multiple surgeries. Concerns regarding OCA include the higher complication and reoperation rates compared to other techniques, such as ACI/MACI. The review highlights the need for further comparison studies to determine the superior technique between OCA and MACI.

Particulated Juvenile Allograft Cartilage (PJAC)

The PJAC technique is used to remove the damaged cartilage without violating the subchondral bone. Then, juvenile cartilage is placed on the fibrin glue at the base of the defect without filling the complete depth of the defect. Fibrin glue fills the remaining depth of the defect to fully embed the cartilage tissue. PJAC for cartilage restoration of patellar defects was examined in four studies[7,28-30]. Tompkins et al[28] revealed general positive results across various subdomains of the KOOS, IKDC, and Tegner score, while in the study by Wang et al[30], significant improvements were observed in mean IKDC and Knee Outcome Survey-Activities of Daily Living (KOS-ADL) scores. The mean lesion size was reported just by Wang et al[30] and ranged from 2.14 ± 1.23 cm^2. Tompkins et al[28] demonstrated anterior knee pain in seven of thirteen knees at the last follow-up. Two knees required manipulation under anesthesia for arthrofibrosis. Additionally, three patients required reoperation for symptomatic grafts, two for graft hypertrophy, and one for debridement of a partially filled defect. In the study proposed by Wang et al[30], there were no complications after the surgery at the last follow-up (mean follow-up of 3.84 years). Pearsall et al[7] present promising clinical outcomes for partially juvenile articular cartilage (PJAC) allograft transplantation in treating articular cartilage defects in the patellofemoral joint, highlighting favorable patient-reported outcomes (PROs) and a 100% return-to-sport rate. However, the author also notes a significant 14.6% reoperation rate and frequent complications, with anterior knee pain being the most common issue, typically managed through nonoperative treatments like viscosupplementation. The study proposed by Marmor et al[29] highlights PJAC as a promising technique for treating patellar cartilage defects, demonstrating significant improvements in knee function and quality of life. However, the lack of a clear association between magnetic resonance imaging (MRI) results and patient-reported outcomes suggests that other factors, such as additional surgical procedures, play a crucial role in the observed clinical improvements. Further research is needed to refine the understanding of PJAC's effectiveness and its place among other cartilage restoration techniques. PJAC is noted for its single-stage, off-the-shelf nature, which eliminates the need for donor-site morbidity. Despite these advantages, PJAC demonstrated a high complication rate that might outweigh its benefits. Then, PJAC offers a convenient and less invasive option compared to other techniques, but its high complication rates present significant concerns. This highlights the need for further research and evaluation before PJAC can be routinely applied in treating patellar cartilage lesions.

SYNTHETIC SCAFFOLDS

Two studies[30,31] reviewed synthetic scaffolds. The mean lesion sizes ranged from 2.1 to 2.64 cm^2. The study performed by Perdisa et al[32] reported significant improvements in various clinical scores (IKDC, Tegner) from preoperative levels to the 24-month follow-up. Joshi et al[31] evaluated 10 patients with patellar synthetic resorbable scaffold with a minimum follow-up of 24 months. At the 12-month follow-up, 8 out of 10 patients showed improvement in clinical outcome scores. Subsequent monitoring at 18 and 24 months revealed worsening SF-36 and KOOS scores. At the last follow-up, 7 patients required reoperation. Two underwent implanted patellar arthroplasty, while the remaining 5 underwent implant removal followed by bone filling of the defect, marrow stimulation, and fibrin coat application. These two studies[31,32] reported conflicting results for synthetic grafts. This inconsistency underscores the need for further research to clarify their effectiveness and reliability before they can be routinely used in treating patellar cartilage lesions.

Osteochondral Autograft Transplantation (OAT)

To perform the OAT technique, osteochondral plugs are extracted from a non-weight-bearing region of the trochlea, processed, and inserted into the defect area. These steps are repeated until the lesion is filled as completely as possible. OAT is reviewed in 7 studies[33-39], 6 of which represented the mean size lesion, which ranged from 1 to 4 cm^2, in the other one[37] was not described. In all of the studies, significant improvements were observed after the surgery (Lysholm and IKDC scores were the most used). There were no reported complications in 4 studies[34,35,37,38] out of 7. Astur et al[33] reported three cases of arthrofibrosis in 33 patients, while Figueroa et al[34] reported two cases of arthrofibrosis in 38 patients.

OAT consistently demonstrated more excellent or good results at over 3-year follow-up when compared to microfracture (MF), with significantly fewer documented failures[40]. Unlike other methods, OAT had no reported failures, although two cases of arthrofibrosis were noted in one study[34]. Despite its benefits, concerns about donor site morbidity arise when OAT is applied to larger lesions. Overall, OAT is seen as a cost-effective approach with enhanced postoperative outcomes for smaller chondral defects, though its use in larger lesions remains debated. Further studies are needed to solidify its standing compared to other techniques like osteochondral allograft (OCA) and autologous chondrocyte implantation (ACI/MACI).

DISCUSSION

A comprehensive review of 27 studies[7,9-12,14,17-25,28-39] focusing on six distinct surgical techniques was conducted (Table 1). While there was no standardized outcome measure, the IKDC score was the most fre-

Table 1. Summary of the studies analyzed.

Study	Year	Procedure	Age	Patients (M/F)	Clinical score	Complications
Teo et al[17]	2013	ACI	16.8	23 (19/4)	IKDC, Lysholm	Periosteal hypertrophy
Gillogly and Arnold[18]	2014	ACI	31 ± 7	23 (11/12)	CKRS, IKDC, Lysholm, SF-36	Graft hypertrophy (8)
von Keudell et al[20]	2017	ACI	32 ± 10	30 (12/18)	N/A	Failed graft (3), arthroplasy, graft hypertrophy (7), chondroplasty (5), arthrofibrosis (4)
Mehl et al[19]	2019	ACI	33 ± 11	78 (46/32)	Kujala, IKDC	Revision ACI, TKA
Niemeyer et al[21]	2019	ACI	33.4	45 (29/16)	KOOS	N/A
Niemeyer et al[22]	2019	ACI	34	75 (22/53)	N/A	N/A
Sadlik et al[9]	2015	AMIC	N/A	12 (7/5)	KOOS, IKDC, VAS	N/A
Gille et al[10]	2023	AMIC	36.1 ± 15.4	64 (32/32)	KOOS, Lysholm	N/A
Waltenspül et al[11]	2021	AMIC	27.9	32 (12/21)	KOOS	4 failed, 1 partial AMIC membrane dissection, 1 anterior knee pain, 1 Instability and MPFL reconstruction
Tradati et al[12]	2020	AMIC	< 50	14 (9/5)	IKDC, Tegner, Kujala, VAS	N/A
Migliorini et al[14]	2021	AMIC	34.5	38	IKDC, VAS, Tegner, KOOS	Failed graft (5)
Cohen et al[38]	2012	AOT	< 60	17	Lysholm, Kujala	N/A
Astur et al[33]	2014	AOT	33	N/A	N/A	Arthrofibrosis (3)
Astur et al[39]	2016	AOT	N/A	20 (9/11)	Lysholm, Fulkerson, Kujala	Thigh hypotrophy (11)
Chadli et al[37]	2016	AOT	15	7	IKDC, Lysholm	N/A
Yonetani et al[36]	2019	AOT	38	6	Lysholm	Arthrofibrosis (2)
Akgün and Akpolat[35]	2019	AOT	29.7	14 (8/6)	Lysholm, Kujala	N/A
Figueroa et al[34]	2020	AOT	28.5	26	Kujala, WOMAC	N/A

Continued

Table 1 *(Continued)*. Summary of the studies analyzed.

Study	Year	Procedure	Age	Patients (M/F)	Clinical score	Complications
Gracitelli et al[25]	2015	OCA	33.7	27 (14/13)	IKDC	Loose body removal, failed transplant, 1 revision 1 patellectomy
Mirzayan et al[23]	2020	OCA	28.9	17	KOOS, IKDC, Tegner, Lysholm, CKRS, VAS	N/A
Lin et al[24]	2020	OCA	38.8 ± 10.9	49 (22/27)	IKDC, KOOS, VAS	N/A
Tompkins et al[28]	2013	PJAC	26.4	13	IKDC, KOOS, Tegner	Arthrofibrosis, gross graft hypertrophy, mild graft hypertrophy,
Wang et al[30]	2019	PJAC	27.9	27 (18/9)	IKDC, KOS-ADL	N/A
Pearsall et al[7]	2024	PJAC	23.4 ± 9.7	41 (21/20)	PROMIS, Kujala	Anterior knee pain (12), arthrofibrosis (1), trochleoplasty (1)
Marmor et al[29]	2024	PJAC	26.6 ± 8.1	65	KOOS, IKDC, Kujala	Graft failure (2), synovial reaction (14), subchondral edema (12)
Joshi et al[31]	2012	Synthetic graft	33.3	10	KOOS, SF-36	Pain, TKA, removal graft (5)
Perdisa et al[32]	2017	Synthetic graft	30	34 (18/16)	IKDC, Tegner	Realignment

International Knee Documentation Committee: IKDC, Knee Injury and Osteoarthritis Outcome score: KOOS, Cincinnati Knee Rating system: CKRS, Short Form Health Survey 36: SF-36, Visual Analogue scale: VAS, Western Ontario and McMaster University score: WOMAC, Knee Outcome Survey Activities of Daily Living: KOS-ADL, Patient-Reported Outcomes Measurement Information system: PROMIS, autologous matrix-induced chondrogenesis: AMIC, autologous chondrocyte implantation: ACI, osteochondral allograft: OCA, particulated juvenile allograft cartilage: PJAC, osteochondral autograft transplantation: OAT, total knee arthroplasty: TKA, medial patello-femoral ligaments: MPFL, not applicable: N/A.

quently employed (14 studies[9,12,14,17-19,23-25,28-30,32,37]). Moreover, there was much variability in concomitant procedures (MPFL reconstruction, TTO, and lateral release were the most commonly used) and lesion size, which posed challenges when comparing the surgical approaches. OAT, ACI, and AMIC emerged as the most extensively studied procedures for isolated patellar chondral defects. Other techniques, including OCA, PJAC, and synthetic grafts, were less frequently examined.

Only three studies[40-42] specifically focused on addressing patellar cartilage issues. The reviews conducted by Noyes and Barber-Westin[41] and Mouzopoulos et al[42] discussed a variety of techniques, including non-restorative procedures such as arthroplasty, periosteal transplantation, and isolated tibial tubercle osteotomies. Only in the review by Ginesin et al[27], methods like osteochondral allografts and emerging techniques such as PJAC and synthetic grafts were included in their discussion.

It is important to underline the existence of different laws between each country on chondral management. Consequently, while various surgical techniques are available, selecting a specific method is not solely based on scientific data. This review explores modern techniques aimed at restoring cartilage in isolated patellar chondral defects. The effectiveness of these procedures can be impacted by various factors, including the location and size of the defect, treatment cost, patient adherence, associated health conditions, and whether the defect is contained within the cartilage or extends beyond it. However, none of the studies analyzed in this review provided a comprehensive assessment

considering all these variables. Consequently, the success and feasibility of the evaluated techniques were influenced by multiple factors. Given the significant variability and inconsistency in the reported data, reaching a definitive conclusion about the optimal surgical approach for patellar chondral defects is challenging. Each surgical technique analyzed in this review is summarized in Table 2, with indications and contraindications for each.

CONCLUSIONS

Based on the studies reviewed, OAT was predominantly used for smaller chondral lesions (< 2 cm^2) and showed minimal complication rates with satisfactory outcome scores, while aMFx//AMIC techniques were used for chondral lesions > 2 cm^2 and demonstrated low complication rates alongside satisfactory outcome scores. Scaffold-based ACI consistently demonstrated greater mean improvement in measured outcome scores and fewer complications compared to previous generations of ACI. Further prospective studies are needed to compare OCA and scaffold-based ACI for larger patellar defects to determine a better technique. Additionally, PJAC and synthetic scaffolds require more investigation to assess their clinical utility.

Table 2. Summary of the surgical technique indications and contraindications.

Surgical Techniques	Indications	Contraindications
Autologous Matrix-Induced Chondrogenesis (AMIC)	Chondral lesions > 2 cm^2	• Advanced arthritis; • Elderly patients; • Chondral lesions > 4 cm^2
Particulated Juvenile Allograft Cartilage (PJAC)	Chondral lesions < 4 cm^2	• Multiple joint defects; • Joint instability; • Few studies to support this technique
Autologous Chondrocyte Implantation (ACI)	Chondral lesions > 2 cm^2	• Advanced arthritis; • Patients with coagulation diseases; • Patients with poor compliance; • Very expensive technique.
Osteochondral Autograft Transplantation (OAT)	Chondral lesions < 2 cm^2	• Lesions > 4 cm^2; • Advanced joint deformities; • Severe arthritis
Osteochondral Allograft (OCA)	Chondral lesions > 4 cm^2	• Elderly patients; • Multiple joints defects; • International laws.
Synthetic graft	Chondral lesions < 4 cm^2	• Advanced arthritis; • Chondral lesions > 4 cm^2; • Few studies support this technique.

Informed Consent:

Not applicable.

Ethics Approval:

Ethics approval was not required due to the nature of the study.

Conflict of Interest:

The authors declare that they have no conflict of interest.

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F. Familiari, P. Ferrua, G. Fedele, and G. Carlisi conceptualized the study, formulated and conducted the electronic search, reviewed the studies, and were involved in data analysis and final manuscript preparation and editing. R. Russo participated in the formulation and conduction of electronic search, review of studies, data analysis and editing of the manuscript. P.S. Randelli and G. Gasparini were involved in the conceptualization of the idea, data analysis, final manuscript preparation, and editing. All authors have read and approved the final submitted manuscript.

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