Chapter 6

Chondral Lesion in the Hip Joint and Current Chondral Repair Techniques

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Abstract

This chapter gives a detailed review of the composition, structure and biomechanics of articular cartilage in the joint. W have looked at the most common types of cartilage lesions and at the existing methods of articular cartilage repair techniques in the hip joint. Articular cartilage is specialized hyaline cartilage which makes a firm, smooth and slippery surface that resists plastic deformation. It has a unique structure and mechanical properties that provide joints with a surface that combines low friction, shock absorption and wear resistance, while bearing large repetitive loads throughout an individual's lifetime. Cartilage lesions in the hip are most common on the acetabular side and typically present as focal area of delamination or chondral flap. Joint preserving techniques are becoming increasingly common. The spectrum of options includes palliative procedures such as joint lavage and chondral debridement, reparative procedures such as microfracture and direct chondral repair, and restorative procedures such as mosaicoplasty. Preservation of the host tissue is most attractive solution to cartilage damage, particularly in young active individuals. Tissue engineering offers one solution but many problems have to be overcome before these techniques become a reality.

Keywords: chondral repair, mosaicoplasty, ACI, MACI, hip joint

1. Introduction

Sports injuries or trauma are a common cause of chondral injuries resulting in joint pain, limitation of function and disability [1]. Articular cartilage is avascular and has very limited capacity for repair [2]. In view of this, chondral lesions that do not penetrate the subchondral bone

(partial thickness) do not heal and usually progress to the degeneration of the articular surface [2]. The most common joint affected with chondral injuries is the knee joint [3]. The knee joint accounts for approximately 75% of all reported chondral lesions [4]. In a bibliometric analysis for the most cited topics of arthroscopic procedures, cartilage repair techniques accounted for 53% of all citations, making this the most cited topic in arthroscopic orthopedic surgery and second most cited topic in orthopedics [5]. Cartilage lesions in the hip joint can be due to either traumatic or atraumatic pathologies, these can be associated with labral tears [6, 7], femoroacetabular impingement (FAI) [8], arthritis [9], osteonecrosis and dysplasia [10]. A direct association between acetabular labral injuries and chondral lesions of the femoral head and acetabulum has been reported by various authors [11, 12]. Hip morphology makes chondral injuries in the hip joint difficult to manage, but with recent advances and increased availability of hip arthroscopy over the past years [13], repair techniques commonly applied to the knee joint are being transferred to the hip [14]. Although, in the current literature there is no evidence, early detection and management of chondral lesion may pre-empt degeneration of the entire joint, making hip preserving techniques particularly useful in young active patients.

2. Describing chondral lesion in the hip joint

The hip joint is roughly spherical in shape, but its orientation does not fit exactly. This makes documentation of intra-articular hip lesion challenging. Traditionally a clock face method has been used to topographically report the focus of damage in the hip joint. Although practical the clock face method becomes confusing during arthroscopy and on changing sides. Ilizaliturri et al. [15] have developed and validated an alternative method which is based on anatomical landmarks easily recognizable during arthroscopy (**Figure 1**).

The geographical zone method divides both the acetabulum and the femoral head into six corresponding zones (Zones 1–6) [15]. The acetabulum is divided by two imaginary vertical lines that follow the anterior and posterior limits of the acetabular fossa, which divide it into three sections. A horizontal line perpendicular to the previous lines is placed at the superior limit of the fossa dividing the acetabulum into a superior and inferior part. As a result the acetabulum

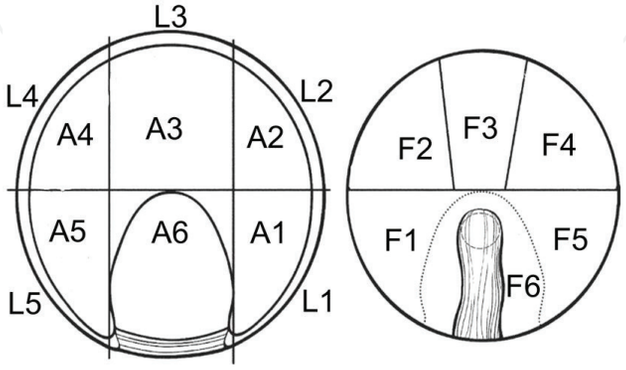

Figure 1. Modified geographical zone mapping system for right acetabulum and right femoral head. Zones A—acetabular zones, Zones L—labral zones, and Zones F—femoral head zones. Adopted from Ilizaliturri et al. [15].

is divided into six zones. Zone 6 corresponds to the fovea on the acetabulum and to the area around the insertion of ligamentum teres on the femoral head. Zone 1 corresponds to the anteroinferior region, Zone 2 to the anterosuperior region, Zone 3 to the central superior region, Zone 4 to the posterosuperior region, Zone 5 to the posteroinferior region on both acetabulum and femoral head while Zone 6 corresponds to the fovea on the acetabulum and the corresponding area around the insertion of ligamentum teres on the femur [15]. This geographical zone method of describing pathology in the hip joint has been used and validated by many authors [6, 16–26].

2.1. Classification for chondral lesions

The spectrum of cartilage damage varies from mild to severe. It is essential to have a reliable classification system for chondral lesion seen during surgery in the hip joint. Most classification for chondral lesions are based on classification used in any other joint [27, 28] but lately new classification are being developed to describe various chondral lesions specific to the hip joint [9, 24]. The most common classification used in the literature is the Outerbridge classification (**Figure 2**) [28] which was described in 1961 and cited 914 times [29] and the second most common classification is the one developed by the International Cartilage Repair Society (ICRS) [27] which was described in 2003 and cited 169 times [29]. **Figure 3** demonstrates the differences between the two classifications.

The Outerbridge classification categorizes chondral injury into four grades from I (slight) to IV (severe) (**Figures 2** and **3**). It is simple and reproducible and new classification systems for the hip joint are based on it [9, 24]. In a Grade I cartilage lesion there is softening or oedema, Grade II there is less than 1.3 cm cartilage fragmentation or tear, Grade III if fragmentation or tear of cartilage is more than 1.3 cm and Grade IV if subchondral bone is visible and breached. New classification systems for the hip joint have taken this further and have described the amount of delamination in the cartilage [9, 24]. For the purpose of this study the Outerbridge classification [28] has been used to describe cartilage injury.

2.2. Type of chondral lesions

Non-arthritic cartilage injuries in the hip refer to focal chondral defects on either the femoral or the acetabular side of the joint. Cartilage lesions in the hip are most common on the

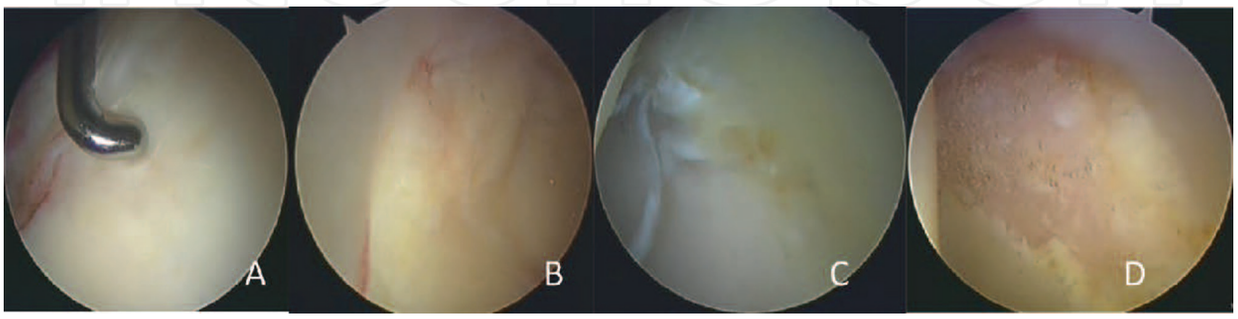

Figure 2. Outerbridge classification during hip arthroscopy. (A)—Grade I, (B)—Grade II, (C)—Grade III, and (D)—Grade IV.

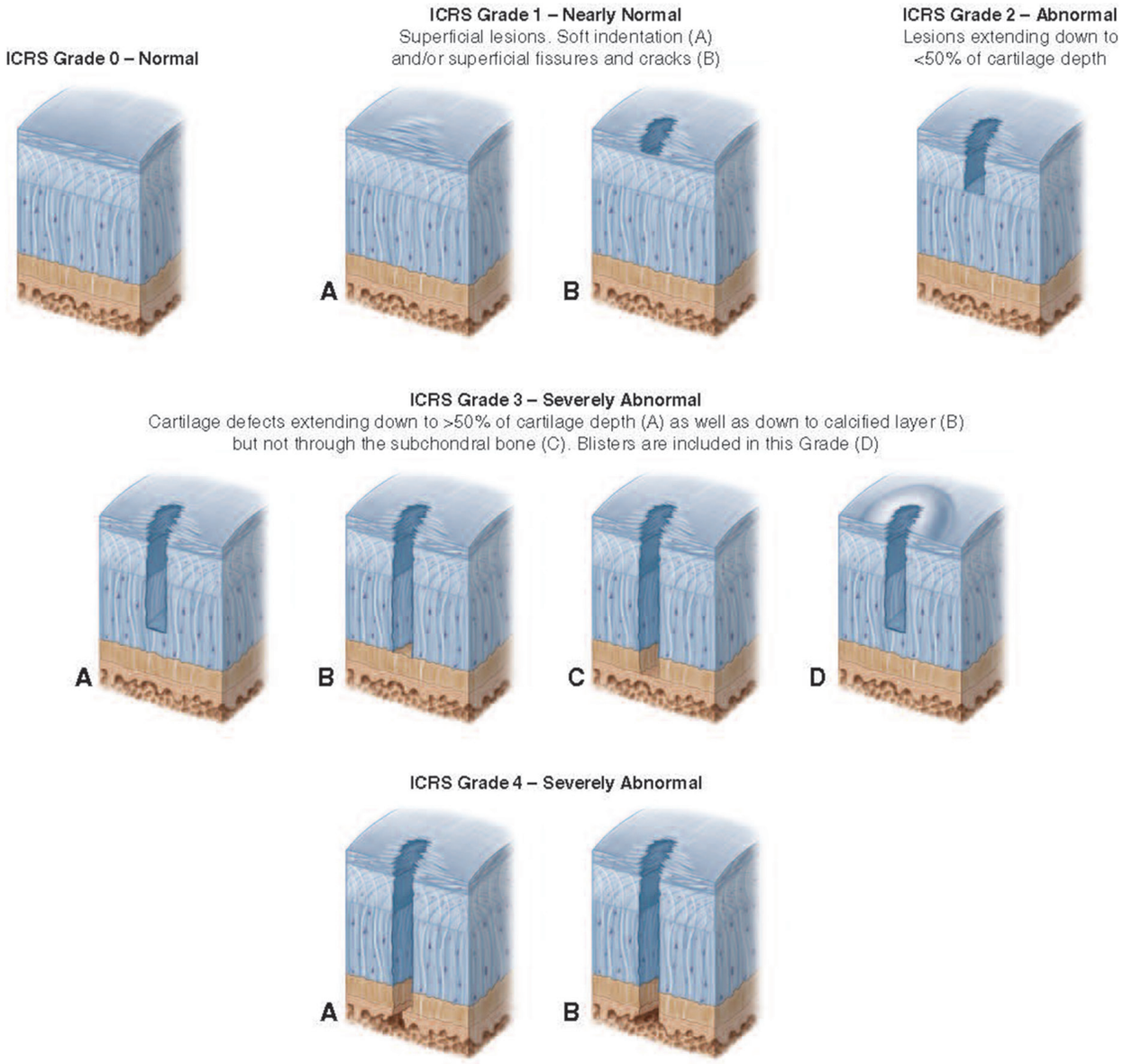

Figure 3. ICRS classification. Adopted from www.cartilage.com.

acetabular side and typically present as focal area of delamination or chondral flap (carpet type lesion). The most common condition resulting in these type of lesions is femoroacetabular impingement (FAI) [30–36]. Most acetabular cartilage lesions are localized to the anterior and anterosuperior region of the acetabulum, present in 59–88% of cases and in the posterior or posterosuperior acetabulum in 25–55% of cases [37]. Lesions on the posterior aspect are commonly related to repetitive posterior loading of the posterior rim of the acetabulum or by axial impact in high energy contact sports [38]. Cartilage lesions on the anterior and anterosuperior aspect are more common in FAI as described by Ganz et al. in both Cam and Pincer type impingement [30–32]. In a series of 273 patients who underwent hip arthroscopy, McCarthy et al. reported that 26% of patient had and Outerbridge IV chondral lesion. They have also reported three distinct patterns Outerbridge IV chondral lesions: (i) isolated

lesions with a chondral flap (62%), (ii) localized full-thickness chondral wear without an associated flap (38%), (iii) global degenerative joint disease with areas of full-thickness cartilage loss (6%) (**Figure 4**) [39]. They have also reported that most Grade IV anterior lesions consisted of a chondral flap in continuity with a tear of the articular margin of the labrum. This region was termed the 'watershed zone' by McCarthy et al. [39].

Cartilage lesions on the femoral head are less common, but typically occur from impact loading across the hip joint [33, 40]. Lesions on the femoral head can present as shear injuries, delamination, chondral flaps, fissuring, fractures and impaction injuries. The type and degree of injury depends on the amount and direction of the impact load [33, 38, 40, 41]. Fissuring of cartilage is reported to occur at 25% strain of articular cartilage specimens and the extent of damage to chondrocytes depends on the quality of the underlying bone [42]. In a recent study by Philippon et al. all patients sustained a labral tear and chondral defect following a traumatic hip dislocation. In 14% of the cases an isolated femoral head lesion was observed. Avascular necrosis (AVN) is another known cause of focal cartilage injury to the femoral head, and is secondary to loss of structural integrity of subchondral bone [42]. A wide spectrum of chondral lesions is associated with AVN from mild delamination to complete collapse.

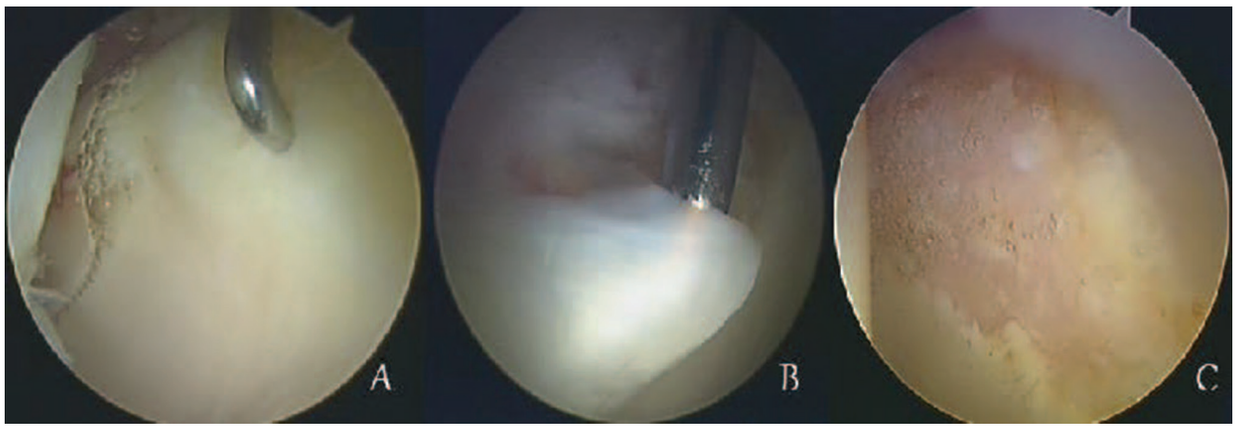

Figure 4. Three different patterns of Grade IV lesions. (A)—Wave sign, (B)—Carpet, and (C)—Global degeneration.

3. Current articular repair techniques

The current goal for surgical intervention is to correct the cause of injury and address the associated chondral pathology. The cause of chondral damage is mostly due to abnormal morphology either the acetabulum or the femoral head and surgery is tailored to the underlying anatomical abnormality. Femoroacetabular impingement is the most common cause of chondral injury in the acetabulum, osteochondroplasty of the femoral neck is one technique used to address this abnormality. Osteochondroplasty only addresses the abnormality on the femoral neck while other techniques are required to repair the associated chondral injury in the acetabulum. Joint-preserving techniques traditionally used in the treatment of cartilage lesions in the knee

joint are becoming increasingly utilized in the hip joint. The experience in the hip is limited at this point, but the spectrum of options includes palliative procedures such as joint lavage and chondral debridement, reparative procedures such as microfracture of subchondral bone and recently combined with direct chondral repair [43–47], and restorative procedures such as mosaicoplasty [48], autologous chondrocyte implantation (ACI) [32, 34, 35, 49–59].

3.1. Arthroscopic lavage and debridement

Arthroscopic washout or lavage has been the primary treatment for chondral lesions for the past 24 years [60]. During arthroscopic lavage, inflammatory mediators, loose cartilage and any cartilaginous debris residing in the joint causing synovial inflammation, effusion and bio-mechanical obstruction is washed out. Jackson has reported symptomatic improvement in 45% of patients at 3.5 years and measurable improvement in 80% of patients after arthroscopic lavage [61] with similar results reported by other authors [62, 63]. Most commonly debridement of chondral debris is carried out with arthroscopic lavage. McLaren et al. reported excellent control of pain in 38% of patients and improved function 22% of cases after arthroscopic debridement and lavage [64], similar results were also reported by Gibson et al. [65]. Sözen et al. have reported improvement in Harris Hip Scores (HHS) in 62% of patients after arthroscopic debridement and lavage in osteoarthritis of the hip joint [66]. Arthroscopic lavage and debridement only addresses the patients' symptoms and slow further degeneration by reducing chondral debris in the joint but it does not facilitate defect repair nor does prevent future defect enlargement. Moseley et al. reported no improvement in symptoms or function when arthroscopic lavage and debridement when compared with placebo arthroscopy [67].

3.2. Bone marrow stimulation

Bone marrow stimulation is the most frequent used technique for treating small symptomatic lesions of the articular cartilage in both knee and hip joint. The most common bone marrow stimulation technique is microfracture. This procedure is straightforward and the costs are low compared with other treatment modalities. Microfracture has become increasingly popular among orthopedic surgeons as preferred treatment for chondral defects [45, 50, 68–72].

When subchondral bone is perforated during microfracture it brings undifferentiated stem cells into the defect from the marrow. A marrow clot is established within the microfractured area [68]. The newly formed clot provides an environment for both pluripotent marrow cells and mesenchymal stem cells to differentiate into stable tissue within the base of the lesion [68]. Histological evaluation indicates that fibrocartilaginous tissue is the final product covering the previous lesion [73]. However the overall concentration of mesenchymal stem cells is quite low and declines with age [74]. Reparative fibrocartilage consists of Type-I, Type-II and Type-III in varying amounts and does not resemble the surrounding hyaline cartilage with less Type-II collagen [75, 76].

Phillippon et al. reported that eight of nine patients had 95–100% coverage of an isolated acetabular chondral lesion or acetabular lesion associated with a femoral head lesion, with Grade I or II appearance of the repair product at an average of 20 months follow-up with only

one patient progressing to generalized osteoarthritis [55]. Although there are no published long term studies on microfracture in the hip join, studies with good long term results exist for microfracture of the knee [71, 72, 77–79]. Lodhia et al. concluded that microfractures in the hip helps patients to achieve favorable outcomes of their hip with similar results to a matched cohort of patients, who may have a chondral lesion that did not warrant microfracture [46]. Even with meticulous surgical technique and proper patient selection, the results of microfracture appear to deteriorate over time [80]. Although microfracture is an easy reproducible technique that is commonly employed as a first line treatment the results are not as good in older patients and tend to deteriorate over time.

3.3. Direct chondral repair

Direct chondral repair refers to techniques in which a full-thickness chondral flap is repaired back to the subchondral bone rather than debrided. The most recent reported direct chondral repairs are techniques using suture repair [47] and fibrin adhesive [43, 44] in combination with microfracture. These techniques are used on the acetabular side of the hip joint.

3.3.1. Suture repair

This technique describe by Sekiya et al. is used to repair, a chondral flap, where microfractures are applied under the chondral flap. An anchor loaded with absorbable sutures is than fixed in the perilabral sulcus, the suture is passed over the labrum and through the chondral flap, back through the labrum to tie it in the perilabral sulcus [47]. This allows initially stability until the chondral flap heals back in place through fibrosis stimulated by the microfractures. This technique has been only reported by Sekiya et al. and at 2 years follow-up, the patient reported to feel 95% normal, with a Harris Hip Score of 93 and Hip Outcome Score Sports subscale of 81. There are no large studies on this technique available to date and further research is warranted.

3.3.2. Fibrin adhesive repair

Fibrin adhesive is a biological compound, which has been used in many fields of surgery. The haemostatic and adhesive properties of fibrin glue are well known to neurosurgeons [81], ophthalmologists [82, 83], otolaryngologists [84], general [85, 86] and orthopedic surgeons [87, 88]. In orthopedics fibrin adhesive can be used to reattach native hyaline cartilage to the underlying subchondral bone to create an anatomical and durable repair [89]. In the hip joint, Tzaveas et al. reported repair of a chondral flap by using a combination of microfracture and fibrin adhesive under the chondral flap. Follow-up of 43 patients for 1–3 years showed significant improvement in modified Harris Hip Scores with this technique [43]. No randomized control studies of this technique with microfracture or any other technique exists and further studies are required.

3.3.3. Cyanoacrylate

Cyanoacrylates are a class of synthetic glues that rapidly solidify upon contact with weak basis, such as water or blood [90]. Compared with other tissue adhesives cyanoacrylates

are easier to use, have quicker polymerization and guarantee higher bonding strength. The use of cyanoacrylate tissue adhesive is well described in the literature for closure of skin wounds [91–93]. Cyanoacrylates is a generic name for a group of tissue adhesives such as ethyl-2-cyanoacrylate, *n*-butyl-2-cyanoacrylate and 2-octyl cyanoacrylate distributed under various names like Histoacryl®, Indermil®, Dermabond® or Glubran®. All cyanoacrylate bond body tissue and show a bacteriostatic effect. In medical practice, *n*-butyl- and octyl-cyanoacrylate are most commonly used. Both biomechanical [94, 95] and cytotoxic [96–98] properties of cyanoacrylate have been tested extensively. *n*-Butyl-2-cyanoacrylate have been approved for internal use including atriovenous embolization [99], endoscopic treatment of bleeding ulcers [100, 101], occlusion of biliary [102] and pancreatic fistulas [103], fixation of polypropylene mesh in open [104, 105] and laparoscopic hernia repair [106]. In orthopedic literature, cyanoacrylate (Dermabond®) has been used for skin closure with excellent result when compared with staples after total joint arthroplasty. A biomechanical study on the use of cyanoacrylate (Histoacryl®) for meniscal repair, reported decrease failure rates when compared to vertical suture repair [95] but no *in vivo* study is yet available. Octyl-cyanoacrylate was used to fix meniscal transplant in a rabbit model, the authors had to sacrifice all animals earlier than planned due to severe inflammatory reaction with caseous necrosis in the operated joint and they have recommended against the use of octyl-cyanoacrylate to fix transplanted menisci [107]. A new cyanoacrylate, 'Glubran 2' (GEM Srl, Viareggio, Italy) is authorized for surgical use and with a CE mark for 'internal use'. Glubran 2 is different to other cyanoacrylates as it has a different chemical composition making it a co-monomer rather than a simple monomer and is composed of *n*-butyl-2-cyanoacrylate and methacryloxysulfolane monomer [104]. The difference in compositions, allows polymerization at lower temperatures and reduced inflammatory reaction when compared to other cyanoacrylates [97, 108]. In recent years a number of clinical studies in general surgery have reported good results when 'Glubran 2' has been used *in vivo* [104–106]. At this stage there is no clinical study evaluating the use of cyanoacrylate intraarticularly.

Biomechanical data published on chondral repair techniques has shown improve resistance to shear forces across the chondral surface when compared to fibrin adhesive repair in cadaveric models [109]. Furthermore we have identified early biomechanical failure in fibrin adhesive repair, which failed at only 50 cycles, while suture of chondral flaps were more biomechanically stable throughout the 1500 cycle testing [109]. The small number of reported outcomes and early laboratory failure may limit fibrin glue clinical use, however, both fibrin glue, suture and cyanoacrylate repair warrant further investigation.

3.4. Whole tissue transplantation

The use of whole tissue chondral transplantation using either an autograft or an allograft is well known in the orthopedics [56, 110–115].

In autologous osteochondral transplantation, occasionally referred as osteoarticular transfer system (OATS), is an effective method for resurfacing osteochondral defects and most commonly used in the knee joint. This technique involves transplantation of multiple cylindrical

osteochondral plugs harvested from a non-weight or less weight bearing areas of the articular surface in the joint and transferred to create a congruent and durable area in the defect. Koh et al. assessed contact pressures on a swine knee model and reported that flush or slightly sunk grafts could restore contact pressures to nearly normal levels, but elevated angled grafts adversely increased contact pressures [116]. However, they used only one plug, which does not correlate with clinical practice. Kock et al. reported reduction in contact pressures after OATS to be 30% less than contact pressures before the procedure with an empty defect in a human cadaveric knee [117]. The outcomes of autologous mosaicoplasty are promising, Hangody and Füles evaluated the largest series of mosaicoplasty performed for localized Outerbridge Grade III or IV lesions and reported good to excellent results for 92% of the femoral lesions, 87% of tibial lesions and 79% of patellofemoral lesions [118]. Ollat et al. reported satisfactory results in 72.5% of the patients at 8 years of follow-up and that the largest defects with the longest follow-up have the worst prognosis [111]. Osteochondral mosaicoplasty of the femoral head has mixed prognosis; Rittmeister et al. reported that four out of five hips had unsatisfactory results after 5 years follow-up and underwent total hip arthroplasty [119], while Girard et al. reported satisfactory improvements in Postel Merle d'Aubingé Score and global range of motion in the hip joint at an average follow-up of 30 months [120]. Nam et al. reported on two cases that underwent OATS combined with osteochondral fragment fixation after traumatic anterior dislocation of the hip joints [121]. They showed good clinical outcomes and graft incorporation using magnetic resonance imaging (MRI) [121]. Emre et al. have reported good, pain free results a 3 years after surgery [122]. Good clinical outcomes were also reported for fragment fixation combined with OATS for the treatment of osteochondral defects after posterior fracture-dislocation of the hip joint [123]. Recently, good results have been reported from arthroscopic OATS procedure in one patients with 2 year follow-up [48, 124]. Arthroscopic OATS procedures for treating osteochondral lesions of the femoral head are promising but more studies with more patients and longer follow-up periods are required to fully understand the benefits of mosaicoplasty in the hip joint.

Osteochondral allograft transplantation is chondral surface reconstruction that involves transplantation of a cadaveric graft consisting of intact, viable articular cartilage and its underlying subchondral bone into the defect. Currently fresh osteochondral allografts are utilized to treat a broad spectrum of articular cartilage pathology, from focal chondral defects to joints with established osteoarthritis in the hip, knee and ankle joint [125–127]. Advantages to the use of osteochondral allografts include the ability to achieve precise surface architecture, immediate transplantation of viable hyaline cartilage, the potential to replace large defects and no donor site morbidity. Like any allograft transplantation, limitations include; limited graft availability, high cost, risk of immunological reactions and rejections, potential for disease transmission and technically demanding aspect of machining and sizing the allograft [128]. A number of retrospective studies have been performed to assess the outcomes of osteochondral allograft transplantation for the treatment of focal osteochondral defects of the knee, and they have demonstrated good-to-excellent results [129–132]. Krych et al. have reported improvement in Harris Hip Score at 2 and 3 year follow-up in two cases that underwent osteochondral allograft of the acetabulum [113]. Gross et al. reported survival rates for osteochondral allografts of 95% at five years, 85% at 10 years and 73% at fifteen years for posttraumatic femoral condylar lesions [133].

3.5. Cell based and scaffold treatment

Autologous chondrocyte implantation (ACI) was originally described by Brittberg et al. [134]. ACI is an innovative technique to restore cartilage cells into full-thickness chondral defects. In ACI there is development of hyaline like cartilage rather than fibrocartilage in the defect, leading to better long term outcomes and longevity of the healing tissue. Good out comes have been reported by various authors. ACI involves two surgical procedures, the first operation is used to harvest the tissue required and the second procedure is required to implant the chondrocytes in the defect. During the second procedure periosteal is also harvested from a different site and used to contain the chondrocytes in the chondral defect. ACI is not without limitations; not many patients are willing to undergo two procedures and there is a risk of donor site morbidity at the periosteal harvest site. Adverse events after ACI have been reported in 46% of patients undergoing the procedure, with graft failure accounting for 25%, delamination accounting for 22% and tissue hypertrophy occurred in about 18% of cases [135]. Peterson et al. reported 52 adverse events, including 26 instances of periosteal hypertrophy and seven graft failure in 101 patients [136].

In second generation or scaffold based ACI, harvested chondrocytes are delivered on an absorbable scaffold that supports the cells preimplantation culturing and postoperative healing process. In matrix-associated chondrocyte implantation (MACI) procedure chondrocytes are incorporated into various types of tissue engineered scaffolds. Various tissue-engineered compounds are being used as scaffolds including hyaluronan, alginates, agarose hydrogels and gelatin scaffolds [137–140]. The results from MACI to treat chondral defects have been encouraging, Behrens et al. reported substantial improvement in clinical outcome scores in 35% of patients at 5 year follow-up [141]. Marcacci et al. reported improvement in quality of life as assessed by the EuroQol - Visual Analogue Scale (EQ-VAS) in 93% of patient at 2 year follow-up after hyaluronan-based scaffold MACI, with resumption of sports at same or slightly lower level in 56.7% of patients at 12 months [142]. Although promising results are being reported after MACI, long term clinical outcomes associated with this procedure are still limited.

The autologous matrix-induced chondrogenesis (AMIC), further develops the scaffold technique in combination with micro-fracturing [59]. It is a one-step procedure that involves microfracturing of the debrided cartilage lesion and a commercially available collagen I/III matrix for covering the blood clot and its MSCs. Fixation is with partial autologous fibrin glue in which the thrombin part is yielded from the patient's serum. The indications of AMIC are symptomatic full-thickness chondral and subchondral defects in the major joints, maximum size of 2–4 cm^2, posttraumatic or osteochondrosis dissecans, and location in the main weight bearing area of the joint or maximum area of pain [59, 143]. In one study, patients with large Grade IV chondral lesions experienced significant improvement up to 24 months after the AMIC procedure [144]. Recently, Fontana has reported on the 5 year follow-up of 201 patients treated with AMIC in the hip joint. This study reported continuous improvement with respect to each evaluation time point in modified Harris Hip Scores peaking at 3 years follow-up [59]. The AMIC technique is further beneficial because it eliminates the need for specialized centers and laboratory support to cultivate cells, in turn reducing total therapy time and overall cost, compared to twostage procedures such as MACI.

4. Conclusion

Management of chondral lesion the hip joint to preserve the native joint in young active patients with chondral lesion is challenging for the orthopedic surgeon. Joint-preserving technique in the hip joint continue to evolve with recent reports showing promising results. Indications for these techniques continue to expand and a simplified algorithm was proposed by El Bitar et al. for join preserving management of articular cartilage lesions in the hip joint [14]. The literature so far is limited to low evidence studies with lack of control groups making comparison of different treatment options difficult. Further research in these different modalities is required to formulate a best treatment practice guidelines in the treatment of chondral lesions in the hip.

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